



Problem-Based Learning Supported by Assembler Edu: Impacts on Science Learning Outcomes and Students' Self-Confidence

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Abstract: This study aims to examine differences in IPAS learning outcomes between students taught through Problem-Based Learning (PBL) assisted by Assembler Edu and those taught through conventional instruction, as well as to analyze the interaction between the learning model and students' self-confidence. The study employed a quasi-experimental design using a pretest-posttest non-equivalent control group approach. The participants were 115 fifth-grade students from Cluster II Tegallalang Elementary Schools, comprising 57 students in the experimental group and 58 in the control group. The research instruments included a multiple-choice IPAS learning outcomes test and a self-confidence questionnaire, both of which were validated and tested for reliability. Content validity was assessed by two expert lecturers using Gregory's formula. The learning outcomes test demonstrated very high reliability ($KR-20 = 0.958$), and the self-confidence questionnaire also showed very high reliability (Cronbach's $\alpha = 0.929$). Data were analyzed using ANCOVA. The results indicate that the learning model significantly affected IPAS learning outcomes ($F = 56.791, p < 0.001, \text{Partial } \eta^2 = 0.340$), while self-confidence also had a significant effect ($F = 43.628, p < 0.001, \text{Partial } \eta^2 = 0.284$). Furthermore, a significant interaction was observed between the learning model and self-confidence ($F = 6.486, p = 0.012, \text{Partial } \eta^2 = 0.056$). These findings suggest that PBL assisted by Assembler Edu is more effective than conventional instruction, indicating that the integration of problem-based learning with AR-supported media can reduce learning barriers and enhance conceptual understanding in a meaningful way.

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Introduction

Primary education plays a strategic role in preparing students with critical thinking, life skills, and readiness to face twenty-first-century challenges through meaningful and contextual learning (Nikolic et al., 2023; Subedi, 2022). In Indonesia, the Merdeka Curriculum positions Natural and Social Sciences (IPAS) as an integrative subject intended to help students understand natural and social phenomena holistically while developing analytical, creative, and problem-solving skills grounded in real-life contexts (Hikmawati et al., 2024; Hutami et al., 2023). Science learning outcomes reflect achievement across cognitive, affective, and psychomotor domains, which together support conceptual understanding and scientific thinking (Anggraini & Wulandari, 2021; Báró, 2024). The cognitive domain is particularly important because it relates directly to conceptual mastery, analytical ability, and the accuracy of scientific conclusions, making instructional quality a key determinant of successful science learning (Abbasi et al., 2023; Batool et al., 2023).



However, elementary students' science learning outcomes remain problematic, especially in scientific literacy and conceptual understanding (Nugraha, 2022; Saraha & Ardiansyah, 2023). These difficulties are often linked to teacher-centered instruction, limited exploratory activities, and insufficient media for visualizing abstract science concepts (N. M. Ali et al., 2023; Paramita et al., 2025; Suma et al., 2020; Suwastini et al., 2022). Preliminary data from fifth-grade students in Cluster II Tegallalang show that average science achievement in four of six schools remained below the Minimum Learning Achievement Criteria (KKTP) of 6.50, with mean scores ranging from 6.40 to 6.45. This suggests that expected standards have not yet been achieved.

The problem is not only low scores but also weak conceptual understanding and underdeveloped scientific thinking, both of which should emerge through active, investigative, and contextual learning experiences (Kusadi et al., 2020; Meilani et al., 2020; Noor et al., 2020; Syudirman et al., 2025). Interviews with teachers indicated that students struggled with abstract topics such as energy, living systems, and the water cycle, and often relied on memorization rather than connecting concepts to everyday phenomena. Skills such as analyzing information, explaining cause-and-effect relationships, and drawing conclusions also remained limited because students had insufficient opportunities for discussion, experimentation, and the use of concrete or digital media (Hikmawati et al., 2021; Yasa et al., 2021). As a result, students tended to be passive, less enthusiastic, and hesitant to express their opinions, which contributed to low achievement across assessments (Agustina & Margunayasa, 2024; Saraha & Ardiansyah, 2023; F. Yasmin et al., 2023).

To address these issues, learning must be more student-centered and supported by media that make concepts engaging and understandable (N. M. Ali et al., 2023; Olvah et al., 2024). Problem-Based Learning (PBL) is relevant because it engages students with real-life problems, promotes critical thinking and collaboration, and develops conceptual understanding through investigation and solution building (Qondias et al., 2022; Qoriah, 2023). Prior studies have shown that PBL improves science learning outcomes and strengthens scientific attitudes (Afandi et al., 2024; Rezkillah & Haryanto, 2020), while meta-analyses confirm its substantial positive effect across educational levels (Funa & Prudente, 2021; Jampel & Antara, 2024; Pramana et al., 2024).

PBL can be even more effective when supported by interactive digital media, especially for abstract science content that requires concrete visualization (Ali, 2023; Chairudin et al., 2023). Assemblr Edu, an Augmented Reality (AR)-based platform, enables students to observe and explore three-dimensional objects through mobile devices, making learning more immersive and supportive of deeper conceptual understanding (Ramdani et al., 2025; Ruslan & Hamid, 2024). AR-based learning has been shown to increase engagement and support knowledge construction, particularly in science education (Ni'mah & Putri, 2024; Pasande & Hakim, 2025). Its integration with PBL can strengthen problem-solving because students are able to observe phenomena, test ideas, and discuss solutions more concretely through digital visualization (Pozuelo-Muñoz et al., 2023; Suwastini et al., 2022). Assemblr Edu was selected over other AR platforms because it is accessible and practical for elementary classrooms, with a user-friendly interface, mobile-based operation, and relatively simple integration of three-dimensional visualizations without complex technical preparation. Pedagogically, it is well suited to primary science learning because it presents abstract concepts in concrete, interactive, and contextual ways that support exploration and discussion in the PBL process (Arnyana & Suma, 2025; Chairudin et al., 2023; Funa & Prudente, 2021).



The effectiveness of learning models and media is also shaped by students' psychological characteristics, particularly self-confidence (Rosyida et al., 2025; Tabriz et al., 2024). Self-confidence refers to students' belief in their ability to complete tasks and face challenges, and those with higher self-confidence tend to be more active, persistent, and resilient (Kappes et al., 2020; Rezkillah & Haryanto, 2020). PBL combined with AR may strengthen self-confidence by providing meaningful experiences, visual support, and feedback that help students feel capable of understanding the material (George & B, 2022; Maulana & Halidjah, 2025). Yet previous studies have mostly examined PBL and AR separately, while research on the interaction between PBL assisted by Assemblr Edu and self-confidence in science learning remains limited (Pozuelo-Muñoz et al., 2023; Rosyida et al., 2025). Therefore, this study aims to analyze differences in science learning outcomes between students taught through PBL assisted by Assemblr Edu and those taught conventionally, examine the interaction between learning model and self-confidence, and compare outcomes among students with high and low self-confidence under both learning conditions.

Research Method

This study employed a quantitative quasi-experimental design using a pretest–posttest non-equivalent control group design to examine the effect of Problem-Based Learning supported by Assemblr Edu on fifth-grade students' science learning outcomes. The population comprised 154 students from six elementary schools in Cluster II Tegallalang. Samples were selected through class-level random sampling after group equivalence was established using students' previous semester report card scores as indicators of initial academic ability. The experimental group consisted of 57 students from SDN 1 and 2 Kedisan, while the control group consisted of 58 students from SDN 1 and 2 Kenderan.

Data were collected through test and non-test techniques. Science learning outcomes were measured using a multiple-choice test, while self-confidence was assessed through a five-point Likert-scale questionnaire. Both instruments were validated by two lecturer experts using Gregory's formula. Item analysis showed that 20 of 30 test items were valid, with very high reliability ($KR-20 = 0.958$), and 25 of 30 questionnaire items were valid, with very high reliability as well (Cronbach's Alpha = 0.929). Assemblr Edu, an Augmented Reality-based learning platform, served as the main instructional medium in the experimental class.

Data were analyzed using descriptive and inferential statistics. Descriptive statistics included mean, median, mode, and standard deviation, while inferential analysis involved prerequisite tests of normality, homogeneity, and linearity at the 0.05 significance level. Hypothesis testing was conducted using ANCOVA to compare posttest scores by controlling for pretest results as covariates and to examine the main and interaction effects of the learning model and self-confidence. All analyses were performed using SPSS version 26.

Results and Discussion

The ANCOVA test results were used to examine differences in science learning outcomes between the experimental and control groups by controlling the effect of pretest scores as covariates. The use of pretest scores aimed to ensure that differences in posttest learning outcomes were truly caused by the differences in the instructional models applied, rather than by students' initial abilities. This analysis also improved the accuracy of interpretation because the assessment was conducted after adjusting for the initial abilities of each group. The ANCOVA results are presented in Table 1.



Table 1. ANCOVA Test Results
Tests of Between-Subjects Effects

Dependent Variable: Posttest						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5871,817 ^a	4	1467,954	40,430	0,000	0,595
Intercept	55791,900	1	55791,900	1536,604	0,000	0,933
Pretest	775,534	1	775,534	21,360	0,000	0,163
Kelas	2062,012	1	2062,012	56,791	0,000	0,340
RPD	1584,063	1	1584,063	43,628	0,000	0,284
Kelas * RPD	235,492	1	235,492	6,486	0,012	0,056
Error	3993,944	110	36,309			
Total	753887,500	115				
Corrected Total	9865,761	114				

a. R Squared = ,595 (Adjusted R Squared = ,580)

Based on the ANCOVA results in Table 1, the class factor or learning model showed a significance value of 0.000, which is lower than 0.05. This indicates a significant difference in science learning outcomes between students taught through Problem-Based Learning assisted by Assemblr Edu and those receiving conventional instruction after controlling for pretest scores; thus, H_0 was rejected and H_1 was accepted. In other words, PBL assisted by Assemblr Edu produced significantly better science learning outcomes than conventional instruction. This finding confirms that problem-based learning integrated with digital technology creates more meaningful learning experiences because students are actively involved in critical thinking, investigation, discussion, and solution development based on contextual problems rather than passively receiving information (Lubis et al., 2024; Suparya et al., 2022). In this process, PBL places students at the center of learning, whereas conventional instruction tends to depend on lectures and limits students' opportunities to explore concepts independently (Afandi et al., 2024; Hutami et al., 2023).

The effectiveness of PBL was further strengthened by the use of Assemblr Edu as an Augmented Reality (AR)-based medium that provides interactive three-dimensional visualizations, enabling students to observe, manipulate, and explore science objects more concretely and contextually (Chairudin et al., 2023; Pozuelo-Muñoz et al., 2023). This is in line with the Cognitive Theory of Multimedia Learning, which explains that learning is more effective when information is processed through visual and auditory channels simultaneously, thereby strengthening attention and conceptual connections (Chairudin et al., 2023; Pozuelo-Muñoz et al., 2023). AR also helps reduce cognitive load, facilitates understanding of abstract information, and increases student engagement during the investigation and reflection stages of PBL. From a constructivist perspective, knowledge is formed through direct experience and social interaction, so group discussions, problem exploration, and collaboration in PBL provide meaningful opportunities for students to actively construct science understanding (Qondias et al., 2022; Qoriah, 2023). Previous studies have consistently shown that PBL improves science learning outcomes in elementary schools, especially by strengthening analytical and problem-solving skills, although most have not integrated AR media such as Assemblr Edu; thus, this study contributes novelty by combining PBL with interactive visual technology (Ariyani & Kristin, 2021; Dewi et al., 2021). Other empirical studies also show that problem-based learning supported by visual media positively affects conceptual

understanding, and Assemblr Edu extends this benefit through a more immersive and exploratory learning experience (Indiati & Devega, 2023; Nugroho et al., 2023).

The ANCOVA results also showed that the significance value in the Class \times Self-Confidence row was 0.012, which is lower than 0.05. This indicates a significant interaction between the learning model and students' self-confidence on science learning outcomes, meaning that the effect of the learning model was influenced by students' levels of self-confidence. Therefore, the effectiveness of PBL assisted by Assemblr Edu differed between students with high and low self-confidence, and H_0 was rejected while H_1 was accepted.

The results of Hypothesis 2 testing indicate a significant interaction between the learning model and students' levels of self-confidence on science learning outcomes. This finding suggests that the effect of Problem-Based Learning assisted by Assemblr Edu on science learning outcomes is not uniform across all students but varies depending on their level of self-confidence. To clarify this interaction pattern and provide a visual representation of differences in science learning outcomes across combinations of learning models and self-confidence levels, an interaction diagram based on the Estimated Marginal Means values is presented in Figure 1.

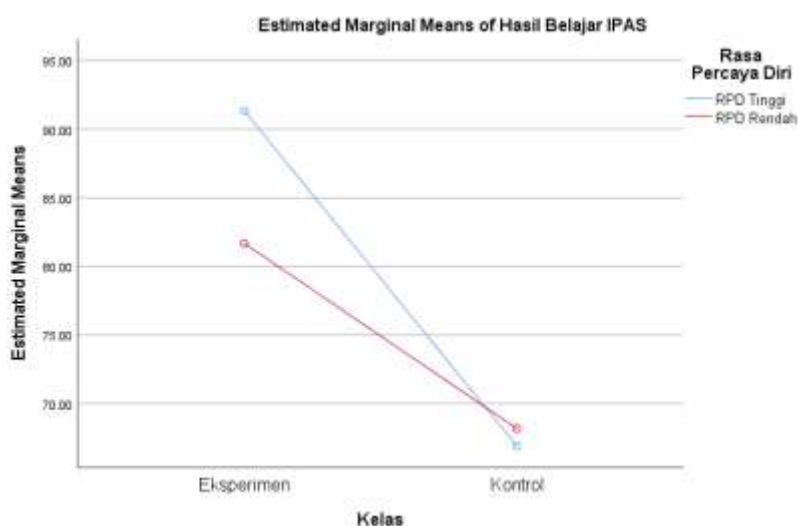


Figure 1. Interaction between Learning Model and Self-Confidence on Science Learning Outcomes

Based on the Estimated Marginal Means interaction diagram of posttest scores, there is a clear interaction between the learning model and students' self-confidence in shaping science learning outcomes. This interaction is best understood through the slope of the lines. In the experimental group, which implemented Problem-Based Learning assisted by Assemblr Edu, the line is steeper, indicating that the difference between students with high and low self-confidence is more pronounced. Students with high self-confidence achieved the highest posttest scores, while those with low self-confidence also improved, though to a lesser extent. This suggests that PBL assisted by Assemblr Edu was effective overall, but its benefits were stronger for students who were already more confident in engaging in discussion, inquiry, and problem-solving (Maulana & Halidjah, 2025; Rosyida et al., 2025).

In contrast, the flatter slope in the control group indicates a smaller gap between high- and low-confidence students, but this does not reflect better equity. Rather, both groups achieved relatively low scores, suggesting that conventional instruction did not provide sufficient opportunities for active exploration or contextual problem-solving, thereby limiting



overall achievement (Tabriz et al., 2024; Zhao et al., 2020). Thus, the flatter slope reflects uniformly lower performance rather than successful gap reduction.

The steeper slope in the experimental group shows that self-confidence played a stronger role in a more participatory learning environment. Even so, students with low self-confidence still benefited from Assemblr Edu because its concrete visualizations and interactive support helped them understand abstract science concepts more easily (Chairudin et al., 2023; Ni'mah & Putri, 2024). Overall, PBL assisted by Assemblr Edu was more effective than conventional instruction, although additional scaffolding is still needed to further narrow the achievement gap. Next, Table 2 Pairwise Comparisons was used to examine specific differences in learning outcomes between groups within high and low self-confidence categories after score adjustment using estimated marginal means.

Table 2. Pairwise Comparison Test Results

Pairwise Comparisons				
Dependent Variable: Posttest				
(I) Kelompok Rasa Percaya Diri	(J) Kelompok Rasa Percaya Diri	Mean Difference (I-J)	Std. Error	Sig. ^D
Eksperimen Rasa Percaya Diri Tinggi	Eksperimen Rasa Percaya Diri Rendah	5,188 ^{*.B,C}	2,023	0,012
	Kontrol Rasa Percaya Diri Tinggi	5,811^{*.B,C}	2,033	0,006
	Kontrol Rasa Percaya Diri Rendah	21,951 ^{*.B,C}	2,100	0,000
Eksperimen Rasa Percaya Diri Rendah	Eksperimen Rasa Percaya Diri Tinggi	-5,188 ^{*.B,C}	2,023	0,012
	Kontrol Rasa Percaya Diri Tinggi	,622 ^{b,C}	2,008	0,758
	Kontrol Rasa Percaya Diri Rendah	16,763^{*.B,C}	2,040	0,000

Based On Estimated Marginal Means

*. The Mean Difference Is Significant At The ,05 Level.

B. An Estimate Of The Modified Population Marginal Mean (I).

C. An Estimate Of The Modified Population Marginal Mean (J).

D. Adjustment For Multiple Comparisons: Least Significant Difference (Equivalent To No Adjustments).

Based on the Pairwise Comparisons test results, in the group of students with high self-confidence, the comparison between the experimental group taught using Problem-Based Learning assisted by Assemblr Edu and the control group receiving conventional instruction showed a significance value (Sig.) of 0.012, which is lower than the significance level of 0.05. This result indicates a significant difference in science learning outcomes between the two groups among students with high self-confidence. Therefore, H_0 was rejected and H_1 was accepted, meaning that Problem-Based Learning assisted by Assemblr Edu produced better science learning outcomes than conventional instruction for students with high self-confidence.

This finding demonstrates that limited self-confidence does not automatically hinder improvements in learning outcomes when instruction is designed to be interactive and supportive, as PBL provides a collaborative structure that allows for social support, while Assemblr Edu functions as visual scaffolding that helps students understand abstract concepts more concretely (Isnaeni & Sa'diyah, 2024; Pasande & Hakim, 2025). Students with low



self-confidence generally face difficulties initiating discussions, expressing opinions, or making academic decisions; therefore, conventional instruction with limited exploratory activities may cause them to become more passive and fall behind (Kappes et al., 2020; Stiggins, 2025). PBL assisted by AR offers a clearer starting point through visual representations of problems, enabling students to better understand the context, feel more confident to ask questions, and become more engaged in completing tasks collaboratively (Radianti et al., 2020; Pozuelo-Muñoz et al., 2023). These results align with previous research showing that PBL supported by visual media can improve learning outcomes among students with low motivation or readiness, as the learning process provides concrete experiences that gradually strengthen understanding and participation (Fithriyani et al., 2023; Indiaty & Devega, 2023).

The Pairwise Comparisons results for students with low self-confidence showed that the comparison between the experimental group taught using Problem-Based Learning assisted by Assemblr Edu and the control group receiving conventional instruction had a significance value (Sig.) of 0.000, which is lower than the significance level of 0.05. This finding indicates a significant difference in science learning outcomes between the two groups among students with low self-confidence. Therefore, H_0 was rejected and H_1 was accepted, meaning that the implementation of Problem-Based Learning assisted by Assemblr Edu demonstrated a significant advantage compared to conventional instruction for students with low self-confidence.

This means that students with high self-confidence achieved more optimal learning outcomes when participating in Problem-Based Learning assisted by Assemblr Edu compared to conventional instruction. This condition can be explained by the notion that students with high self-confidence tend to have better self-control, stronger motivation, and a greater tendency to actively face academic challenges; therefore, PBL, which requires investigation, analysis, and presentation, becomes a space for self-actualization that strengthens learning achievement (Maulana & Halidjah, 2025; Rosyida et al., 2025). PBL assisted by Assemblr Edu provides a learning environment that enables students to explore information independently, utilize AR visualizations to analyze phenomena, and construct solutions more systematically, resulting in deeper conceptual understanding compared to conventional instruction that tends to limit opportunities for exploration (Chairudin et al., 2023; Qoriah, 2023). Observations showed that students with high self-confidence were more willing to express ideas, construct arguments, lead discussions, and utilize 3D object manipulation features to strengthen problem analysis, making the learning process more active and meaningful. These findings are consistent with research indicating that PBL is more effective for students with positive psychological characteristics such as self-confidence and independence, as they are better able to carry out problem-based learning stages optimally (Safitri et al., 2023; Yasmin & Negara, 2024).

Overall, this study confirms that Problem-Based Learning assisted by Assemblr Edu is more effective in improving science learning outcomes compared to conventional instruction, and that this effectiveness is significantly influenced by students' self-confidence. PBL provides a learning process that requires active engagement and problem-solving, while Assemblr Edu strengthens learning through concrete, interactive, and contextual AR visualizations that help students build stronger conceptual understanding of science (Pozuelo-Muñoz et al., 2023; Radianti et al., 2020). Self-confidence acts as a differentiating factor that influences how optimally students benefit from problem-based learning and digital media; therefore, teachers need to consider variations in students' self-confidence by strengthening



learning support, forming balanced collaborative groups, and providing feedback that encourages students to actively participate in learning (George & B, 2022; Stiggins, 2025).

Conclusion

The ANCOVA results showed that the learning model had a significant effect on students' science learning outcomes, with $F = 56.791$, $p = 0.000$, and Partial Eta Squared = 0.340, indicating a large effect size. This means that students who participated in Problem-Based Learning (PBL) assisted by Assemblr Edu achieved significantly better science learning outcomes than those who received conventional instruction, even after controlling for pretest scores. The analysis also revealed that self-confidence had a significant main effect on learning outcomes ($F = 43.628$, $p = 0.000$, Partial Eta Squared = 0.284), showing that students' psychological characteristics contributed substantially to their academic performance. More importantly, there was a significant interaction effect between the learning model and self-confidence, with $F = 6.486$, $p = 0.012$, and Partial Eta Squared = 0.056, indicating that the effectiveness of PBL assisted by Assemblr Edu varied according to students' levels of self-confidence.

Further pairwise comparison results support this finding. Students with high self-confidence in the experimental group performed significantly better than those with high self-confidence in the control group, with a mean difference of 5.811 and $p = 0.006$. Likewise, students with low self-confidence in the experimental group outperformed those with low self-confidence in the control group, with a mean difference of 16.763 and $p = 0.000$. These findings indicate that PBL assisted by Assemblr Edu was more effective than conventional instruction for both confidence groups, although the magnitude of the benefit differed. Overall, the results suggest that the combination of problem-based learning and AR-supported media not only improves science learning outcomes but also provides a meaningful instructional advantage by supporting students with different levels of self-confidence.

Recommendation

Future implementation of this study suggests that teachers apply Problem-Based Learning assisted by Assemblr Edu in a structured and continuous manner to enhance student engagement, conceptual understanding, and scientific thinking skills. Special attention should be given to students with low self-confidence through gradual support, role distribution in group work, positive feedback, and the creation of a safe and supportive learning environment. School leaders are encouraged to facilitate training on the use of Assemblr Edu, provide adequate digital devices and internet access, and support policies that promote innovative learning practices. For future research, broader sample coverage, different science topics, and additional variables such as learning motivation, critical thinking, and collaboration should be considered to obtain more comprehensive findings on the effectiveness of AR-assisted Problem-Based Learning. Potential barriers that may influence research outcomes include limited technological infrastructure, teachers' readiness in integrating AR into instruction, and variations in students' digital literacy and self-confidence, which need to be addressed to ensure optimal implementation and more accurate research results.



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