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CULTIVATING CRITICAL INFERENCE SKILLS: A PROBLEM-BASED LEARNING MODEL FOR HIGH SCHOOL STUDENTS

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Abstract: In the era of Industry 4.0, the demand for 21st-century competencies such as critical and inferential reasoning has become increasingly essential for educational success and workplace readiness. However, many traditional classroom practices still focus primarily on content delivery rather than developing students' higher-order thinking skills. Responding to this gap, this study investigates the effect of the Problem-Based Learning (PBL) approach on enhancing students' inference skills compared with conventional teaching methods. The research was conducted among in-service vocational English teachers participating in the Teacher Professional Education Program. A quasi-experimental design was employed, involving control and experimental groups, with data collected through pre-test and post-test assessments. The Shapiro–Wilk test confirmed that the data in both groups were normally distributed at both the pre-test and post-test. The findings revealed that the PBL group demonstrated a significant improvement in inference skills, while the control group showed only marginal progress. This indicates that PBL's student-centered and inquiry-based framework effectively stimulates reasoning processes through problem identification, hypothesis formulation, evidence-based analysis, and reflective thinking. The authenticity of learning contexts in PBL also fosters deeper cognitive engagement and facilitates the transfer of inference skills to novel situations. Consequently, this study provides empirical support for the implementation of constructivist pedagogies in English language teaching, emphasizing the importance of integrating reasoning-oriented learning strategies to develop learners' critical and inferential thinking. The implications highlight the need for teacher education programs to systematically incorporate PBL in order to cultivate essential higher-order thinking competencies required in the 21st-century professional landscape.
Keywords: *Problem-Based Learning; inference skills, critical thinking; constructivist pedagogy; vocational English education.*

INTRODUCTION

In order to meet the expectations of Industry 4.0, education in the twenty-first century places a strong emphasis on producing human resources with critical thinking, creativity, and adaptive learning skills. Because they prioritize rote memory and factual recall over active engagement and inquiry, traditional teacher-centered pedagogies have frequently failed to foster higher-order thinking. As part of the competency-based curriculum reform, creative pedagogical approaches like Problem-Based Learning (PBL) have been widely adopted to address the difficulties of contemporary education. PBL promotes critical and inferential thinking as crucial elements of academic performance and career preparedness by encouraging students to build knowledge through the solution of real-world issues (Afandi et al., 2024; Alreshidi & Lally, 2024; Idris et al., 2021). In Indonesia's educational transformation, the paradigm shift toward student-centered learning has become essential, with the development of inference skills, students' capacity to draw logical conclusions from evidence, serving as a critical cognitive target for promoting intellectual independence and lifelong learning (Ansya & Salsabilla, 2024; Guo et al., 2024; Wirantaka & Sukarno, 2022).

PBL is successful in raising learning outcomes

and fostering higher-order cognitive development in a variety of topics, according to a large body of research. Research shows that students who participate in PBL exhibit superior analytical thinking and creative problem-solving skills compared to students who get traditional teaching (Affandy et al., 2024; Boom-Cárcamo et al., 2024; Fitria et al., 2024). Incorporating creative pedagogy into PBL improves students' ability to make connections between concepts and develop hypotheses in the context of science education (AlAli, 2024; Ardiansyah et al., 2024). These results show that inquiry-driven learning promotes metacognition and reflective judgment by pushing students to analyze information in depth. As a result, PBL has become a pedagogical innovation that promotes learning transfer and long-term comprehension outside of the classroom (Ma et al., 2024; Zakaria et al., 2025).

PBL provides an authentic framework for teaching English as a foreign language (EFL), allowing students to utilize language in a meaningful way to solve contextual issues while simultaneously improving their communication and reasoning abilities. According to Guo et al. (2024) and Shafamarwa et al. (2024), PBL-based EFL classrooms foster inferential comprehension by asking students to analyze evidence, interpret meaning, and make logical arguments during discussions. According to Çelik et al. (2024) and Lin and Chen (2024), reading comprehension, inference accuracy, and learner engagement are all improved when PBL is combined with AI-supported text processing tools like ChatGPT. These findings show that inferencing processes are inherently embedded in problem-driven situations, establishing PBL as a tactical method for fostering language-based reasoning skills (Hui et al., 2025; Wirantaka & Sukarno, 2022).

The connection between PBL and the growth of 21st-century abilities, including critical thinking, teamwork, creativity, and digital literacy, is also highlighted by an expanding corpus of research. According to Fitria et al. (2024), blended PBL greatly improves key science learning competencies. According to Alreshidi and Lally (2024), teacher training in PBL implementation results in quantifiable increases in students' self-efficacy and motivation. Additionally, by combining inquiry with social responsibility, PBL helps achieve the Sustainable Development Goals, according to research by Nguyen et al. (2024). These results demonstrate that PBL builds broader competences that are essential for learners' adaptability and global employability in addition to improving cognitive accomplishment (Nisah & Syukri, 2024; Safitri et al., 2024).

A key component of reasoning that connects observation and interpretation is inference, along with critical thinking. It entails drawing inferences by fusing new information with existing knowledge, a skill necessary for both reading comprehension and problem-solving (Chen et al., 2024; Song et al., 2024). According to research by Hwang et al. (2024) and Dixon and Oakhill (2024), students' overall learning success is predicted by their inferential comprehension. PBL strengthens cognitive flexibility by fostering inference through iterative cycles of hypothesis production, testing, and reflection (Idris et al., 2021; Marisda et al., 2024; Sulistyanto et al., 2024).

The effectiveness of PBL depends on the responsibilities that teachers play in its implementation. Research indicates that students' engagement in inquiry-based learning is directly impacted by teachers' readiness, communication, and classroom management (Hidayat, 2024; Alreshidi & Lally, 2024; Rahmandani et al., 2024). Students' reasoning and inferential correctness greatly improve when teachers direct inquiry processes with reflective questioning and feedback (Amirulloh et al., 2025; Ardiansya et al., 2024). However, studies also show that many teachers still find it difficult to match the inquiry sequence of PBL with lesson design, which results in uneven implementation outcomes (Hidayati et al., 2024; Atmasari et al., 2024).

PBL promotes deep conceptual learning and cognitive transfer, according to empirical data in science and math education. For example, Islamiati et al. (2024) showed that learning style exchanges and PBL had a substantial impact on students' analytical performance. In a similar vein, Ifada et al. (2024) discovered that in group-based problem-solving contexts, PBL improves cooperation and mathematical reasoning. According to Harahap et al. (2024), the impact of PBL on critical thinking outcomes is mediated by students' initial ability, demonstrating that structured inquiry promotes cognitive development at all proficiency levels (Nurlinda et al., 2024; Sarnoko et al., 2024).

STEM sectors are not the only ones where PBL has improved inferential thinking. Similar results are found in humanities and language education research. Incorporating contextual concerns into reading and writing activities improves inferencing and interpretation,

according to studies by Tiara et al. (2024) and Ardiansyah et al. (2024). Similarly, Byeon et al. (2024) showed that multimodal, task-based engagement in PBL scenarios helps students formulate hypotheses and make decisions. These results are consistent with constructivist viewpoints, which emphasize that learning happens when students actively create and defend meaning (Divito et al., 2024; Lee, 2025).

By offering scaffolding for thinking processes, the incorporation of artificial intelligence tools like ChatGPT has increased PBL's instructional potential. According to Hui et al. (2025), clinical students' inferential accuracy and reflective learning were greatly enhanced by ChatGPT-assisted PBL. In a similar vein, Yusuf et al. (2024) and Allgeuer et al. (2024) found that AI-supported debate improves argument quality and metacognitive regulation. These technologies make PBL even more adaptable in digital classrooms by assisting students in developing hypotheses, testing interpretations, and honing logical reasoning during problem-solving in EFL contexts (Agrawal et al., 2024; Lin & Chen, 2024).

PBL consistently improves students' reasoning skills across fields, according to a number of meta-analyses. According to Walker and Leary (2009, as referenced in Wirantaka & Sukarno, 2022) and Fitria et al. (2024), students who are exposed to problem-based inquiry do better in critical thinking, creativity, and inferential comprehension than students in typical classrooms. In a similar vein, Lee (2025) discovered that first-time PBL participants reported increased motivation and a better comprehension of learning processes. These results support PBL's empirical basis as a successful teaching strategy that fosters transferable reasoning and decision-making abilities (Mauliana et al., 2024; Muliawati & Aldin, 2024).

Even with these encouraging findings, other studies continue to highlight difficulties with time management, classroom logistics, and the mental demands of self-directed inquiry. Teachers frequently struggle to encourage reflection or keep course objectives and student-led inquiry coherent (Hidayat, 2024; Ni'mah et al., 2024). However, when faced with unstructured issues without enough scaffolding, learners may encounter cognitive overload (George et al., 2024; Parvizi-Wayne et al., 2024). To maximize the advantages of PBL, these problems highlight the necessity of adaptive instructional designs and ongoing teacher support (Karttunen et al., 2025; Husain et al., 2025).

In this context, PBL research in Indonesia has expanded dramatically in recent years, especially in elementary and secondary education. Research by Afandi et al. (2024), Aprina et al. (2024), and Larasati et al. (2024) repeatedly demonstrates that PBL enhances students' critical thinking and problem-solving involvement. However, there are still few empirical studies on inference abilities, a particular subdimension of reasoning, and the majority of current research concentrates on learning outcomes or general critical thinking. Therefore, more research is required to ascertain how PBL supports inferential processes, particularly in English learning environments where linguistic proficiency depends on comprehension and interpretation (Ansya & Salsabilla, 2024; Nirwana et al., 2024).

Although several studies confirm that PBL improves general cognitive and affective outcomes, little is known about how it specifically promotes inference-making, which is the ability to make inferences by connecting past knowledge with textual or situational evidence. The majority of earlier studies place more emphasis on creativity or general critical thinking than on the specific ability of inference reasoning. Thus, the purpose of this study is to find out how using the Problem-Based Learning paradigm in senior high school English classes enhances students' ability to draw conclusions. (Idris et al., 2021; Wirantaka & Sukarno, 2022; Ardiansyah et al., 2024).

By separating inference skill as a separate cognitive outcome inside the PBL framework, this study bridges the fields of language learning and higher-order reasoning, introducing a fresh empirical focus. This study particularly analyzes changes in inferential reasoning through methodical PBL stages in real-world classroom settings, in contrast to earlier research that looks at motivation or general problem-solving. Additionally, it incorporates reflective discourse and new AI-assisted inquiry tools as scaffolding mechanisms to improve inferential processing (Hui et al., 2025; Yusuf et al., 2024; Lin & Chen, 2024).

The study is important from a theoretical and practical standpoint. Theoretically, by offering empirical proof that PBL successfully fosters inference reasoning, a fundamental aspect of critical thinking, it enhances constructivist learning theory. In a practical sense, it provides curriculum designers and teachers with pedagogical implications for incorporating

problem-based tasks into English instruction so that students can comprehend, reason, and draw conclusions based on evidence. According to Guo et al. (2024), Alreshidi & Lally (2024), and Zakaria et al. (2025), the results are anticipated to support educational reforms that foster inquiry-based and reflective pedagogies that cultivate 21st-century skills necessary for lifelong learning and professional competence.

METHOD

The study was conducted using a quantitative research method with a quasi-experimental design to investigate the impact of implementing the Problem-Based Learning (PBL) approach on students' inference skills. The research took place in three state senior high schools in Brebes Regency, namely SMA Negeri 1 Brebes, SMA Negeri 2 Brebes, and SMA Negeri 3 Brebes. All three schools have implemented the Merdeka Curriculum, emphasizing student-centered learning and inquiry-based approaches, making them suitable sites for implementing and evaluating the PBL model. Each school involved two groups: one class that implemented the Problem-Based Learning approach and one class that did not. The participants of the study included three English teachers and their students. Prior to the data collection, the researcher met the participating teachers to obtain their consent and discuss the uniform understanding of the PBL implementation, the research timeline, and the students who would participate in the study through a focus group discussion. Afterward, the teachers prepared the necessary teaching and learning materials, such as lesson plans, media, student worksheets, and test instruments.

During the teaching phase, the teachers implemented the Problem-Based Learning approach following the stages proposed by Arends (2012), which included orienting students to the problems, organizing students for study, assisting independent and group investigations, developing and presenting artefacts and exhibits, and analyzing and evaluating the problem-solving process. At this stage, the implementation of the PBL approach was linked to students' inference skills, which were assessed using the Watson-Glaser Critical Thinking Appraisal (W-GCTA). This instrument, developed by Watson and Glaser (2012), measured critical thinking abilities, particularly inference skills, which are essential for students' analytical reasoning and decision-making.

The data were collected through pre- tests and post-tests administered to both the PBL and non-PBL classes. The test consisted of items measuring students' inference skills, with a maximum score of 100, and was conducted within 2 × 45 minutes. To ensure validity, the test instruments were reviewed by teaching and learning experts and linguists with relevant academic qualifications. Each student's score on the inference skill items was summed to obtain a total score representing their overall inference skill ability. The collected numerical data were analyzed using the Statistical Package for the normality test was first conducted to determine whether the data were normally distributed. If the assumption of normality was met, parametric analyses were applied. The Independent Samples t-test was used to compare the inference skills of students between the PBL and non-PBL classes, while the Paired Samples t-test was employed to compare the pre-test and post-test scores within each class. Through this analysis, the study aimed to determine whether the implementation of the Problem-Based Learning approach significantly contributed to improving students' inference skills.

RESULTS AND DISCUSSION

The Results and Discussion section presents the findings of the study concerning the effect of implementing the Problem-Based Learning (PBL) approach on students' inference skills, as one of the core dimensions of critical thinking. The analysis compares the performance of students in the PBL group and the control group through both pre-test and post-test results. The dependent variable in this study is the students' inference skill, while the independent variable is the learning approach applied namely, the PBL and non- PBL (control) methods.

To examine the impact of the intervention, several statistical tests were conducted. First, normality testing was performed to ensure the data met the assumptions for parametric analysis. Subsequently, Paired Samples t-tests were applied to determine whether there was a significant improvement in inference skills within each group (pre-test versus post-test), while Independent Samples t-tests were employed to compare the mean inference skill scores between the PBL and control groups at both testing stages.

Normality inference skills pre test

Table 1. *Normality inference skills pre test*

Treatment	Statistic	df	Sig.
Control	0.981	95	0.172
Problem based	0.983	102	0.207

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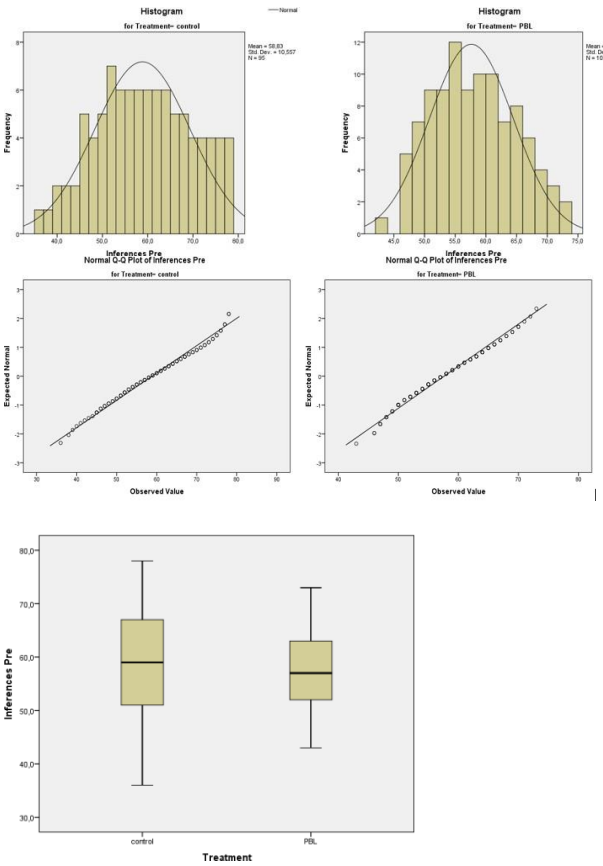


Figure 1. *Normality plot of inference skills pre-test*

The normality test results for students' inference skills in the pre-test are presented in Table 1 and visualized through histograms, Q–Q plots, and boxplots for both the control and Problem-Based Learning (PBL) groups. Based on the Shapiro–Wilk test, the significance values for the control group (Sig.= 0.172) and the PBL group (Sig. = 0.207) were both greater than 0.05. These results indicate that the data in both groups were normally distributed, thus meeting the assumption required for conducting parametric statistical analyses such as the Independent Samples t-test and Paired Samples t-test.

The histograms show that the distribution of students' inference scores in both groups approximated a bell-shaped curve, which supports the result of the Shapiro–Wilk test. The control group's scores ranged from approximately 40 to 80, with a mean of 59.83 and a standard deviation of 10.557, while the PBL group's scores ranged from around 45 to 75, with a mean of

57.63 and a standard deviation of 6.858. The slight difference in mean scores before the implementation of PBL suggests that both groups began with relatively comparable levels of inference ability, ensuring fair comparison in the subsequent analysis.

The Q–Q plots further confirm the normality of the data, as the plotted points for both groups align closely along the diagonal line, indicating that the observed values correspond well with the expected normal distribution. Similarly, the boxplot comparison between the control and PBL groups shows that both distributions are symmetrical and balanced, with no extreme outliers detected. This visual evidence reinforces that the data are homogeneous and normally distributed, validating the suitability of parametric testing for examining the differences in inference skills across the two treatment conditions.

Independent t-test inference pre test

The results of the pre-test on students' inference skills showed no significant difference between the control group (M = 58.83) and the Problem-Based Learning (PBL) group (M = 57.63), with a *p*-value of

0.340 (see Figure 1). This finding indicates that both groups had comparable baseline abilities before the implementation of the PBL intervention. Such similarity in pre-test performance suggests that the initial inference skill level was relatively homogeneous, ensuring that any subsequent differences observed in the post-test could be attributed to the treatment rather than to pre- existing disparities (Creswell & Creswell, 2018).

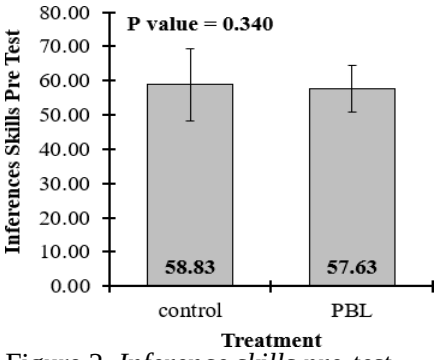


Figure 2. *Inference skills pre-test*

Inference skill defined as the cognitive ability to draw logical conclusions from available information is a critical component of higher-order thinking (Ennis, 2011). The absence of a significant pre-test difference aligns with previous research emphasizing the need for an equal baseline before experimental treatment, particularly in studies examining instructional interventions (Fraenkel, Wallen and Hyun 2019). A comparable initial mean score between the two groups ensures internal validity in evaluating the effects of PBL on students' reasoning and critical

thinking (Gall, Gall and Borg 2010).

Furthermore, the finding that students' pre-test inference skill levels were moderate in both groups suggests that traditional instructional methods used prior to the intervention might have provided only limited opportunities for developing complex reasoning (King, Goodson and Rohani 2012). Previous studies also noted that conventional teacher-centered instruction tends to focus on knowledge recall rather than the development of inference and analytical skills (Schmidt, Rotgans and Yew 2011).

The comparable pre-test scores between the control and PBL groups provide a strong foundation for evaluating the effectiveness of PBL in enhancing inference skills during the subsequent intervention phase. PBL, as described by Barrows and Tamblyn (1980), engages learners in solving authentic problems, which can foster inferential reasoning through active exploration, hypothesis generation, and reflection. Thus, while the pre-test indicates similar initial capacities, the post-test analysis will be crucial to determine whether the problem- based learning approach effectively improves students' inference skills over time.

Normality inference skills post test

Table 2. *Normality inference skills post test*

Treatment	Shapiro-wilk		
	Statistic	df	Sig
Control	0.984	95	0.283
Problem-based learning	0.989	102	0.610

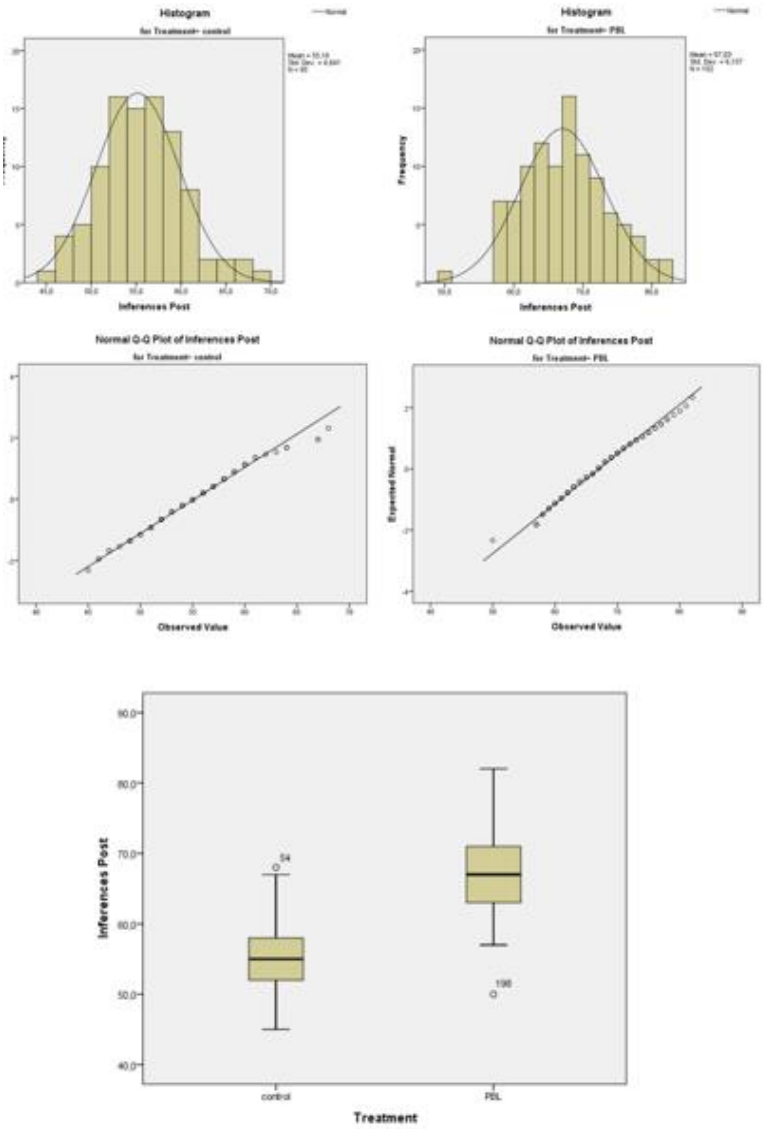


Figure 3. *The test result*

The normality test results for the post-test inference skill scores are presented in Table 2, accompanied by histograms, Q–Q plots, and boxplots for both the control and Problem-Based Learning (PBL) groups. Based on the Shapiro–Wilk test, the obtained significance values for the control group (Sig. = 0.283) and the PBL group (Sig. = 0.610) were both greater than 0.05, indicating that the data from both groups were normally distributed. This confirms that the assumption of normality was satisfied, allowing for further analysis using parametric statistical tests, such as the Independent Samples t-test and Paired Samples t-test, to compare inference skill improvements across treatment conditions.

The histograms show that both distributions approximated a normal bell-shaped curve, reflecting a balanced spread of post-test scores around the mean. The control group achieved a mean score of 55.16 with a standard deviation of 4.641, while the PBL group obtained a higher mean of 67.03 with a standard deviation of 6.557. This suggests that, after the intervention, students who learned through the PBL approach demonstrated a notably higher level of inference skill compared to those in the control group. The smaller spread of scores in the control group indicates moderate consistency, whereas the wider distribution in the PBL group reflects varied yet generally higher performance outcomes.

The Q–Q plots for both groups further support the results of the normality test. The plotted points closely follow the diagonal line, signifying that the observed data align with the expected normal distribution. There are no major deviations or curvature patterns, confirming that the inference skill data exhibit a normal distribution pattern for both groups.

Additionally, the boxplot comparison illustrates a visible difference in central tendency between the two groups. The PBL group's median score is notably higher than that of the control group, demonstrating the positive effect of the PBL approach on students' inference abilities. Although a few mild outliers appear in both groups, they remain within acceptable limits and do not significantly distort the data distribution.

Independen T-Test Inference Post Test

The test results showed that in the Inferences Post-Test, the average score of the PBL group (Mean = 67.03) was significantly higher than that of the control group (Mean = 55.16). The t-test results yielded a Sig. (2-tailed) value of 0.000 (< 0.05) with a mean difference of 11.87 points, indicating a significant difference between the two groups after the treatment.

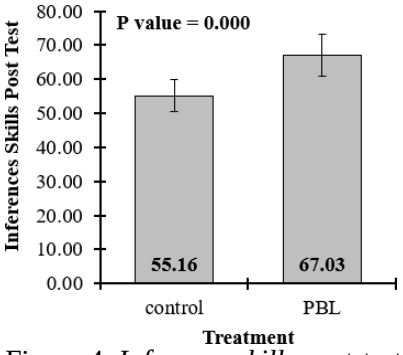


Figure 4. *Inference skills post-test*

This finding demonstrates that the implementation of PBL had a substantial positive effect on improving students' ability to make logical inferences. The marked increase in the PBL group's mean score indicates that engaging learners in problem- centered activities significantly enhances their cognitive reasoning and analytical competence (Hmelo-Silver 2004; Loyens Kirschner and Paas 2011).

The improvement observed in the PBL group can be attributed to the constructivist learning environment fostered by PBL, in which students actively construct knowledge through the exploration of authentic problems (Barrows, 1986). By requiring students to hypothesize, gather evidence, and justify conclusions, PBL encourages the development of higher-order cognitive processes, including inference-making, analysis, and synthesis (Savery 2015). In contrast, the control group, which likely experienced more traditional lecture-based instruction, showed minimal improvement, consistent with prior findings that teacher- centered methods often fail to stimulate deep reasoning and independent thought (Prince and Felder 2006).

Furthermore, the significant post-test difference supports the theoretical premise that PBL enhances metacognitive awareness and promotes meaningful learning through reflection and collaboration (Dolmans et al. 2005). When learners work collaboratively to solve complex, ill-structured problems, they engage in discourse that requires articulating reasoning and evaluating alternative perspectives key elements of inference skill development (Schmidt, Rotgans and Yew 2011).

This result is also consistent with empirical evidence from previous studies showing that PBL increases students' critical thinking and reasoning performance in diverse educational contexts (Walker and Leary 2009; Tiwari et al. 2006). The

increase in inference skill scores among PBL participants demonstrates the transformative potential of learner-centered pedagogies in promoting deep cognitive engagement and transferable problem-solving abilities.

Paired t-test treatment control

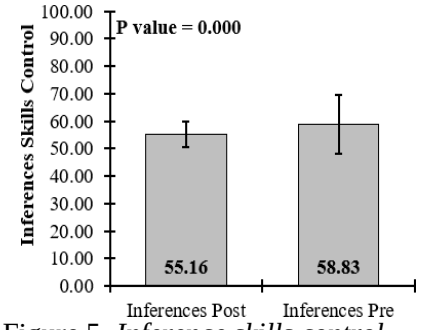


Figure 5. *Inference skills control*

The comparison of inference skill scores in the control group between the pre- test (M = 58.83) and post-test (M = 55.16) revealed a statistically significant decrease, as indicated by the *p*-value of 0.000 (see Figure 3). This finding suggests that students who were taught through conventional or lecture- based instruction experienced a decline in their ability to draw logical inferences after the learning intervention. The reduction in mean score may reflect the limited cognitive engagement fostered by traditional teaching methods, which often emphasize content transmission rather than student-centered exploration and reasoning (Prince and Felder 2006).

Traditional, teacher-directed instruction tends to position learners as passive recipients of information, offering minimal opportunities for them to construct meaning, question assumptions, or synthesize knowledge independently (Kirschner, Sweller and Clark 2006). As a result, students may not effectively develop or retain higher- order cognitive processes such as inference, analysis, and evaluation. The observed decline in performance could also be linked to the lack of contextualized problem-solving or collaborative discussion, which are critical components for enhancing inferential reasoning (Hmelo-Silver 2004; Schmidt, Rotgans and Yew 2011).

Moreover, without guided inquiry or reflective dialogue, learners in the control group may have failed to connect new knowledge with prior experiences, leading to superficial understanding and reduced long- term retention (Bransford, Brown and Cocking 2000). This aligns with research indicating that lecture-based instruction often results in temporary recall rather than deep conceptual understanding (Freeman et al. 2014). Therefore, the significant decrease in inference skill scores among the control group underscores the limitations of traditional approaches in sustaining cognitive growth over time.

In contrast, active learning and problem-oriented approaches, such as Problem-Based Learning (PBL), have been shown to promote critical reasoning, metacognitive awareness, and sustained improvement in inference skills (Walker and Leary 2009; Savery 2015). These findings reinforce the pedagogical argument that student engagement, collaboration, and inquiry-based learning are essential elements in nurturing complex reasoning skills that traditional instruction alone cannot adequately support.

Paired t-test treatment problem-based learning (PBL)

The average Inferences score on the post-test (Mean = 67.03) was significantly higher than the pre-test (Mean = 57.63). The average difference was 9.40 points with a standard deviation of 2.19. The t-test yielded a t-value of 43.443 with 101 degrees of freedom (df) and a significance level of p =0.000 (<0.05). These results indicate a significant increase in students' inference skills after participating in PBL-based learning. Thus, the implementation of PBL has proven highly effective in improving students' inference skills, as evidenced by the consistent and statistically significant increase in scores. These findings confirm that the PBL model provides a significantly greater positive contribution compared to conventional learning.

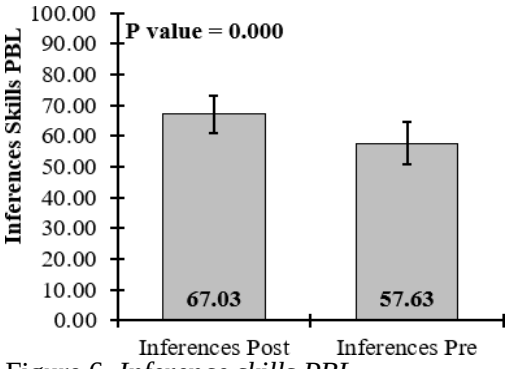


Figure 6. *Inference skills PBL*

This finding provides compelling evidence that PBL was markedly more effective in developing inference reasoning than conventional instruction. Inference, as a higher-order cognitive process, requires students to interpret data, recognize patterns, and construct logical relationships between evidence and conclusions. The structured inquiry characteristic of PBL where learners

identify, analyze, and solve real-world problems appears to stimulate precisely these reasoning pathways (Hmelo-Silver 2004; Schmidt et al. 2011).

The improvement in the PBL group's inference performance can be explained by the cognitive engagement and contextual learning that PBL promotes. During the PBL process, learners must not only acquire factual information but also interpret and connect it to generate meaningful conclusions, which directly trains inference-making ability (Dolmans et al. 2016). According to Vygotsky's (1978) social constructivist theory, such reasoning develops most effectively through guided interaction, where learners collaboratively construct meaning and refine their understanding through dialogue and reflection. In this study, the consistent and statistically significant increase in inference scores (mean difference

= 9.40, t = 43.443, p < 0.001) reflects the PBL group's enhanced ability to engage in analytical and inferential thinking through problem exploration and peer discussion. Similar findings were reported by Sungur and Tekkaya (2006), who found that PBL environments significantly enhanced students' self-regulation and reasoning abilities by engaging them in inquiry cycles that required continuous inference-making and justification.

Conversely, the control group's inference scores demonstrated a significant decline from pre-test to post-test (mean difference = -3.67, t = -3.926, p < 0.001). This unexpected decrease suggests that conventional, lecture-based instruction not only failed to foster inference development but may have constrained students' reasoning flexibility. Traditional teaching methods often emphasize the reproduction of knowledge rather than its interpretation, limiting opportunities for learners to practice inferential thinking (Kirschner, Sweller and Clark 2006; Prince 2004). Without active engagement or cognitive conflict, learners may become passive recipients of information, leading to superficial understanding and reduced ability to draw logical conclusions independently. This finding corroborates the arguments of Tiwari et al. (2006), who noted that students in non- PBL settings tend to show stagnation or regression in reasoning performance due to the absence of inquiry-based cognitive stimulation.

The results also align with metacognitive learning theory, which posits that inference-making is strengthened when learners monitor, evaluate, and regulate their thought processes (Zimmerman, 2002). In the PBL framework, learners continuously hypothesize, test, and revise their assumptions based on evidence, a cycle that promotes both inferential and reflective thinking (Hmelo-Silver and Barrows 2008). This iterative process fosters describe as "conceptual change," where learners reconstruct their mental models to accommodate new information and generate valid inferences. The structured guidance of facilitators, combined with peer discussion and self-directed learning, thus creates an optimal cognitive environment for inference development.

Another explanation for the PBL group's superior performance lies in the authenticity of learning contexts embedded in the Problem-Based Learning model. Authentic learning refers to instructional contexts that mirror the complexity and ambiguity of real-life situations, enabling learners to apply knowledge meaningfully rather than memorizing abstract concepts (Herrington and Oliver 2000). In PBL, learners engage with real or simulated problems that are ill-structured, containing incomplete or conflicting information, which compels them to actively interpret data, identify causal relationships, and predict outcomes through logical reasoning (Dochy et al. 2003; Savery 2015). This process fosters *epistemic engagement* a deep cognitive involvement in making sense of the problem which is crucial for developing inference- making skills (Schmidt et al. 2011).

The authenticity of the problem context in PBL stimulates learners to continuously bridge theory and practice, thereby activating higher-order cognitive processes such as analysis, synthesis, and evaluation. According to *Cognitive Apprenticeship Theory* (Collins, Brown and Holum 1991), authentic tasks enable learners to externalize reasoning processes and gradually internalize expert-like thinking patterns through guided inquiry and reflection. Consequently, students not only acquire domain knowledge but also develop *inferential reasoning*, as they must justify conclusions, weigh evidence, and test alternative explanations in order to resolve complex problems (Hmelo-Silver 2004; Loyens et al. 2013).

Research by Walker and Leary (2009) empirically supports this mechanism, showing that students engaged in PBL demonstrate significant gains in analytical reasoning and inference generation compared to those in traditional settings. This improvement arises because PBL requires learners to synthesize knowledge across multiple disciplines,

encouraging them to construct meaning and reason through uncertainty rather than rely on rote memorization. Similarly, Dochy et al. (2003) emphasize that the *contextualized and problem-oriented nature* of PBL enhances transferability of inference skills students become capable of applying reasoning strategies to novel and unfamiliar contexts, a hallmark of adaptive expertise (Bransford, Brown and Cocking 2000).

From a pedagogical perspective, these findings highlight the critical importance of designing instructional strategies that deliberately cultivate inference-making rather than assuming it will emerge naturally from content exposure. The decline in inference scores observed among the control group underscores a fundamental limitation of traditional didactic instruction—that passive exposure to declarative knowledge does not necessarily foster higher-order cognitive processes such as reasoning, analysis, or inference construction (Kirschner, Sweller, & Clark, 2006). Inference is not an automatic consequence of learning content; rather, it is a complex cognitive skill that must be explicitly practiced, scaffolded, and contextualized through reflective inquiry and guided discovery (Loyens et al. 2013; Hmelo-Silver 2004; van de Pol, Volman and Beishuizen 2010).

In Problem-Based Learning (PBL), scaffolding is achieved through the structured stages of problem exploration, hypothesis formulation, evidence evaluation, and reflection. These stages are designed to externalize students' reasoning processes, allowing facilitators to provide *cognitive scaffolds* that guide learners in connecting data, identifying causal relationships, and drawing logical conclusions (Hmelo-Silver and Barrows 2008). Such scaffolding gradually transfers cognitive responsibility from teacher to learner, in alignment with

Vygotsky's Zone of Proximal Development (ZPD), where learners develop independent reasoning abilities through mediated interaction and dialogue (Vygotsky 1978). This aligns with constructivist learning principles, emphasizing that knowledge is actively constructed through experience, social negotiation, and metacognitive reflection rather than transmitted from teacher to student.

Furthermore, inference-making within PBL contexts is supported by metacognitive engagement students are encouraged to question assumptions, justify reasoning, and evaluate the validity of their conclusions (Schmidt et al. 2011). This process strengthens *epistemic awareness*, enabling learners to recognize the uncertainty inherent in problem-solving and to approach knowledge as dynamic and evidence-based. As a result, PBL environments nurture reasoning-based learning, where understanding develops through iterative cycles of inquiry, hypothesis testing, and reflection, rather than through rote memorization (Hmelo-Silver 2004; Dolmans et al. 2016).

In summary, the results conclusively show that Problem-Based Learning significantly improved students' inference reasoning, while conventional methods led to a measurable decline. The PBL approach created a cognitively rich environment that encouraged hypothesis generation, evidence-based justification, and logical reasoning all essential for developing inference skills. These findings reinforce a growing body of literature supporting PBL as a transformative pedagogy for cultivating higher-order thinking, reasoning, and lifelong learning competencies (Dolmans et al. 2016; Schmidt et al. 2011; Walker and Leary 2009). The implication is clear: instructional models aiming to enhance students' reasoning and inferential abilities must move beyond content delivery to engage learners in authentic, reflective, and problem-centered inquiry.

CONCLUSION

This study concludes that Problem-Based Learning (PBL) significantly improves students' *inference-making abilities* compared to traditional instructional methods. The post-test results revealed that students in the PBL group demonstrated higher levels of analytical reasoning, logical interpretation, and inferential transfer, while those in the control group experienced a measurable decline in these skills. These findings suggest that reasoning and inference are not passive outcomes of content exposure but cognitive processes that require deliberate engagement through inquiry, problem analysis, and reflection.

The success of PBL can be attributed to its authentic and contextually rich learning environments, which encourage learners to interpret incomplete information, identify causal relationships, and generate hypotheses grounded in logical reasoning. This approach promotes deeper cognitive engagement and facilitates the transfer of knowledge to novel contexts. The findings thus support the principles of constructivist learning theory, emphasizing that meaningful learning occurs when students actively construct understanding through exploration, collaboration, and metacognitive reflection.

Overall, the evidence from this study reinforces that Problem-Based Learning serves as an effective pedagogical framework for fostering higher-order thinking and inference reasoning. Beyond improving academic outcomes, PBL cultivates essential 21st-century skills such as critical thinking, adaptability, and self-directed learning that are vital for lifelong intellectual growth. Therefore, the integration of PBL into educational practice represents a transformative step toward developing learners who are not only knowledgeable but also capable of reasoning, evaluating evidence, and solving complex real-world problems.

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