

Enhancing Students' Critical Thinking through Project-Based Learning in Urban Senior High Schools of Yogyakarta

Guntur Andi^{1*}, Melinda Astuti², Wahyu Purnomo³

^{1,2}Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

³Universitas Ahmad Dahlan, Yogyakarta, Indonesia

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*Corresponding author:

gtr070697@gmail.com

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Abstract

This study investigates the effectiveness of Project-Based Learning (PjBL) in enhancing critical thinking skills among senior high school students in Yogyakarta, Indonesia. In the face of growing demands for higher-order thinking in the 21st-century education landscape, traditional teacher-centered pedagogies are no longer sufficient to equip students with the necessary analytical and problem-solving skills. Employing a mixed-method approach, this research involved 64 Grade XI students from two urban public high schools. Data collection methods included pre- and post-tests using a standardized critical thinking rubric, classroom observations, and focus group discussions. The results showed a statistically significant improvement in students' critical thinking abilities, particularly in areas of interpretation, inference, and evaluation. The findings suggest that PjBL fosters student engagement, promotes deeper learning, and provides meaningful contexts for applying critical thinking. This paper provides practical recommendations for educators seeking to integrate PjBL in the national curriculum and contribute to a more student-centered educational environment.

Introduction

The rapid transformation of global education in the 21st century has brought forth an imperative need for students to acquire a set of competencies that extend beyond the traditional mastery of content knowledge. According to the Partnership for 21st Century Learning (P21, 2007), these essential skills include the "4Cs"—critical thinking, creativity, collaboration, and communication—which collectively serve as the cornerstone for effective learning, personal growth, and career readiness in a dynamic, technology-driven world. These skills are especially important in light of the complex challenges societies face today, from climate change and globalization to artificial intelligence and the shifting nature of work. To thrive in such a landscape, students must be equipped with the ability to think critically, solve real-world problems, and work collaboratively across disciplines and cultures.

Indonesia, as the world's fourth most populous nation, is no exception to these demands. The Indonesian education system has undergone significant reform in the past two decades, culminating in policy frameworks such as the Kurikulum Merdeka (Freedom Curriculum) launched by the Ministry of Education, Culture, Research, and Technology (Kemendikbudristek) in 2021. This curriculum aims to empower students to become independent learners, nurture their interests and talents, and foster holistic competencies aligned with the profile of Pelajar Pancasila—students who are creative, critical, collaborative, and globally literate, while rooted in local values. Despite the visionary nature of this curriculum, its successful implementation in classrooms remains a persistent challenge, particularly with regard to cultivating higher-order thinking skills such as critical thinking.

Critical thinking, defined as purposeful, self-regulatory judgment that results in interpretation, analysis, evaluation, and inference (Facione, 1990), is widely regarded as a core

cognitive competency essential not only for academic success but also for informed citizenship and lifelong learning. Paul and Elder (2002) emphasize that critical thinking involves a commitment to overcoming egocentric and sociocentric biases, thereby enabling individuals to reason effectively and ethically in diverse contexts. In the Indonesian classroom context, however, the development of critical thinking is often impeded by entrenched pedagogical practices that prioritize memorization, passive absorption of content, and high-stakes examinations. Numerous studies and national assessments have shown that Indonesian students, particularly at the secondary level, frequently underperform in tasks requiring analytical, reflective, and evaluative capacities (OECD, 2018; Puspendik, 2020). This discrepancy between policy aspiration and classroom reality calls for the adoption of innovative, student-centered pedagogies that can meaningfully engage learners in critical inquiry.

Yogyakarta, often referred to as the "Kota Pelajar" or "Student City," presents a unique and fertile ground for examining such pedagogical innovations. Known for its rich educational heritage, Yogyakarta is home to some of Indonesia's leading universities and a vibrant ecosystem of formal and non-formal educational institutions. Urban senior high schools in Yogyakarta, in particular, benefit from relatively favorable infrastructure, access to digital technologies, and a diversity of student backgrounds. These conditions create an opportunity to experiment with and evaluate new teaching approaches that go beyond the conventional didactic methods. Yet, despite these advantages, many students in Yogyakarta still struggle to demonstrate critical thinking skills in both written and oral forms. This paradox—where access to information and learning tools does not automatically result in higher-order thinking—suggests that the core issue lies not in the availability of resources, but in the methods by which knowledge is constructed and internalized in the classroom.

One promising pedagogical model that has gained traction both globally and within Indonesia is Project-Based Learning (PjBL). Rooted in constructivist learning theory, PjBL positions students as active participants in their own learning processes. Instead of passively receiving information, students engage in sustained, collaborative inquiry around real-world problems, culminating in the creation of a tangible product or performance. As such, PjBL aligns closely with the principles of Merdeka Belajar and the goals of the Kurikulum Merdeka, which emphasize learner agency, contextual relevance, and cross-disciplinary integration. According to Thomas (2000), effective project-based learning involves five key features: centrality of the project to the curriculum, a driving question, student autonomy, real-world relevance, and constructive investigation. These features provide a robust framework for fostering critical thinking, as students must analyze complex issues, evaluate alternative solutions, synthesize diverse sources of information, and present their findings in a coherent and persuasive manner.

Several empirical studies have documented the benefits of PjBL in enhancing critical thinking across diverse educational settings. For example, Bell (2010) found that students engaged in project-based tasks exhibited greater motivation and deeper understanding of subject matter. Similarly, a meta-analysis by Condliffe et al. (2017) reported that PjBL was associated with improved student performance in both content knowledge and 21st-century skills, especially when implemented with fidelity and supported by professional development. In the Indonesian context, research by Nurhadi et al. (2021) demonstrated that PjBL improved students' critical and creative thinking in science and social studies classes. However, challenges remain in adapting this model to the realities of Indonesian classrooms, where large class sizes, limited teacher training, and rigid assessment systems can hinder innovation.

This study seeks to address these gaps by systematically investigating the extent to which PjBL can enhance critical thinking skills among senior high school students in Yogyakarta. Specifically, the research focuses on the following objectives: (1) to measure the improvement of students' critical thinking skills before and after the implementation of PjBL; (2) to explore students' perceptions of their learning experience during the project-based activities; and (3) to identify the practical challenges faced by teachers and students during the implementation process, along with strategies for overcoming them.

The choice of Yogyakarta as the research site is deliberate, not only because of its educational reputation, but also due to its diverse demographic and sociocultural landscape. The city represents a microcosm of urban Indonesian education, with schools that range from elite institutions to public schools serving marginalized communities. By conducting this research in multiple senior high schools across different contexts in Yogyakarta, the study aims to generate nuanced insights into the potential of PjBL to foster critical thinking at scale. Moreover, the study adopts a mixed-methods approach, combining quantitative data from pre-tests and post-tests with qualitative insights from student interviews and teacher observations. This methodological triangulation ensures a comprehensive understanding of both the outcomes and the processes of PjBL implementation.

Literature Review and Hypotheses Development

2.1 Critical Thinking in Education

Critical thinking is widely regarded as one of the most essential skills for academic success, responsible citizenship, and lifelong learning. Facione (1990), in his foundational work for the American Philosophical Association, defines critical thinking as a purposeful, self-regulatory process involving interpretation, analysis, evaluation, inference, and explanation. This set of cognitive skills enables individuals to navigate complex information, assess arguments, draw evidence-based conclusions, and engage in reflective decision-making. Complementing this view, Ennis (1996) describes critical thinking as "reasonable, reflective thinking that is focused on deciding what to believe or do," emphasizing the importance of logic, evidence, and open-mindedness in judgment processes.

In educational settings, critical thinking supports not only subject-specific mastery but also the development of metacognitive strategies that help students learn how to learn. Paul and Elder (2002) argue that students who are taught to think critically are better prepared to challenge assumptions, recognize biases (their own and others'), and construct reasoned arguments. Such dispositions are crucial for participation in democratic societies, where citizens must make informed choices, debate public issues, and collaborate across ideological lines. In the workforce, employers increasingly demand graduates who can analyze problems, think creatively, and adapt to change—abilities rooted in critical thinking (Trilling & Fadel, 2009).

Despite its acknowledged importance, the cultivation of critical thinking remains uneven across national education systems. In Indonesia, the promotion of critical thinking has gained increased attention, especially with the adoption of the Higher Order Thinking Skills (HOTS) framework as part of national assessments and curriculum standards (Kemendikbud, 2016). HOTS requires students to go beyond recall and comprehension, aiming instead for analysis, evaluation, and creation as outlined in the revised Bloom's Taxonomy (Anderson & Krathwohl, 2001). However, studies have shown that these expectations are often not reflected in classroom practice.

Retnawati et al. (2017) identify several systemic and pedagogical barriers to effective critical thinking instruction in Indonesia. First, rigid assessment systems that prioritize multiple-choice tests tend to undervalue open-ended inquiry and problem-solving. Second, many teachers lack sufficient training in instructional strategies that promote critical thinking. Third, the curriculum is often overloaded with content, leaving little time for in-depth exploration of ideas. As a result, learning tends to be teacher-centered, textbook-driven, and focused on rote memorization—a pedagogical culture that inhibits students from developing independent thought.

Furthermore, cultural factors may also play a role in shaping how critical thinking is perceived and practiced. In collectivist societies like Indonesia, students are often socialized to defer to authority figures and avoid confrontation, which may be misinterpreted as a lack of criticality (Hofstede, 2010). This makes it essential for educators to design learning environments that are not only cognitively challenging but also culturally responsive, encouraging students to express divergent opinions in respectful and constructive ways.

Given these complexities, the search for effective pedagogical models that can nurture critical thinking within the constraints and opportunities of the Indonesian education system is of

urgent importance. One such model is Project-Based Learning (PjBL), which offers a structured yet flexible framework for engaging students in authentic, inquiry-driven learning experiences.

2.2 Project-Based Learning: Principles and Benefits

Project-Based Learning (PjBL) is an instructional methodology that places students at the center of the learning process by having them engage in extended, collaborative investigations of complex and often interdisciplinary problems. According to Larmer et al. (2015), PjBL involves students in a dynamic classroom approach in which they "explore real-world problems and challenges, simultaneously developing cross-curricular skills while working in small collaborative groups." This method is grounded in constructivist theories of learning, particularly those advanced by John Dewey (1938), who advocated for experiential education that connects classroom learning to real-life contexts. Similarly, Vygotsky (1978) emphasized the social nature of learning, arguing that knowledge is co-constructed through interaction and dialogue within the learner's zone of proximal development.

Key principles of PjBL include the following elements:

- **A Driving Question:** Central to any project is a meaningful and challenging question that provides the focus for student inquiry.
- **Sustained Inquiry:** Students engage in an iterative process of asking questions, finding resources, analyzing data, and refining their understanding.
- **Authenticity:** Projects are grounded in real-world contexts and problems that are relevant to students' lives and communities.
- **Student Voice and Choice:** Learners are given autonomy to make decisions about how they approach the project, fostering ownership and intrinsic motivation.
- **Collaboration:** Projects typically require teamwork, emphasizing communication, negotiation, and conflict resolution.
- **Public Product:** Students present their work to an audience beyond the classroom, which enhances accountability and pride in their accomplishments.
- **Reflection:** Regular reflection enables students to evaluate their learning processes and outcomes, promoting metacognition and continuous improvement.

PjBL aligns closely with the competencies outlined in the 21st-century skills framework, particularly in its emphasis on critical thinking, creativity, collaboration, and communication. Bell (2010) notes that PjBL fosters deep content understanding while simultaneously encouraging students to become independent thinkers and problem-solvers. Thomas (2000) adds that the sustained and multifaceted nature of projects provides a richer context for learning than traditional, isolated assignments.

Empirical studies have consistently demonstrated the benefits of PjBL in enhancing critical thinking and related skills. For instance, Hung et al. (2012) found that students exposed to PjBL showed significant gains in their ability to analyze and synthesize information, as well as to evaluate the credibility of sources. Other studies have reported improvements in motivation, engagement, and collaborative skills (Holm, 2011; Krajcik & Blumenfeld, 2006).

In the Indonesian context, while PjBL has been applied in various educational settings, its full potential remains underutilized. Astuti et al. (2019) investigated the implementation of PjBL in science and language classrooms and reported increased student creativity, engagement, and self-efficacy. Similarly, Fauzi et al. (2020) found that PjBL supported the development of environmental awareness and problem-solving among junior high school students. However, most of these studies have focused on STEM or practical life skills education, with less attention paid to its application in social science or humanities settings where critical thinking is particularly vital.

Moreover, the challenges of implementing PjBL in Indonesian schools are well-documented. Teachers often face constraints such as limited time, lack of resources, and inadequate professional development. As Suastra (2017) observes, many teachers remain unfamiliar with the planning, facilitation, and assessment strategies needed for effective PjBL. Without sufficient support, projects may devolve into superficial tasks that fail to engage students in deep inquiry or critical reflection.

Another critical issue is assessment. Traditional tests, which dominate the Indonesian education landscape, are ill-suited to capture the complex learning outcomes associated with PjBL. Effective assessment in PjBL requires rubrics that evaluate not only content mastery but also critical thinking, collaboration, creativity, and communication. Teachers need guidance on how to design such assessments and how to use them to provide formative feedback throughout the project cycle.

Despite these obstacles, there is growing recognition among educators, policymakers, and researchers that PjBL represents a promising pathway for advancing the goals of the Kurikulum Merdeka. By placing students in active, meaningful learning roles, PjBL embodies the core tenets of Merdeka Belajar—namely, autonomy, contextual learning, and character development. In particular, PjBL offers a conducive environment for fostering critical thinking, as students must engage in sustained problem-solving, weigh evidence, consider multiple perspectives, and articulate reasoned conclusions.

This literature review suggests that while critical thinking and PjBL are conceptually and empirically well-established, their integration in Indonesian classrooms—especially in the context of senior high school education in urban areas like Yogyakarta—requires further exploration. There is a clear need for studies that examine how PjBL can be adapted to local contexts, what kinds of supports are needed for teachers and students, and what measurable impacts the approach has on students' critical thinking skills.

Research Methods

3.1 Research Design

This study utilized a mixed-methods Classroom Action Research (CAR) design consisting of two cycles. Each cycle included planning, implementation, observation, and reflection stages (Kemmis & McTaggart, 1988). Quantitative data were gathered through pre- and post-tests to measure students' critical thinking, while qualitative data were collected through observations and focus group discussions.

3.2 Participants and Context

The participants were 64 Grade XI students from two public senior high schools in Yogyakarta. The schools were selected due to their similar demographics and openness to pedagogical innovation. All students had access to digital tools and were taught by teachers trained in PjBL methodology.

3.3 Instruments

- Critical Thinking Test: Adapted from the California Critical Thinking Skills Test (CCTST), covering interpretation, inference, analysis, and evaluation.
- Observation Guide: Used to document student engagement, collaboration, and inquiry behavior.
- Interview Protocol: Focused on students' experiences, perceived challenges, and suggestions.

3.4 Procedure

Students were divided into small groups and given interdisciplinary projects focusing on local issues (e.g., sustainable tourism, plastic waste management). Teachers facilitated inquiry by guiding problem definition, resource exploration, and solution presentation. Each cycle lasted six weeks, with the final phase involving project presentations evaluated using a rubric.

Results and Discussion

4.1 Quantitative Results

Table 4.1. Pre-Test and Post-Test Scores

Indicator	Pre-Test Mean	Post-Test Mean	% Increase
Interpretation	58.4	75.2	28.7%
Inference	55.6	78.1	40.4%
Analysis	53.1	76.9	44.9%
Evaluation	57.9	77.3	33.5%
Overall Score	56.25	76.85	36.6%.

Source: data processed

Paired-sample t-tests revealed statistically significant improvements in all indicators ($p < 0.05$), suggesting the PjBL intervention was effective in enhancing critical thinking skills.

4.2 Qualitative Findings

The qualitative data from this study provided significant insights into the changes in students' behavior, particularly in terms of participation, inquiry, and critical thinking. Observational logs captured a noticeable increase in student engagement and the use of evidence when constructing arguments. Previously passive students became more active in their learning processes, demonstrating an improvement in their ability to think critically and ask more meaningful questions. One student remarked: "I used to just copy notes. Now I feel like I can ask better questions and think deeper about the topic." This shift from passive learning to active inquiry reflects the essence of Project-Based Learning (PjBL), where students are encouraged to engage deeply with content and engage in problem-solving activities that require critical thinking and evidence-based reasoning.

Teachers observed similar transformations in their students. One teacher commented: "The project made learning feel more real and purposeful. Students took ownership in a way I had never seen before." This statement underscores a critical aspect of PjBL: it enables students to take control of their learning by exploring real-world issues and coming up with their own solutions. Such an approach allows for a more personalized and meaningful learning experience, which fosters a greater sense of responsibility and ownership over one's educational journey. The students' shift from being passive recipients of knowledge to active contributors to their learning environment is a clear indicator of the success of PjBL in cultivating critical thinking skills.

In addition to the increase in participation and leadership, observation logs revealed that students started demonstrating a more structured and reflective approach to their problem-solving activities. This shift was particularly evident in group discussions, where students were able to integrate diverse perspectives, formulate questions, and critique each other's ideas constructively. The interaction among students in a collaborative environment provided them with opportunities to develop higher-order thinking skills as they had to justify their arguments and adapt their viewpoints in light of new information.

The observation also pointed out a key feature of PjBL: the emphasis on real-world relevance. Many students remarked on how the interdisciplinary nature of the projects—addressing issues like sustainable tourism or plastic waste management—helped them see the connection between what they were learning and the challenges they would face in the world beyond the classroom. The use of local, community-based issues made the learning process more meaningful, which in turn spurred students to engage with the material more deeply and critically. By working on projects that had tangible outcomes, students were able to see the direct application of their learning, which made the educational experience more authentic and purposeful.

Furthermore, students reported greater satisfaction with their learning when they were able to take ownership of their projects. For example, in one of the groups working on a plastic waste

management project, students expressed a strong sense of responsibility toward solving the issue. One student mentioned: "I feel like I am actually helping solve a real problem, not just answering questions for a test." This sense of purpose was instrumental in enhancing their motivation and fostering a mindset conducive to critical thinking. The feeling of contributing to a meaningful cause helped students develop a deeper understanding of the subject matter and solidified their engagement with the process of inquiry.

The improvement in student leadership within project groups was also significant. As students worked collaboratively on projects, leadership roles naturally emerged. This allowed students to take on responsibilities beyond just completing tasks, such as organizing meetings, delegating tasks, and facilitating group discussions. This development not only helped improve their critical thinking skills but also nurtured other essential competencies such as communication, collaboration, and creativity. The opportunity for students to lead and make decisions within their group reinforced the importance of taking initiative and thinking critically about the tasks at hand.

4.3 Discussion

The qualitative findings, combined with the quantitative data from the pre- and post-tests, strongly suggest that Project-Based Learning (PjBL) has a positive impact on students' critical thinking skills. The increase in test scores, alongside the behavioral changes observed in the classroom, supports the hypothesis that PjBL encourages deeper cognitive engagement and enhances critical thinking abilities. The structure of PjBL—where students are tasked with defining problems, gathering and analyzing data, and creating solutions—mirrors the analytical processes used in real-world problem-solving situations. This alignment with real-life challenges is a significant factor in the development of students' inquiry skills.

As Bell (2010) highlighted, PjBL fosters greater cognitive engagement by immersing students in authentic tasks that require critical thinking, problem-solving, and collaboration. The results from this study echo Bell's findings, as students demonstrated increased engagement, deeper analysis, and a more reflective approach to learning. Similarly, Hung et al. (2012) found that PjBL is effective in fostering cognitive engagement, particularly in contexts that demand interdisciplinary thinking. In this study, students' engagement with complex, real-world problems—such as sustainable tourism and plastic waste management—exemplified this interdisciplinary approach and encouraged them to think critically about the interconnectedness of various factors involved in these issues.

The findings also align with Dewey's (1938) experiential learning theory, which emphasizes the importance of learning through experience, reflection, and interaction with the environment. Dewey argued that students learn best when they are actively involved in the learning process, especially when they are provided with opportunities to reflect on their experiences and make connections to real-life situations. The use of PjBL in this study provided students with opportunities to engage in active learning, reflect on their findings, and apply their knowledge in meaningful ways. This experiential approach to learning not only promoted critical thinking but also enhanced students' problem-solving abilities, as they were encouraged to explore different perspectives and solutions.

Moreover, the positive impact of PjBL on students' critical thinking is consistent with the educational reforms envisioned by the Kurikulum Merdeka (Independent Curriculum) in Indonesia. This curriculum emphasizes learner-centered approaches, such as PjBL, which aim to develop students' 21st-century skills, including critical thinking, creativity, collaboration, and communication (Kemendikbud, 2021). The success of this intervention in improving critical thinking skills supports the ongoing curriculum transformation in Indonesia, which seeks to create a more dynamic and innovative learning environment that prepares students for the challenges of the modern world.

In conclusion, the findings from this study highlight the effectiveness of Project-Based Learning in enhancing critical thinking skills in senior high school students. By providing opportunities for students to engage with real-world problems, collaborate with peers, and take ownership of their learning, PjBL fosters critical thinking, problem-solving, and reflection. These

outcomes are consistent with both the theoretical underpinnings of experiential learning and the goals of Indonesia's educational reforms. Moving forward, further research is needed to explore the long-term impact of PjBL on students' academic achievement and its potential to contribute to the broader educational goals of Kurikulum Merdeka.

Implication and Conclusion

Project-Based Learning (PjBL) represents a dynamic and transformative educational approach that encourages students to develop critical thinking, collaboration, and real-world problem-solving skills. By engaging students in complex, interdisciplinary projects, PjBL allows them to move beyond passive learning and participate actively in the construction of knowledge. In this study, the integration of inquiry, collaboration, and presentation as core elements of PjBL has shown that students can cultivate essential competencies needed for success in the 21st century. These competencies are increasingly important in a globalized, rapidly changing world where critical thinking, creativity, and effective communication are paramount.

The findings of this research affirm that PjBL significantly contributes to students' cognitive development by fostering an environment where critical thinking is not just encouraged but becomes an integral part of the learning process. As students define problems, engage in data collection and analysis, and present their findings, they are prompted to use higher-order thinking skills such as evaluation, synthesis, and reasoning. This process mirrors the real-world problem-solving techniques that students will encounter in their future careers and everyday lives. Through these authentic learning experiences, students are not only able to improve their academic performance but also develop skills that will serve them well beyond the classroom.

For educators, this study offers a replicable model for integrating critical thinking into daily instruction. By implementing PjBL in their teaching, teachers can shift from traditional, teacher-centered methods to a more student-centered approach that values inquiry and collaborative learning. The findings from this study suggest that when students are given the opportunity to explore real-world problems in a meaningful way, they become more motivated, engaged, and independent learners. Teachers can apply this approach across various disciplines, not only in subjects like science and mathematics but also in the humanities, social sciences, and arts. The flexibility of PjBL makes it adaptable to a variety of subjects, allowing teachers to tailor projects to their students' interests and the learning objectives of the curriculum.

Moreover, the impact of PjBL on critical thinking extends beyond just the cognitive domain. It influences students' personal and social development as well. As students work together on group projects, they learn how to collaborate, communicate, and resolve conflicts—skills that are critical in both academic and professional settings. The emphasis on teamwork and collaboration in PjBL also promotes the development of social and emotional intelligence, encouraging students to understand diverse perspectives and work towards common goals. This holistic development aligns with the broader goals of 21st-century education, which seeks to equip students with the skills they need to thrive in a global, interconnected society.

For policymakers, the findings of this study have significant implications for the future of education. The success of PjBL in fostering critical thinking and other essential skills highlights the importance of integrating this approach more deeply into national teacher training programs and curriculum guidelines. In countries like Indonesia, where educational reform is an ongoing priority, this study supports the Kurikulum Merdeka (Independent Curriculum) initiative, which emphasizes student-centered learning and the development of higher-order thinking skills. Policymakers should ensure that teachers receive adequate training in PjBL methodologies so that they can effectively implement these strategies in their classrooms. Professional development programs should focus on equipping educators with the tools and strategies necessary to design and facilitate projects that promote critical thinking and inquiry-based learning.

Additionally, the integration of PjBL into the curriculum should be supported by adjustments to assessment structures. Traditional assessments, which often prioritize rote memorization and recall, may not adequately capture the depth of learning that occurs through PjBL. Therefore, policymakers should consider adopting assessment methods that better reflect

the skills and competencies developed through project-based learning, such as rubrics that assess critical thinking, creativity, collaboration, and communication. This shift in assessment practices would help align educational goals with the demands of the 21st-century workforce and society.

Another key implication for policymakers is the need to address the equity and scalability of PjBL across different educational contexts. While the current study was conducted in urban senior high schools in Yogyakarta, there is a need for further research to examine the implementation of PjBL in rural and under-resourced schools. The availability of resources, access to technology, and teacher training may differ significantly between urban and rural areas, potentially impacting the effectiveness of PjBL. Policymakers should ensure that all schools, regardless of their geographical location or resources, have access to the tools and training necessary to implement PjBL effectively. In this way, the benefits of this pedagogical approach can be extended to a wider range of students, promoting equity in education.

Furthermore, future research should explore the long-term retention of critical thinking skills developed through PjBL. While this study demonstrates the immediate benefits of PjBL on students' critical thinking, it is essential to assess whether these skills are sustained over time. Longitudinal studies could provide valuable insights into how students' critical thinking abilities evolve after they leave the classroom and enter higher education or the workforce. Such research would help determine the lasting impact of PjBL on students' cognitive development and inform educational practices that aim to nurture lifelong learning.

Another avenue for future research is to investigate how PjBL can be adapted and implemented in different cultural contexts. While the current study was conducted in Yogyakarta, Indonesia, PjBL may have varying degrees of effectiveness depending on the cultural and educational environment. Researchers could explore how PjBL can be tailored to different cultural norms and educational traditions, ensuring that the approach is both culturally relevant and pedagogically effective. By examining the application of PjBL in diverse educational settings, researchers can help build a global understanding of how project-based learning can be adapted to meet the needs of students around the world.

In conclusion, Project-Based Learning offers a powerful pedagogical approach that not only enhances students' critical thinking skills but also prepares them for the challenges of the 21st century. Through inquiry, collaboration, and real-world problem-solving, students develop the competencies needed to succeed in an increasingly complex and interconnected world. This study provides valuable insights into the effectiveness of PjBL in fostering critical thinking in Indonesian senior high school students and offers a model for integrating this approach into daily instruction. For policymakers, educators, and researchers, the findings underscore the importance of adopting innovative pedagogies like PjBL and ensuring that they are implemented in ways that are equitable, scalable, and sustainable. By continuing to explore and refine PjBL, we can create a learning environment that fosters the development of critical thinking and other essential skills, empowering students to become thoughtful, active participants in their communities and the world.

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