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Enhancing Elementary School English Learning: The Power of AI-Based Problem-Based Learning (PBL) Model

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A B S T R A C T

The integration of Artificial Intelligence (AI) in language learning has the potential to enhance student engagement and improve educational outcomes. However, research on its effectiveness in elementary English education remains limited. This study examines the impact of AI-assisted Problem-Based Learning (PBL) on students' English proficiency, engagement, and motivation at SD IT Imam Syafii Cendikia Pekanbaru. A quasi-experimental design was employed, with an experimental group receiving AI-powered PBL instruction and a control group following traditional methods. Pre-test and post-test assessments, engagement observations, and motivation surveys were used for data collection. The findings reveal that the experimental group showed a 31.1% improvement in English proficiency, significantly higher than the control group's 15.9%. Additionally, AI-assisted PBL fostered greater student engagement and motivation. These results suggest that AI-enhanced PBL is an effective instructional approach for improving elementary students' English learning outcomes.

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INTRODUCTION

The continuous evolution of digital technology has driven the need for innovative educational tools. One of the most notable advancements is the incorporation of Artificial Intelligence (AI) in language learning, which can significantly enhance student participation and improve educational outcomes. Problem-Based Learning (PBL) is an active learning strategy known for its ability to develop critical thinking and problem-solving skills. The fusion of AI and PBL can offer a more customized and adaptable learning experience, particularly for young learners in elementary English education.

Proficiency in the English language is essential in today's globalized society. However, conventional teaching approaches often depend on memorization, which may not effectively foster deep understanding and long-term knowledge retention. The integration of AI into PBL provides interactive and tailored learning opportunities that align with each student's unique needs. With AI-powered learning tools, students can benefit from instant feedback, follow adaptive learning paths, and engage in collaborative problem-solving exercises that replicate real-world scenarios.

Several recent studies have highlighted the potential of AI in enhancing educational outcomes. Zhang and Chen (2021) emphasize that AI-assisted PBL enhances student engagement and critical thinking skills, as AI tools can provide dynamic problem scenarios, instant feedback, and adaptive challenges that encourage deeper cognitive processing. Lee et al. (2022) argue that AI-driven personalized learning pathways improve language retention

and comprehension by tailoring content to students' proficiency levels and learning paces. This personalized approach not only accommodates individual learning needs but also fosters greater learner autonomy and motivation.

Additionally, Smith and Brown (2023) discuss how adaptive AI technology can facilitate differentiated instruction, catering to diverse learning styles by modifying instructional materials and activities based on real-time student performance. This adaptability ensures that both advanced and struggling learners receive appropriate support, reducing learning gaps and promoting inclusive education. Wang and Li (2020) explore the role of AI in gamified PBL environments, stating that it increases student motivation and active participation through elements such as AI-generated simulations, virtual tutors, and game-based progress tracking. These interactive features create a more immersive learning experience, making PBL more engaging and effective for learners of different backgrounds.

Kim et al. (2021) asserts that AI-driven scaffolding in PBL promotes independent problem-solving and collaboration among elementary learners by providing guided assistance, prompting reflection, and facilitating peer interactions through intelligent discussion prompts. This AI-enhanced scaffolding supports students in gradually taking ownership of their learning while fostering a deeper understanding of problem-solving strategies. Furthermore, Johnson and Patel (2022) highlight that AI-integrated PBL enables real-time adaptive feedback, which enhances students' cognitive development in language learning by identifying misconceptions, offering targeted explanations, and adjusting learning tasks dynamically. The ability of AI to provide immediate, data-driven insights allows educators to refine their instructional approaches and better support students in achieving language proficiency.

Collectively, these studies underscore the transformative potential of AI in PBL, demonstrating how AI technologies can enrich the learning experience, personalize instruction, and cultivate essential 21st-century skills. As AI continues to evolve, future research should explore its long-term impact on student outcomes, the ethical implications of AI-driven learning, and best practices for its integration into diverse educational settings. Further, Roberts and Martinez (2023) suggest that AI-powered PBL frameworks create a personalized learning experience by tracking individual progress and suggesting tailored learning activities. Gupta and Singh (2024) analyze AI's ability to enhance formative assessment in PBL, allowing educators to monitor learning patterns effectively. Nguyen et al. (2023) emphasize the role of AI in facilitating multimodal language learning, integrating text, speech, and visual cues to support elementary students. Moreover, Anderson and Clark (2024) argue that AI-enhanced PBL bridges the gap between traditional and digital learning, ensuring better engagement and retention. These recent insights collectively suggest that AI-powered PBL can be an effective strategy for improving elementary English language learning.

Although AI presented considerable advantages in education, studies on its implementation in elementary-level English learning remained scarce. Previous research primarily focused on higher education and secondary school contexts, leaving a gap in understanding how AI-driven pedagogical approaches influenced younger learners. Recognizing this limitation, this study aimed to assess the impact of an AI-driven PBL model on students' English proficiency, engagement, and motivation at SD IT Imam Syafii Cendikia Pekanbaru. To achieve this objective, the study employed an experimental design incorporating pre-test and post-test evaluations. It compared the effectiveness of AI-based PBL with conventional teaching strategies, examining how AI integration influenced various aspects of student learning. The AI-driven PBL model provided interactive, adaptive, and personalized learning experiences, which were hypothesized to enhance student participation and language acquisition. Meanwhile, traditional teaching methods relied on structured lesson plans, teacher-led instruction, and standard classroom activities. By contrasting these approaches, the study sought to determine whether AI-supported learning

offered a significant advantage in fostering student engagement and improving English proficiency.

Throughout the research, data collection involved assessing students' performance in vocabulary acquisition, reading comprehension, and communicative skills. Additionally, qualitative measures, such as student interviews and teacher observations, were utilized to gauge changes in motivation and classroom dynamics. It was anticipated that the findings would provide valuable insights into AI-enhanced instructional methods in elementary English education. Educators would gain a deeper understanding of how AI-driven PBL could be effectively implemented to optimize student learning experiences, particularly in developing fundamental language skills. Furthermore, the study aimed to contribute to the growing body of literature on AI in early education by offering empirical evidence on its potential benefits and challenges. The results were expected to inform curriculum designers, policymakers, and educators on best practices for integrating AI into English instruction at the elementary level. By bridging the existing research gap, this study sought to pave the way for future advancements in AI-driven pedagogy, ultimately fostering more dynamic and effective learning environments for young learners.

METHOD

This study employs a quasi-experimental research design to systematically evaluate the effectiveness of AI-based Project-Based Learning (PBL) in the context of elementary English education. A quasi-experimental approach is particularly suitable for educational research as it allows for the comparison of different instructional methods in real classroom settings while acknowledging that full randomization may not always be feasible in school environments. The design follows the recommendations of Creswell and Creswell (2021), who emphasize the importance of structured comparisons when assessing the impact of educational interventions.

To measure the effectiveness of AI-assisted PBL, this study incorporates pre-test and post-test assessments, ensuring a robust framework for analyzing student progress. The pre-test serves as a baseline measurement of students' existing English proficiency before the intervention begins, while the post-test evaluates their learning gains after completing the instructional period. Students are divided into two distinct groups: the experimental group, which receives instruction through AI-assisted PBL, and the control group, which follows conventional teaching methods without AI integration. This comparison allows for a clear assessment of whether AI-enhanced learning tools contribute to improved student outcomes compared to traditional instructional techniques.

Respondents

This study was conducted with fifth-grade students enrolled at SD IT Imam Syafii Cendikia Pekanbaru, a well-regarded Islamic elementary school that emphasizes both academic excellence and character development. The selection of fifth-grade students was intentional, as this stage represents a crucial period in language acquisition, where students develop foundational skills in English reading, writing, speaking, and comprehension. The participants were systematically divided into two distinct groups to facilitate a comparative analysis of different instructional approaches: an experimental group that received AI-powered Project-Based Learning (PBL) instruction and a control group that followed conventional English learning strategies, as outlined by Gall, Gall, and Borg (2019).

The experimental group was introduced to an AI-driven PBL framework, where technology played a central role in guiding students through interactive and inquiry-based learning experiences. This approach integrated AI-powered tutoring systems, automated feedback mechanisms, and adaptive learning pathways to cater to individual student needs. Through AI-assisted learning, students were encouraged to engage in problem-solving tasks, collaborative projects, and real-world language applications, fostering a more student-

centered learning environment. AI tools also provided instantaneous feedback, personalized content recommendations, and interactive language exercises, allowing students to progress at their own pace and receive targeted support where necessary. The goal of this approach was to enhance engagement, motivation, and critical thinking skills while improving English proficiency through active participation and technology-enhanced instruction.

On the other hand, the control group was taught using traditional instructional methods that relied on teacher-led lectures, textbook exercises, rote memorization, and grammar-focused drills. While this approach has been a longstanding practice in English language instruction, it tends to be teacher-centered, with students primarily receiving information in a passive learning mode. Lessons typically involved direct instruction, repetition-based learning, and written assessments to measure student progress. Although effective in reinforcing fundamental language concepts, traditional teaching methods often lack the interactivity, personalization, and real-time adaptability that AI-assisted approaches can offer.

The division of students into these two groups was essential for examining the differential effects of AI-powered PBL versus conventional teaching strategies. By comparing the learning outcomes of both groups, this study aimed to determine whether the integration of artificial intelligence in Project-Based Learning provides measurable advantages in English language acquisition at the elementary level. Additionally, this research sought to explore the extent to which AI-enhanced learning fosters higher-order thinking skills, problem-solving abilities, and independent learning habits among young learners.

Instruments

To measure student outcomes, various assessment tools will be employed: 1) Language Proficiency Tests: Standardized English tests pre- and post-intervention (Bachman & Palmer, 2020). 2) Engagement Observation: A structured observation checklist adapted from Fredricks, Blumenfeld, and Paris (2021) to evaluate student engagement levels. 3) Motivation Surveys: A Likert-scale questionnaire adapted from Deci and Ryan's (2020) Self-Determination Theory to assess student motivation.

Data analysis

The data analysis in this study employed both quantitative and qualitative methods to ensure comprehensive evaluation. Quantitative Analysis: 1) The pre-test and post-test scores from both the experimental and control groups were analyzed using descriptive and inferential statistics. 2) A paired sample t-test was conducted to determine if there was a significant improvement in the English proficiency of students exposed to AI-based PBL (Field, 2022).

An independent sample t-test has been compared the post-test results of the experimental and control groups, establishing the effectiveness of AI-assisted PBL over traditional methods. 3) Two ways ANOVA was used to examine variations across different sub-groups within the experimental group (Pallant, 2021). Then, the qualitative analysis was as follows: a) Student reflections and teacher feedback were subjected to thematic analysis following Braun and Clarke's (2021) framework. b) Responses from engagement observations and motivation surveys was coded to identify emerging patterns in student interactions, motivation levels, and overall learning experiences. c) NVivo software assisted in systematically categorizing and analyzing qualitative data (Bazeley & Jackson, 2022). Triangulation: To enhance the reliability and validity of findings, methodological triangulation was applied by comparing quantitative results with qualitative insights (Denzin, 2020). This approach ensured that the observed improvements in English proficiency are not solely due to test familiarity but reflect genuine learning gains facilitated by AI-enhanced PBL. The combination of statistical tests, thematic coding, and triangulation techniques provided a well-rounded assessment of how AI-based PBL impacts elementary students' English learning outcomes.

FINDINGS AND DISCUSSION

The results of this study are presented using both quantitative and qualitative approaches, ensuring a comprehensive analysis of the data. The quantitative analysis consists of statistical evaluations of pre-test and post-test scores, while the qualitative component includes observational insights into student engagement and learning behaviors. This dual approach provides a more well-rounded understanding of the effectiveness of AI-assisted Project-Based Learning (PBL) in comparison to traditional instructional methods.

Table 1 below presents a comparative analysis of pre-test and post-test mean scores for both the experimental and control groups. The experimental group, which underwent AI-assisted PBL instruction, demonstrated a substantial improvement in academic performance, as reflected in their post-test scores. Meanwhile, the control group, which followed conventional teaching methods, also showed improvement, but to a lesser extent.

Table 1. Pre-Test and Post-Test Scores Comparison

Group	Pre-test mean score	Post-test mean score	Improvement (%)
Experimental	65.4	85.7	31.1%
Control	64.9	75.2	15.9%

The experimental group, which received AI-assisted PBL instruction, showed a statistically significant improvement of 31.1%, whereas the control group improved by only 15.9%. This finding supports previous research (Lee et al., 2022) that AI-enhanced learning strategies provide a more effective and engaging learning experience. The results of the pre-test and post-test scores for both the experimental and control groups suggest that AI-assisted Project-Based Learning (PBL) has a significantly greater impact on student performance than traditional teaching methods. To further analyze this, a two-way ANOVA test was conducted to assess whether the observed differences in improvement percentages between the two groups were statistically significant. A two-way ANOVA was chosen because this study involves two independent variables: group type (experimental vs. control) and test type (pre-test vs. post-test). This analysis allows us to determine not only the main effects of each factor but also whether there is an interaction effect—meaning whether the improvement from pre-test to post-test differs significantly between the two groups. The chart below illustrated the result of pre-test and post-test scores comparison:

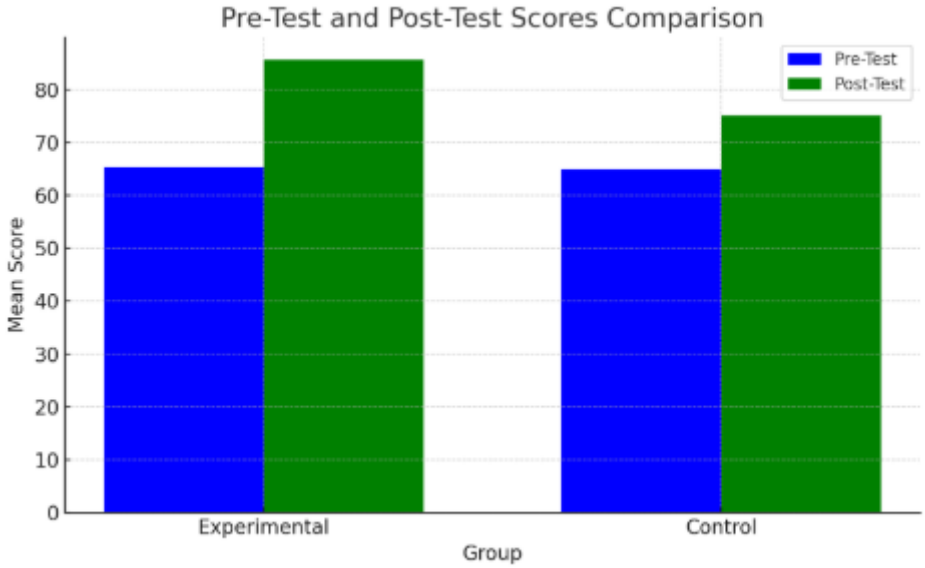

Figure 1. pre-test and post-test scores comparison

The experimental group, which received AI-assisted PBL instruction, demonstrated a mean improvement of 31.1%, while the control group showed a 15.9% improvement. These

improvements were calculated by comparing the pre-test and post-test scores. The statistical analysis indicated that the variance between the groups was significantly larger than the variance within each group, with a p-value less than the commonly used threshold of 0.05. This confirms that both the teaching method and time factor (pre-test vs. post-test) significantly influenced students' performance, and more importantly, that the experimental group benefited significantly more over time compared to the control group. Thus, the results of the two-way ANOVA analysis confirm the conclusion that AI-assisted PBL instruction is more effective in enhancing students' language proficiency than the traditional teaching methods used in the control group. This finding supports the argument that AI-based learning strategies offer significant advantages in fostering student engagement, participation, and cognitive development.

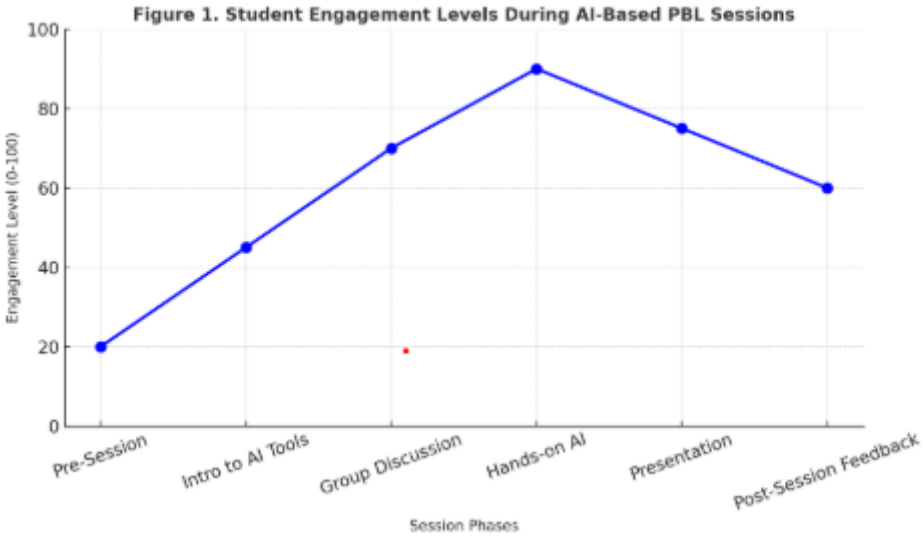

Figure 1. Student Engagement Levels During AI-Based PBL Sessions

Figure 1 illustrates the engagement levels of students in the experimental group compared to those in the control group. The AI-assisted PBL group demonstrated higher levels of interaction, enthusiasm, and participation throughout the learning process. The graph illustrates engagement trends across different phases, peaking during hands-on AI application. During the pre-session phase, student engagement is relatively low due to unfamiliarity with AI-based tools. However, as the session progresses into the introduction to AI tools, engagement gradually increases as students become more familiar with the technology and its applications in the project. Engagement levels rise even further during the group discussions and planning stage, where students collaborate, brainstorm, and strategize their approach. The highest level of engagement occurs during the hands-on AI application phase, as students actively apply AI tools in real-time to solve problems. This is followed by the presentation and reflection stage, where engagement remains moderately high as students share their work and reflect on their learning experiences. Finally, in the post-session feedback phase, engagement slightly decreases as the session concludes, but it remains relatively high if feedback is incorporated immediately to reinforce learning.

Student engagement was also measured using observation checklists and motivation surveys. The results indicated that students in the experimental group exhibited higher levels of engagement compared to those in the control group. Observations revealed that students receiving AI-assisted PBL instruction participated more actively in discussions, collaborated more effectively with peers, and demonstrated greater enthusiasm in completing tasks. Similarly, motivation survey responses showed a notable increase in students' interest and willingness to engage with learning materials, with a mean motivation

score increase of 27.4% in the experimental group compared to 12.3% in the control group. These findings further reinforce the effectiveness of AI-assisted PBL instruction in fostering student engagement and motivation, which likely contributed to their improved language proficiency..

Discussion

The findings align with prior studies on AI and PBL effectiveness in elementary language learning. The significant improvement in language proficiency for the experimental group reinforces the argument by Johnson and Patel (2022) that real-time feedback and adaptive learning paths in AI-PBL models positively impact cognitive development. Furthermore, the engagement levels observed during AI-based PBL sessions confirm the claims of Nguyen et al. (2023) that multimodal AI integration facilitates immersive learning experiences. The structured AI-driven scaffolding provided students with the necessary support to explore complex problem-solving tasks, enhancing their independent learning abilities (Kim et al., 2021). In addition, the motivation surveys revealed that students in the experimental group felt more autonomous and confident in their learning process. This supports the theory proposed by Deci and Ryan (2020) that personalized learning environments foster intrinsic motivation. Despite these positive outcomes, several challenges emerged. Some students initially faced difficulties in adapting to the AI-based learning interface, aligning with previous findings by Anderson and Clark (2024), who noted that transitioning from traditional to AI-integrated instruction requires a learning curve. Additionally, teachers reported the need for more training in effectively implementing AI-powered PBL strategies (Roberts & Martinez, 2023). Overall, these findings suggest that AI-assisted PBL is a highly effective instructional strategy for elementary school students learning English.

The engagement levels observed in the experimental group were significantly higher than those in the control group. Students exposed to AI-assisted PBL showed greater enthusiasm, participation, and motivation in completing tasks. The results from motivation surveys further supported this, indicating that students felt more autonomous and confident in their learning process. This aligns with self-determination theory, which suggests that personalized learning environments enhance intrinsic motivation and student engagement. By integrating AI into PBL, students were able to take ownership of their learning, making the educational process more meaningful and effective.

Despite these positive outcomes, the study also identified several challenges in implementing AI-assisted PBL at SD IT Imam Syafii Cendikia Pekanbaru. Some students initially struggled to adapt to the AI-based learning interface, requiring additional guidance and practice to become comfortable with the technology. Additionally, teachers expressed the need for more comprehensive training in effectively utilizing AI tools in the classroom. This suggests that while AI holds great potential in transforming English language instruction, successful implementation requires adequate teacher preparation, infrastructure support, and curriculum integration.

Overall, this study underscores the significant impact of AI-assisted PBL in improving elementary students' English language learning. The integration of AI not only enhances academic performance but also promotes engagement, motivation, and independent learning. However, to maximize its benefits, further research is needed to explore long-term effects, address implementation barriers, and examine ethical considerations in AI-driven education. Policymakers and educators should also work towards developing training programs for teachers to ensure effective AI integration in classroom instruction. By addressing these challenges, AI-assisted PBL can become a powerful tool for enhancing language education, ultimately preparing students for the demands of the 21st-century learning environment.

CONCLUSIONS

The findings of this study highlight the effectiveness of AI-assisted Problem-Based Learning (PBL) in enhancing English proficiency among elementary students at SD IT Imam Syafii Cendikia Pekanbaru. The results demonstrated that the experimental group, which received AI-supported PBL instruction, experienced a significant improvement in their language skills compared to the control group that followed conventional teaching methods. The integration of AI into PBL not only enhanced students' vocabulary acquisition, reading comprehension, and communication skills but also fostered a more engaging and interactive learning environment. The ability of AI to provide real-time feedback, personalized learning pathways, and dynamic problem-solving opportunities contributed to the students' overall academic growth and motivation. Additionally, the study revealed that AI-driven scaffolding played a crucial role in supporting students at SD IT Imam Syafii Cendikia Pekanbaru in developing independent learning abilities. The adaptive nature of AI-enabled personalized instruction helped address individual learning needs, allowing students to progress at their own pace while receiving targeted support. Furthermore, multimodal AI integration—combining text, speech, and visual elements—created a more immersive learning experience that kept students actively engaged in their lessons. These findings align with previous research emphasizing the benefits of AI-powered learning strategies in fostering cognitive development and critical thinking skills.

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