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Effectiveness of PJBL with Sketchfab 3D Augmented Reality on Fourth-Grade Students' Critical Thinking Skills

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Abstract

Critical thinking skills are essential competencies that elementary school students need to develop in order to meet the demands of 21st-century learning. However, science instruction is still frequently dominated by conventional teaching approaches, limiting students' opportunities to actively engage in higher-order thinking. Furthermore, studies integrating Project-Based Learning (PjBL) with Sketchfab Web 3D Augmented Reality (AR) to enhance elementary students' critical thinking skills remain limited. Sketchfab Web 3D AR enables students to interact with three-dimensional science objects through web-based augmented reality, providing more immersive and accessible learning experiences. This study aimed to examine the effectiveness of PjBL assisted by Sketchfab Web 3D AR in improving fourth-grade students' critical thinking skills in science learning. A quasi-experimental method with a nonequivalent control group design was employed. The sample consisted of 52 fourth-grade students divided into an experimental class and a control class. Data were collected using a critical thinking skills test and analyzed using descriptive statistics, independent-samples t-tests, effect sizes, and N-Gain analyses. The results revealed a significant difference in critical thinking skills between the experimental and control groups ($p < .05$). The effect size of 1.189 indicated a large effect, while the N-Gain score of 0.568 was moderate. These findings demonstrate that Project-Based Learning assisted by Sketchfab Web 3D AR is effective in enhancing elementary students' critical thinking skills.

Keywords: Augmented Reality, Critical Thinking Skill, Project-Based Learning, Sketchfab

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Abstrak

Keterampilan berpikir kritis merupakan salah satu kompetensi penting yang perlu dikembangkan pada siswa sekolah dasar untuk menghadapi tuntutan pembelajaran abad ke-21. Namun, pembelajaran IPAS masih sering didominasi oleh pendekatan konvensional sehingga membatasi kesempatan siswa untuk terlibat secara aktif dalam proses berpikir tingkat tinggi. Selain itu, penelitian yang mengintegrasikan Project-Based Learning (PjBL) dengan media Sketchfab Web 3D Augmented Reality (AR) untuk meningkatkan keterampilan berpikir kritis siswa sekolah dasar masih terbatas. Sketchfab Web 3D AR memungkinkan siswa berinteraksi dengan objek sains tiga dimensi melalui augmented reality berbasis web, sehingga memberikan pengalaman belajar yang lebih imersif dan mudah diakses. Penelitian ini bertujuan untuk menguji efektivitas model Project-Based Learning yang dibantu oleh Sketchfab Web 3D AR dalam meningkatkan keterampilan berpikir kritis siswa kelas IV pada pembelajaran IPA. Penelitian ini menggunakan metode kuasi eksperimen dengan desain Nonequivalent Control Group Design. Sampel penelitian terdiri atas 52 siswa kelas IV yang dibagi ke dalam kelas eksperimen dan kelas kontrol. Data dikumpulkan menggunakan tes keterampilan berpikir kritis dan dianalisis melalui statistik deskriptif, uji t independen, effect size, dan analisis N-Gain. Hasil penelitian menunjukkan adanya perbedaan yang signifikan dalam keterampilan berpikir kritis antara kelompok eksperimen dan kelompok kontrol ($p < 0,05$). Nilai effect size sebesar 1,189 menunjukkan pengaruh yang besar, sedangkan skor N-Gain sebesar 0.568 berada pada kategori sedang. Temuan ini menunjukkan bahwa model Project-Based Learning yang dibantu oleh Sketchfab Web 3D AR efektif dalam meningkatkan keterampilan berpikir kritis siswa sekolah dasar.

Kata Kunci: Augmented Reality, Keterampilan Berpikir Kritis, Project-Based Learning, Sketchfab

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INTRODUCTION

The Natural and Social Sciences (IPAS) course is an integrated subject that combines concepts from natural sciences and social sciences to help students understand phenomena in their environment holistically and contextually (Zakarina et al., 2024). IPAS instruction at the elementary school level is not only focused on mastering concepts but also on developing the 21st-century skills students need to navigate advancements in science and technology. One such skill that requires development is critical thinking. Critical thinking skills enable students to analyze, evaluate, and interpret information rationally before making decisions or solving problems (Anggraeni et al., 2022). Therefore, the development of critical thinking skills is a crucial aspect of IPAS learning as it helps students understand phenomena more deeply and meaningfully.

Critical thinking skills are among the competencies most in demand in the 21st century. Students with critical thinking skills can assess information based on facts and evidence, identify relationships between concepts, and generate logical solutions to various problems they face (Rendi et al., 2024). In the context of IPAS learning, these skills are necessary so that students not only master the material theoretically but also apply their knowledge in daily life. Therefore, schools need to provide learning experiences that can optimally facilitate the development of critical thinking skills.

However, the current state of IPAS learning in elementary schools still reveals various challenges. Based on observations at SDN Baru 03 Pagi in East Jakarta, instruction remains dominated by lecture-based methods and textbooks as the primary learning resource. Teachers primarily deliver content verbally, leading students to adopt a passive role during the learning process. This situation results in students being less engaged in learning activities and struggling to deeply grasp concepts. This finding aligns with (Shalikhah & Nugroho, 2023), who reported that learning in elementary schools has not fully implemented higher-order thinking skills-oriented instruction in terms of learning models, media, and assessment, limiting the development of students' critical thinking skills. If this situation persists, students' ability to analyze information, solve problems, and draw conclusions will struggle to develop optimally (Susanto et al., 2024).

Preliminary data collected before the study indicated that students' critical thinking skills remained relatively low. The average pretest score of critical thinking skills was 67.85 in the experimental class and 72.32 in the control class. These results indicate that students still experienced difficulties in analyzing information, solving problems, and drawing conclusions based on evidence. Therefore, learning innovations that actively engage students in constructing knowledge and solving real-world problems are needed to improve their critical thinking skills.

One alternative learning approach to address these issues is Project-Based Learning (PjBL). This learning model places students at the center of the learning process through investigative activities, problem-solving, and the completion of projects related to real-world situations (Nabila et al., 2025). Through project-based activities, students gain the opportunity to develop critical thinking, creativity, collaboration, and communication skills in an integrated manner (Andini & Muhammad, 2025). Additionally, PjBL has been proven to enhance 21st-century skills through student-centered learning activities (Simangungsong et al., 2024).

The effectiveness of Project-Based Learning can be enhanced by using innovative learning media. One such medium is the AR 3D Web Sketchfab. Sketchfab is a web-based platform that allows users to access and explore three-dimensional objects interactively via digital devices (Karimah et al., 2025). The use of 3D AR media helps students visualize abstract concepts more

concretely, thereby facilitating understanding and analysis. Additionally, the use of digital technology in learning has been proven to create a more interactive, contextual, and meaningful learning experience for students (Jannah & Atmojo, 2022).

Unlike many AR applications that require software installation or marker-based systems, Sketchfab Web 3D AR can be accessed directly through a web browser and allows students to interact with three-dimensional learning objects more easily. This characteristic makes Sketchfab Web 3D AR more practical and accessible for elementary school learning environments with varying technological resources. Therefore, Sketchfab Web 3D AR has considerable potential to support project-based learning activities and facilitate the development of students' critical thinking skills. The selection of Sketchfab Web 3D AR in this study is also based on its pedagogical advantages for elementary school learning. Through web-based access, students can explore and manipulate three-dimensional objects without installing additional applications, reducing technical barriers during learning activities. This feature enables students to observe learning objects from multiple perspectives, investigate object characteristics more independently, and connect abstract concepts with real-world representations. Such learning experiences are expected to strengthen analytical processes and support the development of critical thinking skills.

The development of digital technology combined with project-based learning models is gaining increasing attention in 21st-century education. Various studies indicate that Project-Based Learning and Augmented Reality technology contribute positively to improving the quality of learning (Sari, 2025). Mostly they shown that Project-Based Learning contributes positively to students' critical thinking skills by engaging learners in problem-solving and inquiry-based activities. These findings are reinforced by Kause et al. (2024), who show that student engagement in project-based learning fosters the development of higher-order thinking skills. Meanwhile, Kusumaningrum et al. (2025) explain that Augmented Reality technology helps students understand abstract concepts through more concrete and interactive visualizations.

Similar findings were also reported by Pamorti et al. (2024), who found that Augmented Reality-based learning media effectively improved students' critical thinking skills in IPAS learning. These findings indicate that interactive AR visualization can facilitate deeper understanding and support higher-order thinking among students. Additionally, Astuti et al. (2025) reported that the use of Augmented Reality-based Sketchfab can enhance students' interest and motivation in learning. These findings indicate that both Project-Based Learning and Augmented Reality have the potential to support the development of students' critical thinking skills.

Although various studies have demonstrated the effectiveness of both Project-Based Learning and Augmented Reality in improving learning quality, previous research still has some limitations. Pangestika & Yulianto (2025) found that implementing Project-Based Learning can enhance students' learning activities and outcomes. Meanwhile, Sa'diyah et al. (2023) placed greater emphasis on the impact of learning on students' learning motivation and social skills. On the other hand, research on Augmented Reality has largely focused on the development of learning media. However, research integrating Project-Based Learning and 3D Web Sketchfab AR media in elementary IPAS learning, particularly to improve students' critical thinking skills, remains relatively limited, leaving insufficient empirical evidence of its effectiveness in classroom practice.

Furthermore, research integrating Project-Based Learning with 3D Web Sketchfab AR media in elementary school IPAS instruction remains very limited, particularly in developing

students' critical thinking skills. Thus, there remains a research gap regarding the effectiveness of integrating Project-Based Learning and 3D Web Sketchfab AR media in fourth-grade elementary school IPAS lessons to enhance critical thinking skills. This study was conducted to address this gap by applying Project-Based Learning supported by 3D Web Sketchfab AR media to landscape materials, thereby providing empirical evidence of its effectiveness in enhancing students' critical thinking skills.

This study offers a novel approach by integrating the Project-Based Learning model with 3D Web Sketchfab AR media in fourth-grade IPAS instruction through a project that involves creating a landscape model to enhance students' critical thinking skills. Based on the above, this study aims to analyze the effectiveness of the Project-Based Learning model supported by 3D Web Sketchfab AR media on students' critical thinking skills in the fourth-grade IPAS subject at the elementary school level. This objective is achieved by implementing Project-Based Learning, supported by 3D Web Sketchfab AR media in the experimental class, and by comparing students' critical thinking skills with those of a class receiving conventional instruction.

METHODS

This study was conducted at SDN Baru 03 Pagi, East Jakarta, during the second semester of the 2025/2026 academic year. The study aimed to determine the effectiveness of the Project-Based Learning model supported by 3D AR Web Sketchfab media on students' critical thinking skills in the fourth-grade IPAS subject. The research method was designed to compare changes in critical thinking skills between students who participated in learning using Project-Based Learning supported by 3D AR Web Sketchfab media and those who participated in conventional learning.

Research Design

The study employed a Nonequivalent Control Group Design involving one experimental class and one control class. Both groups took a pretest to assess their initial critical thinking skills, then received different treatments, and finally took a posttest to measure changes in their skills following instruction. The research design employed in this study is presented in Figure 1.

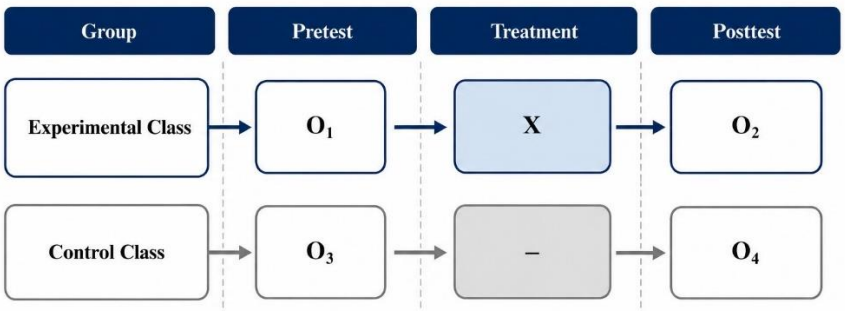


Figure 1. Nonequivalent Control Group Design

As illustrated in Figure 1, the experimental class was administered a pretest (O_1) to determine students' initial critical thinking skills prior to the implementation of the treatment (X), namely Project-Based Learning supported by Sketchfab Web 3D AR media. After the treatment was completed, a posttest (O_2) was administered to evaluate students' critical thinking skills. Similarly, the control class received a pretest (O_3) and a posttest (O_4), but did not receive the

experimental treatment; instead, it participated in conventional learning activities. The comparison of pretest and posttest scores between the experimental and control groups was used to determine the effectiveness of the Project-Based Learning model supported by Sketchfab Web 3D AR media in improving fourth-grade elementary school students' critical thinking skills in IPAS learning.

Research Population and Sample

The research population consisted of all fourth-grade students at SDN Baru 03 Pagi. The research sample was selected using purposive sampling, considering the students' characteristics and relatively comparable learning conditions. Class IV B was designated as the experimental class, while Class IV C was designated as the control class. The sample consisted of 52 fourth-grade students, with 26 students in Class IV B serving as the experimental group and 26 students in Class IV C serving as the control group. The selection of the experimental and control classes was based on the similarity of student characteristics and the school's learning conditions. Both classes were at the same grade level. They received similar instructional materials, ensuring that any differences in outcomes following the intervention could reflect the impact of implementing Project-Based Learning (PBL) supported by 3D AR Web Sketchfab media on students' critical thinking skills.

Research Procedure

In general, the research was conducted in four main stages, namely: (1) research preparation, which included the development of learning materials, learning media, and research instruments; (2) administration of the pretest in the experimental and control classes; (3) the implementation of the treatment, which consists of Project-Based Learning assisted by 3D AR Web Sketchfab media in the experimental class and conventional learning in the control class, and (4) the administration of a posttest and analysis of research data.

The study began with administering a pretest to both groups to determine the students' initial proficiency. Subsequently, the experimental class participated in learning using the Project-Based Learning model supported by 3D AR Web Sketchfab media on the topic of landforms. Students carried out learning activities through the stages of problem identification, project design, activity scheduling, project implementation to create a landscape model, project result presentation, and learning reflection. During project implementation, students utilized the 3D Web Sketchfab AR platform to observe and explore three-dimensional objects as learning resources. Through this platform, students were able to visualize geographical features more concretely and use the information obtained to support project completion and problem-solving activities. Meanwhile, the control class followed conventional learning through lectures, question-and-answer sessions, and assignments without using the 3D Web Sketchfab AR platform. After the entire learning sequence was completed, both groups were given a posttest to measure the students' critical thinking skills following the intervention.

Research Instrument

Research data were collected using a critical thinking skills essay test instrument developed based on critical thinking skill indicators. Before being used in the study, the instrument underwent validity and reliability testing to ensure its suitability for measuring students' critical thinking skills. Content validity was evaluated through expert judgment, and empirical validity was assessed using a product-moment correlation analysis. The validity testing results indicated

that 11 out of 12 essay items met the validity criteria ($r_{count} > r_{table}$), whereas one item was excluded because it did not satisfy the required criterion. Reliability testing yielded a Cronbach's Alpha coefficient of 0.792, indicating high reliability. Therefore, the final instrument consisted of 11 valid and reliable essay questions. According to Susanti et al. (2023), the indicators of critical thinking skills for elementary school students include (1) problem identification, (2) information analysis, (3) problem solving, and (4) drawing conclusions.

These four indicators were then broken down into sub-indicators and test items tailored to the physical geography material in the fourth-grade IPAS curriculum. The instrument matrix was developed to ensure that each critical thinking skill indicator was proportionally represented in the research instrument. The critical thinking skills instrument matrix is presented in Table 1.

Table 1. Critical Thinking Assessment Rubric

Indicator	Sub-Indicator	Question Number
Identifying Problems	Identifying coastal erosion problems based on images and descriptions	1
	Identifying river pollution problems (Ciliwung River)	2
	Identifying landslide problems based on case studies	3
Analyzing Problems	Explaining the relationship between high and low elevations, temperature, and weather	4
	Identifying the causes of forest fires in mountainous areas based on case studies.	5
	Comparing terraced rice fields and flat rice fields in water management	6
Solving Problems	Proposing solutions to protect vegetable crops from continuous rain	7
	Explaining how to address coastal erosion/sand entering homes	8
	Explaining steps to address river pollution	9
Drawing Conclusions	Summarizing the impact of tree presence in mountainous areas on river conditions and water availability	10
	Summarizing the impact of human activities on coral reefs	11

Based on Table 1, the research instrument consists of 11 open-ended questions covering four indicators of critical thinking skills: identifying problems, analyzing problems, solving problems, and drawing conclusions. The instrument was developed based on the critical thinking indicators and refined through validity testing prior to its implementation in the study. In addition to the test instrument, this study utilized laptops, an internet connection, and the 3D AR platform Web Sketchfab as learning media. Materials used in the project activities included clay, plywood, glue, paper, plastic, small twigs, and various other supporting supplies for creating landscape models.

Data Analysis

The collected data were analyzed using descriptive statistics to characterize the research data. Prior to hypothesis testing, normality and homogeneity tests were conducted as prerequisite analyses. Hypothesis testing was performed using the Paired Sample t-Test to determine differences between pretest and posttest scores within each group and the Independent Sample t-Test to examine differences between the experimental and control groups. The magnitude of the

treatment effect was analyzed using Cohen's d effect size. According to Cohen's criteria, effect size values of 0.20, 0.50, and 0.80 indicate small, medium, and large effects, respectively. The effectiveness of the intervention in improving students' critical thinking skills was further analyzed using the N-Gain test. Based on Hake's criteria, N-Gain scores below 0.30 are categorized as low, scores between 0.30 and 0.70 as moderate, and scores above 0.70 as high. All statistical analyses were conducted using IBM SPSS Statistics version 27.

RESULTS AND DISCUSSION

The purpose of this study was to determine the effectiveness of the Project-Based Learning model, supported by the 3D AR Web Sketchfab platform, in developing students' critical thinking skills in the fourth-grade IPAS course. Before testing the hypotheses, the research data were analyzed using descriptive statistics and tested for normality and homogeneity to ensure that the assumptions for parametric analysis were met.

The Learning Process

The study was conducted over five sessions in the IPAS (Natural Sciences) class on the topic of "The Landforms" for fourth-grade students at SDN Baru 03 Pagi in East Jakarta. Learning activities in the experimental class applied a Project-Based Learning model supported by the 3D AR Web Sketchfab platform, while the control class used conventional teaching methods. The learning process was carried out in several stages: administering a pretest, presenting the material, completing the landscape model-making project, presenting the project results, and administering a posttest. As shown in Figure 2, students use the 3D AR platform Sketchfab to visually and interactively observe various landforms. This platform allows students to explore objects from various angles, helping them understand the concepts being studied in a more concrete way.



Figure 2. Students Observe Landscape Features Using 3D AR on Sketchfab

As shown in Figure 3, students work in groups to develop a landscape model project. At this stage, students gather information, design the project, select materials, and address any issues that arise. As shown in Figure 4, students present the projects they have created in front of the class. The presentation activity allows students to explain their work, provide supporting arguments, and respond to questions from their peers and the teacher. The learning process demonstrates how Project-Based Learning and 3D AR Web Sketchfab were integrated into instruction, providing students with opportunities to observe, analyze, discuss, and present information throughout the project.



Figure 3. Creating a landscape Activity



Figure 4. Students' Project Presentations



Figure 5. Screenshot of the 3D Sketchfab Model Used in Instruction

Descriptive Statistics

Descriptive statistical analysis was used to examine trends in changes in students' critical thinking skills following the intervention and to compare the outcomes between the experimental and control groups. The results of the descriptive statistical analysis of students' critical thinking skills are presented in Table 2. According to Table 2, the average critical thinking skills of students in the experimental class increased from 67.85 to 85.22. Meanwhile, the average for the control class increased from 72.32 to 76.08. These results indicate that the improvement in critical thinking skills was greater in the experimental class than in the control class.

Table 2. Descriptive Statistics of Pretest and Posttest Scores

Descriptive Statistics	Experimental Group		Control Group	
	Pretest	Posttest	Pretest	Posttest
Sample Size (N)	27	27	25	25
Minimum	52	74	58	62
Maximum	86	98	86	88
Mean	67.85	85.22	72.32	76.08

Prerequisite Tests for Analysis

Prerequisite tests aim to ensure that the data obtained meet the assumptions of parametric statistics so that the results of hypothesis testing can provide valid conclusions. In this study, the

prerequisite tests conducted included a normality test and a homogeneity test. The normality test was used to assess whether the research data were normally distributed, and the homogeneity test was used to assess whether the variances between the experimental and control groups were equal. The results of these two tests served as the basis for determining whether to use parametric statistical tests in the hypothesis-testing stage.

The Shapiro-Wilk test was used for the normality test because the sample size in each group was less than 50 students. The data were considered normally distributed if the significance value was greater than 0.05. The results of the normality test for the research data are presented in Table 3.

Table 3. Normality Test Results

Group	Data Set	Statistic	df	Sig.	Conclusion
Experimental Group	Pretest	0.963	27	0.442	Normal
	Posttest	0.941	27	0.130	Normal
Control Group	Pretest	0.978	25	0.834	Normal
	Posttest	0.962	25	0.451	Normal

Based on Table 3, all significance values for the pretest and posttest data from both the experimental and control classes are greater than 0.05. These results indicate that all the research data are normally distributed.

Table 4. Homogeneity Test Results

Variable	Levene Statistic	Sig.	Conclusion
Critical Thinking Skills	0.32	0.860	Homogeneous

Based on Table 4, the results of the test for homogeneity of variances using Levene's Test show a p-value of 0.860. Since the p-value is greater than 0.05 (0.860 > 0.05), it can be concluded that the variances of the data between the experimental and control classes are homogeneous.

Hypothesis Testing

The purpose of this study is to determine whether implementing a Project-Based Learning model supported by 3D AR Web Sketchfab media has a significant effect on students' critical thinking skills in the fourth-grade IPAS subject. The testing was conducted by comparing students' critical thinking abilities before and after the intervention in each group, as well as by comparing the final results between the experimental class and the control class.

Table 5. Hypothesis Testing

Statistic	Sig. (2-tailed)	Conclusion
Paired Sample t-Test Experimental Group	0.001	H_1 accepted
Independent Sample T Test	0.001	H_1 accepted

Based on Table 5, a significance value of 0.001 (which is less than 0.05) was obtained in both tests. These results indicate a significant difference in students' critical thinking skills following the implementation of the Project-Based Learning model supported by the 3D AR Web

Sketchfab platform. Thus, H_1 is accepted, and H_0 is rejected, leading to the conclusion that the Project-Based Learning model supported by the 3D AR Web Sketchfab platform has a significant effect on students' critical thinking skills in the IPAS subject for fourth-grade students at SDN Baru 03 Pagi in East Jakarta.

Effect Size Test

An effect size test was conducted to determine the magnitude of the treatment's effect on students' critical thinking skills. A statistical significance test only indicates the presence or absence of an effect. In contrast, the effect size provides information about the strength or magnitude of the treatment effect. The results of the effect size analysis using Cohen's d are presented in Table 6.

Table 6. Effect Size Test

Group	Effect Size (Cohen's d)	Interpretation
Experimental Group	1.189	Large
Control Group		

Based on Table 6, the effect size (Cohen's d) was found to be 1.189, which falls into the large category. These results indicate that the Project-Based Learning model supported by 3D AR Web Sketchfab media has a strong effect on improving students' critical thinking skills. This value indicates that the difference in the results obtained is not only statistically significant but also has a substantial practical impact on the learning process.

N-Gain Test

The N-Gain test is used to analyze the effectiveness of improvements in students' critical thinking skills using the Normalized Gain (N-Gain) test. The N-Gain analysis is conducted to determine the extent of improvement in students' abilities after participating in the learning process compared to their initial abilities. The results of this analysis provide information regarding the effectiveness of the instruction implemented in each group, allowing for a comparison of the level of improvement in critical thinking skills between the experimental and control classes. The N-Gain calculation results are presented in Table 7.

Table 7. N-Gain Test

Indicator	Score	Category
N-Gain (Experimental Group)	0.568	Moderate
N-Gain (Control Group)	0.145	Low

Based on Table 7, the average N-Gain value in the experimental group was 0.568, which falls into the moderate category, while the average N-Gain value in the control group was 0.145, which falls into the low category. These findings indicate that students who learned through the Project-Based Learning model supported by the 3D AR Web Sketchfab platform experienced greater improvement in critical thinking skills than those in conventional learning. The higher N-Gain value in the experimental group suggests that integrating project-based learning with interactive three-dimensional visualization was more effective in facilitating students' critical thinking development. In contrast, the lower N-Gain value in the control group indicates that

conventional learning contributed less to improvements in critical thinking skills. Therefore, the results of the N-Gain analysis support the effectiveness of the Project-Based Learning model assisted by the 3D AR Web Sketchfab platform in improving students' critical thinking skills.

Discussions

These results indicate that the Project-Based Learning model supported by 3D Web Sketchfab AR media is effective in improving students' critical thinking skills in the fourth-grade IPAS subject. This finding is evident from the higher critical thinking skill scores in the experimental class compared to the control class. The results of the hypothesis test, the effect size, and the N-Gain support it. These results indicate that integrating project-based learning with 3D AR media can create a more meaningful learning experience for students. The improvement in critical thinking skills occurs because students are actively involved in every stage of Project-Based Learning, from identifying problems and gathering information to designing projects and presenting project results. These activities encourage students to analyze, evaluate, and make decisions independently. These findings align with Wahid (2024) and Rahayu et al. (2025), who state that project-based learning is effective in developing critical thinking skills through investigative and problem-solving activities.

The learner-centered nature of Project-Based Learning also contributes to the improvement of critical thinking skills. Students do not merely receive information from teachers but construct knowledge through learning experiences gained during the learning process. The results of this study support the findings of Dewi (2022), Ramadhan & Hindun (2023), and Fariza & Kusuma (2024), which indicate that project-based learning can enhance students' creativity, collaboration, and higher-order thinking skills. In addition to the instructional model used, the 3D AR platform Sketchfab also plays a role in enhancing students' critical thinking skills. By visualizing three-dimensional objects, students can observe landscapes in a more concrete, interactive way, making it easier for them to understand the concepts being taught. This finding aligns with the research of Febriani & Suratmi (2025), which shows that Sketchfab media can enhance learning quality by visualizing three-dimensional objects.

The results of this study also support the findings of Hidayati et al. (2025), who found that the use of digital media in project-based learning can increase student engagement in the learning process. The similarity between this study and previous research lies in the use of digital technology for interactive learning. However, previous studies focused more on media development and improving learning outcomes. In contrast, this study emphasizes the effectiveness of integrating 3D Web Sketchfab AR and Project-Based Learning on students' critical thinking skills. The results of this study also support the findings of Seo et al. (2025), which state that integrating AR/VR technology into learning can enhance critical thinking skills through more exploratory learning experiences. During the learning process, students were allowed to analyze information, evaluate project outcomes, and present arguments during presentations. These conditions align with the view of Haryanti et al. (2023) that critical thinking skills develop through active engagement in analysis, evaluation, and decision-making activities.

The improvement in students' critical thinking skills can also be explained through the learning experiences provided during project implementation. Unlike conventional learning, where students primarily receive information from the teacher, students in the experimental class were required to observe, discuss, evaluate evidence, and justify their decisions throughout the project activities. The availability of interactive three-dimensional visualizations enabled students to connect abstract concepts with real-world situations, thereby facilitating deeper analysis and

reasoning. This finding suggests that critical thinking skills develop more effectively when students are actively engaged in constructing knowledge through authentic learning experiences rather than passively receiving information (Kusumaningrum et al., 2025; Pamorti et al., 2024)..

A distinctive finding of this study is that the improvement in students' critical thinking skills was not solely influenced by the use of AR technology or Project-Based Learning in isolation, but by their integration within a single learning process. The 3D AR Web Sketchfab platform enabled students to observe landform objects in a concrete, interactive way. At the same time, Project-Based Learning provided opportunities to analyze information, make decisions, and solve problems through project activities. This combination created a learning environment in which students were actively involved in constructing knowledge rather than merely receiving information from the teacher. Therefore, the improvement in critical thinking skills can be understood as the result of the interaction between immersive visualization and inquiry-based learning experiences (Pangestika & Yulianto, 2025).

The effectiveness of this instructional combination may be explained through cognitive visualization and inquiry processes. Sketchfab Web 3D AR enables students to visualize landform concepts that are often difficult to observe directly, thereby reducing cognitive barriers in understanding abstract content. At the same time, Project-Based Learning requires students to investigate problems, evaluate information, and justify solutions. The integration of these processes allows students to focus not only on understanding concepts but also on applying analytical reasoning during project completion. Consequently, students are given more opportunities to practice critical thinking throughout the learning process.

This study contributes to elementary science and social studies (IPAS) education by providing empirical evidence that integrating Project-Based Learning with the 3D AR Web Sketchfab platform can effectively enhance students' critical thinking skills. Unlike previous studies that primarily examined Project-Based Learning or Augmented Reality separately, this study demonstrates the added value of combining immersive visualization with project-based inquiry activities. From a practical perspective, these findings provide a feasible instructional framework that teachers can implement using commonly available digital devices and internet access, making immersive learning more accessible in elementary school classrooms. Furthermore, the results suggest that web-based AR technology can be integrated into classroom instruction without requiring sophisticated equipment, making it more accessible for wider educational implementation.

CONCLUSION

The results of this study indicate that the Project-Based Learning model supported by 3D AR Web Sketchfab media is effective in enhancing fourth-grade elementary school students' critical thinking skills in the IPAS subject. The integration of project-based learning with three-dimensional object visualization provides a more concrete, interactive, and meaningful learning experience, thereby encouraging students to actively analyze information, solve problems, and present arguments based on their observations. The findings further suggest that the improvement in students' critical thinking skills was influenced not only by the use of AR technology or Project-Based Learning independently, but by the integration of immersive three-dimensional visualization and inquiry-based project activities within a single learning process. This study provides empirical contributions to the development of IPAS learning through the utilization of Project-Based Learning and the 3D AR Web Sketchfab platform as an alternative learning approach that supports 21st-century skills. The implications of this study suggest that teachers

can integrate project-based learning models and interactive digital technology to improve the quality of learning in elementary schools. However, this study has several limitations. First, the participants were drawn from a single elementary school, which may limit the generalizability of the findings. Second, the intervention was conducted within a specific instructional context and focused exclusively on fourth-grade students. Third, the study examined only critical thinking skills and did not investigate other potential outcomes such as creativity, collaboration, or learning motivation.

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