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Implementation Of Project-Based Learning Based On Computational Thinking To Prepare Private Senior High School Students In East Jakarta As The Golden Generation Of 2045

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Abstract

Improving the quality of education is essential to shaping Indonesia's Golden Generation 2045, characterized by excellence, innovation, and global competitiveness. This study focuses on implementing Project-Based Learning (PBL) integrated with Computational Thinking (CT) in private high schools in East Jakarta as a strategic approach to bridge the gaps in access and education quality. The approach emphasizes not only theoretical aspects but also contextual project-based learning that fosters 21st-century skills development.The key issues addressed include disparities in educational access and quality across various schools at both national and local levels, as identified through global indicators. These challenges highlight the need for educational interventions that enhance student competitiveness by applying adaptive and innovative curricula. Computational Thinking is employed to train students in systematic thinking, problem-solving for complex challenges, and innovation through technological applications.This research aims to analyze the effectiveness of Project-Based Learning combined with Computational Thinking in improving student outcomes, creativity, and adaptive skills. The findings are expected to provide strategic recommendations for developing education policies based on innovation, thereby addressing global educational challenges and enhancing the quality of private schools in Indonesia.

Keywords: *Implementation, Project-Based Learning, Computational Thinking*

INTRODUCTION

The effort to educate the nation's life is a mandate of the 1945 Constitution of the Republic of Indonesia that must be realized by the Indonesian government together with all components of the nation. Article 31 of the 1945 Constitution emphasizes the importance of a national education system that is capable of improving the nation's competitiveness. High-quality education serves as the main foundation in shaping competent, innovative, and globally competitive human resources (HR) (Sari, Suryana, Bentri, & Ridwan, 2023a).
However, the quality of education in Indonesia still faces various challenges. According to the 2022 Programme for International Student Assessment (PISA) report, Indonesia ranked 68th out of 81 countries, with Mathematics scores of 379, Science 398, and Reading 371 (Sari, Suryana, Bentri, & Ridwan, 2023b). These results indicate that although there has been an

improvement compared to previous surveys, Indonesian students still lag behind other countries in literacy, critical thinking, and problem-solving skills. Therefore, an innovative learning strategy is needed to significantly improve the quality of education.

In response to these challenges, the government, through the grand vision of Asta Cita, emphasizes the importance of strengthening HR through technology-based education, innovation, and creative learning. One relevant approach to improving education quality is Project-Based Learning (PjBL) based on Computational Thinking. This method is believed to enhance students' critical, creative, and adaptive thinking skills, which are key characteristics of Indonesia's Golden Generation 2045 (Ng, Wang, Luk, & Kwan, 2016).

The implementation of project-based learning integrated with Computational Thinking is not only aimed at improving students' academic competence but also at developing 21st-century skills such as collaboration, communication, and problem-solving (Purwanti, Hujjatusnaini, Septiana, Amin, & Jasiah, 2022). This method aligns with the mandate of Article 31 of the 1945 Constitution, which underscores the importance of equal access to quality education across Indonesia.

In the context of secondary education, particularly in private high schools (SMA) in East Jakarta, implementing this approach is highly relevant. This region holds significant potential for fostering excellence in technology literacy, innovation, and creativity. Data from the National Selection Test Agency for Higher Education (LTMPT) in 2022 shows that several private high schools in East Jakarta have achieved national rankings based on their Computer-Based Written Test (UTBK) scores, such as SMA Labschool Jakarta with a UTBK score of 601.467 and SMA Jakarta Islamic School with a score of 551.933 (Di, 2025). These achievements reflect the importance of innovative learning approaches in enhancing students' competitiveness (Hernandez-Ramos & De La Paz, 2009).

Aside from challenges in educational quality, the advancement of information and communication technology (ICT) has also significantly impacted education. Technology can be utilized to enhance learning effectiveness, accelerate information access, and support digital and remote learning (Ramadhan, Indriyani, Asri, & Sukma, 2020). However, challenges such as disparities in technological access, teacher preparedness, and data security remain obstacles to the effective implementation of technology in education (Noordin, Ali, Nasir, Pairan, & Azmi, 2018).

The application of Computational Thinking in Project-Based Learning has proven effective in enhancing students' critical thinking and problem-solving skills (Lestari, Joharmawan, & Purwati, 2023). A meta-analysis study by Wild (Panjerina, Rosyida, & Hartono, 2023) indicates that integrating CT in PjBL can improve students' analytical and algorithmic abilities, which are essential in facing the challenges of the digital era. In Computational Thinking education, students are taught to break down complex problems into smaller parts, recognize patterns, create abstractions, and develop problem-solving algorithms (Taratukhin & Pulyavina, 2018). Thus, this approach not only enhances academic learning outcomes but also prepares students with relevant skills for the future workforce (Watun, 2024).

In East Jakarta, there are 83 private high schools with varying accreditation levels, where 65.06% are accredited A, 26.51% accredited B, and 4.82% accredited C (Hikmawati, 2022). Most schools have not yet obtained international certification such as ISO 9001, indicating an opportunity to improve education standards in the region. Implementing PjBL based on

Computational Thinking can be an effective strategy in enhancing the quality of education in private high schools in East Jakarta while contributing to Indonesia's improved ranking in PISA assessments in the future (Abdurrahman & Mahmudah, 2023).

Given this background, this study aims to analyze the effectiveness of implementing Project-Based Learning based on Computational Thinking in improving student competencies in private high schools in East Jakarta. This research is expected to contribute to the development of more adaptive educational policies that align with contemporary demands and support the realization of Indonesia's Golden Generation 2045.

Literature Review

Human Resource Management (HRM)

Human Resource Management (HRM) is a crucial aspect of organizational management. According to Sundari & Almubaroq (2023), HRM is a strategic approach aimed at managing and optimizing human resources within an organization. It encompasses various activities, including recruitment, selection, training, development, and performance management, with the primary goal of ensuring that organizations have competent and high-quality personnel. This strategic approach positions human resources as valuable assets and key drivers in achieving organizational objectives. Thus, effective workforce management is essential for organizational success and competitive advantage.

HRM is also closely linked to talent management for achieving organizational goals. Handoko (Ismael, Putra, & Siregar, 2022) describes HRM as both a science and an art in managing human talent to support organizational objectives efficiently. Hasibuan (Herawati, 2022) emphasizes that HRM not only governs the relationship between employees and organizations but also creates a conducive work environment and enhances productivity through proper human resource management.

Additionally, Handoko, as cited in Rosyid et al. (ROHMAH, 2022), defines HRM as a process involving recruitment, selection, development, retention, and utilization of the workforce to achieve both individual and organizational goals. HRM involves dynamic interactions between organizations and employees to ensure sustainable goal achievement. Furthermore, HRM includes performance management, which involves monitoring and evaluating employee contributions to organizational objectives.

According to Herzberg's Two-Factor Theory (Siagian, Sihombing, & Agus, 2023), work motivation is influenced by two factors: motivators and hygiene factors. Motivators, such as recognition, responsibility, and achievement, enhance job satisfaction and motivate employees to perform better. Conversely, hygiene factors, such as salary, working conditions, and peer relationships, prevent dissatisfaction but do not directly increase motivation. Abdulkhamidova's (Fitriyah & Ramadani, 2021b) study suggests that organizations fostering intrinsic motivation among employees tend to achieve higher productivity and job satisfaction. This theory serves as a foundation for HRM strategies in balancing fundamental employee needs with motivational challenges.

Vroom's Expectancy Theory states that employee motivation depends on the relationship between effort, performance, and rewards. Mohd (Sunardi & Hasanuddin, 2019) explains that employees are motivated to work harder if they believe that their efforts will lead to good performance and that such performance will be adequately rewarded. This theory is

highly relevant in designing effective incentive systems, ensuring that rewards align with individual contributions to organizational goals.

Reinforcement Theory by B. F. Skinner emphasizes the role of positive and negative reinforcement in influencing work behavior. Amutan (Eliyasni, Kenedi, & Sayer, 2019) highlights that positive reinforcement, such as rewards and incentives, strengthens desirable behavior, while negative reinforcement or penalties discourage undesired actions. In HRM, this theory is applied to design reward systems that foster appropriate workplace behavior and performance.

Maslow's Hierarchy of Needs suggests that employees' motivation is driven by a hierarchy of needs, ranging from basic physiological needs to self-actualization. Hopper (Ervina, Pradana, & Meinita, 2022) argues that organizations meeting employees' fundamental needs, such as job security and social interactions, create a stable work environment. Moreover, organizations that provide opportunities for recognition and self-development help employees achieve higher levels of motivation, leading to increased productivity and loyalty.

The Competency-Based Theory, as described by Tacettin Açıkgöz & Cem Babadogan (2021), underscores the importance of managing employee competencies to achieve organizational goals. This theory focuses on aligning individual skills with organizational needs, ensuring that employees possess relevant competencies for success. This approach enhances efficiency and allows organizations to remain competitive in an ever-evolving market.

Agency Theory, as explained by Zogning (Katić, Ferraro, Ambra, & Iavarone, 2021) examines the relationship between principals (owners) and agents (employees or managers) within organizations. This theory emphasizes the importance of transparency, incentives, and monitoring mechanisms to mitigate conflicts of interest between principals and agents. In HRM, Agency Theory helps establish governance structures that align organizational and workforce goals, ultimately enhancing accountability and efficiency.

These theories provide a strong conceptual foundation for understanding various aspects of HRM. Herzberg's Two-Factor Theory and Maslow's Hierarchy of Needs focus on employee motivation and well-being, while Equity Theory and Vroom's Expectancy Theory explore the relationship between fairness, incentives, and performance. Skinner's Reinforcement Theory offers a behavioral approach to shaping desired work habits, while Competency-Based Theory and Agency Theory emphasize the importance of aligning competencies, incentives, and organizational objectives. The application of these theories can aid organizations in formulating effective HRM strategies to enhance productivity and job satisfaction.

Implementation of HRM Strategies

The implementation of HRM strategies is often guided by the Planning, Organizing, Actuating, and Controlling (POAC) framework. Faiz et al. (2024) highlight that POAC principles facilitate educational institutions in curriculum planning, teacher management, and learning outcomes assessment. Similarly, Ajeng et al. (2025) emphasize that structured planning and organizing of resources contribute to increased efficiency and improved learning outcomes.

In the industrial sector, Wahjono et al. (Iskandar, 2024) analyze the successful implementation of POAC strategies in PT Kawasaki. The company's structured planning, efficient organization, and stringent control mechanisms optimize production processes and

enhance business competitiveness. The healthcare sector also applies POAC principles, as shown in Jaya (Wijayanto, Supriadi, & Nuraini, 2020) where structured planning and resource allocation significantly contributed to reducing stunting rates in South Sibalaya.
Furthermore, research by Setiawan et al. (Dariman, 2019)underscores the importance of POAC in improving educational quality, particularly in religious schools. Their study illustrates that strategic planning, resource organization, and continuous performance monitoring enhance the effectiveness of educational management.
Overall, these studies demonstrate the significance of effective HRM implementation through structured management frameworks like POAC, ensuring organizational success across multiple sectors.

METHOD

This research employs a qualitative approach to explore social and cultural phenomena through observation, interpretation, and in-depth meaning extraction, as described by Sugiyono (Titu, 2015). Qualitative research encompasses various types, each with a specific focus. Phenomenological research aims to understand individuals' or groups' lived experiences regarding specific phenomena, analyzing these experiences through interviews and observations. Ethnographic research, on the other hand, studies cultural habits and behavioral patterns within a specific community, often requiring direct researcher engagement, such as understanding classroom learning dynamics.
Case study research involves an in-depth examination of a particular case or unit, such as implementing Project-Based Learning (PjBL) based on Computational Thinking (CT) in a specific school. This type of research requires extensive data collection from multiple sources to provide a comprehensive analysis. Grounded theory research focuses on generating new theoretical frameworks based on empirical data, particularly when existing theories are insufficient in explaining observed phenomena. Historical research investigates past events through the analysis of documents, artifacts, and interviews with historical witnesses, making it useful for studying educational policy development and learning method evolution (Febriansyah, Herlina, Nyeneng, & Abdurrahman, 2021). Lastly, narrative research collects and analyzes individual stories to understand their experiences in a given context, often utilized to examine students' learning journeys in project-based education.
Overall, these qualitative research types offer a diverse approach to understanding social and cultural phenomena. The choice of research type depends on the study's objectives and the phenomena under investigation. In the educational context, phenomenology, case studies, and ethnography are commonly used to examine learning dynamics, social interactions, and teaching method developments, offering insights beyond what numerical data can provide.
The subjects of this research consist of individuals directly involved in the learning process at senior high schools in East Jakarta, particularly in the implementation of PjBL-based CT. The selected subjects include school principals, teachers, and students. School principals play a crucial role as policymakers, supporting the implementation of PjBL-based CT by providing necessary facilities, teacher training, and effective learning program management. Informatics teachers serve as the main facilitators responsible for executing PjBL-based CT in classrooms, designing learning projects, and guiding students throughout the process. Students, as active participants, engage in project-based learning and provide

feedback on their learning experiences. These research subjects were selected due to their critical roles in assessing and understanding the application of PjBL and CT-based teaching methods (Yulkifli, Yohandri, & Azis, 2022).

This research focuses on the implementation of PjBL-based CT in preparing high school students in East Jakarta. Several key aspects are analyzed, including school principal policies, teacher competencies, student learning processes, and student learning outcomes. From the school principal's perspective, the study evaluates their role in supporting PjBL-based CT, including policy applications, provision of technological facilities, and teacher training programs. From the teachers' perspective, this research examines their strategies in implementing PjBL-based CT, their technological proficiency, as well as challenges and solutions encountered during the learning process.

The study also investigates students' engagement in PjBL-based CT, analyzing their motivation, participation, and interactions in the learning process. Additionally, this research assesses the impact of PjBL-based CT on students' academic performance and their development of critical and creative thinking skills. These aspects are examined using a qualitative descriptive approach to provide a comprehensive understanding of PjBL-based CT implementation in private senior high schools in East Jakarta and its impact on educational stakeholders (Kamaruddin et al., 2024).

To ensure data validity and depth, multiple data collection methods are employed, including interviews, observations, questionnaires, and documentation. Each method is tailored to capture distinct aspects of PjBL-based CT implementation, contributing to a comprehensive understanding of its role in enhancing students' digital competencies. Structured interviews are conducted with school principals, teachers, and students in private senior high schools in East Jakarta. These interviews aim to explore their experiences, challenges, and requirements in informatics learning before the implementation of the PjBL-CT model.

According to Nuraini et al. (Shuhailo & Derkach, 2021) interviews are one of the most effective ways to obtain in-depth perspectives from individuals directly involved in research, particularly in the context of project-based learning model development (Wahyudi & Winanto, 2018). This method facilitates a deeper understanding of the learning environment from multiple perspectives, providing valuable insights into the practical implementation of PjBL-based CT in East Jakarta's private senior high schools.

RESULTS

School Policy

Based on interviews with four school principals, there were significant differences in the readiness for implementing Project-Based Learning (PjBL) based on Computational Thinking (CT) across different schools. Some schools were at the forefront with well-structured policies and comprehensive implementation across all subjects. These schools had provided extensive training to all teachers, supported by complete facilities such as

modern computer labs, coding devices, collaboration spaces, and augmented reality technology.

Other schools had integrated PjBL-CT policies into several main subjects; however, teacher training needed to be further enhanced for more equitable implementation. While the available facilities were sufficient, there was still a need to add specialized tools such as coding simulators and additional learning aids (Fahrezi & Nafia'ah, 2020).

Another group of schools had just begun formulating policies focused on subjects like Mathematics, Science, and Informatics. Basic training had been conducted, but it was still limited to trial classes, with plans for broader training in the future. The primary challenge in these schools was the lack of adequate facilities, particularly specialized software and collaborative learning spaces.

Meanwhile, some schools were still in the early stages, without specific policies for implementing PjBL-CT. Teacher training was still in the planning phase, and the existing facilities were still oriented toward conventional learning methods, such as general-purpose computer labs.

In terms of success indicators, schools with advanced PjBL-CT implementation had comprehensive assessment methods, including project outcomes, improvements in critical and creative thinking skills, and evaluations through student and teacher satisfaction surveys. Schools that were in the initial stages had started to implement project-based indicators but were still developing a more structured assessment framework. Schools that had not yet implemented PjBL-CT lacked specific indicators as the method was not yet formally adopted (Norawati & Puspitasari, 2022).

To accelerate PjBL-CT implementation, schools at the early stage are recommended to formulate policies promptly, expedite teacher training, and improve relevant facilities. Schools with initial implementations should expand teacher training and add supportive facilities to optimize implementation. Schools that have successfully integrated PjBL-CT can serve as mentors for other schools, given their success in combining policies, training, facilities, and evaluation methods.

The implementation of PjBL-CT aligns with constructivist learning theories, which emphasize the importance of developing higher-order thinking skills through project-based learning. This approach enables students to construct their understanding through exploration and collaboration (Putri et al., 2025). Additionally, research by Ismael et al. (2024) indicates that integrating PjBL with CT skills effectively enhances student competency in mobile programming (Nadzeri et al., 2023). Other studies highlight that the PjBL model can improve students' creative thinking and CT skills, demonstrating that a well-supported PjBL-CT approach can enhance learning quality and student competencies, preparing them for future digital challenges.

Teacher Readiness in Teaching

The analysis results indicate that teachers in the studied schools faced varying challenges in implementing PjBL-CT, depending on each school's preparedness.

Teachers in schools that had not yet formally implemented this method faced the greatest challenges. The primary issues were the lack of training and understanding of PjBL-CT, along with limited facilities that still focused on conventional teaching methods. As a result,

teachers relied on traditional teaching approaches and had yet to develop specific strategies for handling students struggling with Computational Thinking concepts. As an initial effort, teachers planned to introduce simple projects and provide gradual guidance once the method was officially adopted.

In schools where PjBL-CT had been introduced, implementation remained suboptimal due to limited time for project execution and varying student competencies in understanding Computational Thinking. Additionally, inadequate facilities, such as an insufficient number of computers and limited specialized software, posed challenges. To address these issues, teachers designed projects tailored to students' interests and implemented individualized mentoring for students needing additional support. Collaborative strategies and class reward systems were also introduced to boost student motivation and participation.

In schools with moderate implementation, teachers encountered similar challenges, particularly in time constraints that prevented full execution of all PjBL stages. Other issues included limited computer access and unstable internet connections. To keep students engaged, teachers provided simplified, real-life-relevant projects and formed heterogeneous student groups to encourage peer-assisted learning. Additionally, process-based assessments were implemented to ensure consistent student participation throughout the project (Fitriyah & Ramadani, 2021a).

Teachers in schools with advanced PjBL-CT implementation faced fewer challenges due to well-established policies, comprehensive training, and sufficient facilities. The main challenges were adjusting to students' varied levels of understanding and ensuring project completion within the targeted timeframe. Some large-scale projects also required additional software, which was not always readily available. However, teachers addressed these challenges by utilizing free software alternatives or collaborating with external stakeholders. Collaborative learning approaches, student autonomy in project selection, and individualized mentoring further enhanced the effectiveness of PjBL-CT implementation. These strategies were reinforced by process- and outcome-based assessments to encourage active student participation in learning.

From a pedagogical perspective, the PjBL approach in these schools aligns with various educational models and frameworks. Thomas (Desnylasari, Mulyani, & Mulyani, 2016) highlights the significance of collaboration and exploration in enhancing students' critical and creative thinking skills (Darwis et al., 2025). Furthermore, research by Ismael, Jalinus, and Putra (2024) indicates that integrating PjBL with Computational Thinking enhances students' comprehension of mobile programming, which is increasingly relevant in the 21st century (Pratama & Prastyaningrum, 2019).

Overall, teachers in schools with well-established PjBL-CT implementation demonstrated higher preparedness and effective teaching strategies compared to other schools. Teachers in schools with emerging implementation had taken positive steps in overcoming challenges but required further training and improved facilities for optimal implementation. Meanwhile, teachers in schools with no formal PjBL-CT policy faced the most significant difficulties due to the lack of institutional support, training, and infrastructure. Thus, accelerating PjBL-CT adoption in these schools is crucial to ensure that teachers can apply effective strategies similar to those successfully implemented in other institutions (Agustina, Wahyudi, & Sri Putu Verawati, 2024).

Implementing a PjBL-CT model, supported by adequate teacher training and facilities, can enhance learning effectiveness and equip students with the necessary skills for the digital era.

CONCLUSION

The implementation of Project-Based Learning (PjBL) based on Computational Thinking (CT) in private high schools in East Jakarta reveals several key findings regarding school policies, teacher readiness, and student learning experiences.

School Policies

The study found significant variations in the readiness and implementation of PjBL-CT policies across schools. Some schools demonstrated optimal preparedness through comprehensive policies, continuous teacher training, and well-equipped facilities, including modern computer labs and augmented reality technology. These schools also employed measurable success indicators such as project outcomes, improvements in critical and creative thinking skills, and student and teacher satisfaction evaluations. Conversely, other schools had only partially integrated PjBL-CT policies into certain subjects, with limited teacher training and ongoing development of supporting facilities. Meanwhile, some schools remained at the early stages, lacking specific policies, structured training, and adequate infrastructure. To ensure effective implementation, schools with minimal adoption should accelerate policy development, provide extensive teacher training, and enhance supportive facilities. Schools with more advanced implementation could serve as mentors, sharing best practices to strengthen PjBL-CT adoption across private high schools in East Jakarta.

Teacher Readiness and Strategies for Addressing Challenges

Teachers faced varying degrees of challenges depending on their school's level of preparedness for PjBL-CT implementation. In schools with well-established policies and strong institutional support, teachers encountered minimal obstacles, with challenges primarily centered on addressing diverse student comprehension levels and ensuring project completion within the given timeframe. To overcome these challenges, teachers applied strategies such as allowing students to choose project topics, utilizing alternative software when necessary, and providing individualized mentoring. Meanwhile, in schools with moderate implementation, teachers struggled with limited time, inadequate facilities, and gaps in student competency levels. Strategies such as forming heterogeneous student groups, assigning simplified yet relevant projects, and using process-based assessments helped address these issues. On the other hand, teachers in schools that had yet to formally implement PjBL-CT faced the most significant difficulties due to a lack of training, limited facilities, and an absence of structured strategies for helping students grasp Computational Thinking concepts. For these schools, immediate steps should be taken to introduce structured training and facilities to facilitate the effective implementation of PjBL-CT.

Student Learning Experiences in PjBL-CT

The level of school preparedness also significantly influenced student experiences with PjBL-CT. Students in schools with optimal implementation reported the most positive experiences, benefiting from improved comprehension, enhanced critical and creative thinking skills, and

greater adaptability to challenges. The ability to explore project ideas freely contributed to higher motivation and engagement in learning. However, even in these schools, students encountered challenges in understanding complex Computational Thinking concepts such as algorithms and programming logic, which were mitigated through teacher guidance and collaborative teamwork. In schools with partial implementation, students gained valuable experience with real-world projects, particularly in teamwork and problem-solving. However, limited time for project execution and difficulties in grasping advanced Computational Thinking concepts remained challenges that required additional teacher support and group discussions. Meanwhile, students in schools without formal PjBL-CT implementation had limited exposure to this approach, only participating in simple projects without maximizing their potential in critical thinking, creativity, and adaptability. These students expressed a desire for systematic PjBL-CT implementation to help them develop the necessary skills to face future challenges.

Overall, the findings indicate that schools with comprehensive policies and structured implementation provide the best learning experiences for students, while those in the early stages of adoption require significant improvements. Strengthening policies, expanding teacher training, and upgrading facilities will be essential in ensuring that all students can fully benefit from PjBL-CT. By doing so, students will be better equipped with critical, creative, and adaptive thinking skills, preparing them to become part of Indonesia's Golden Generation 2045 and face the challenges of the globalized world effectively.

LIMITATIONS

This study provides valuable insights into the implementation of Project-Based Learning (PjBL) based on Computational Thinking (CT) in private high schools in East Jakarta. However, several limitations must be acknowledged. The study was conducted within a specific group of private schools, limiting the generalizability of the findings to other institutions, including public schools or those in different regions with varying infrastructure and policies. Additionally, there were notable variations in the implementation of PjBL-CT across schools, making it challenging to establish uniform conclusions regarding its effectiveness. While some schools had comprehensive frameworks and well-developed policies, others were still in the early stages, leading to inconsistencies in data comparison.

Another limitation is the focus primarily on teacher and student perspectives, without extensive exploration of insights from policymakers, curriculum developers, or external educational stakeholders. Including these perspectives could have provided a more comprehensive understanding of the challenges and opportunities in implementing PjBL-CT. Furthermore, the study was conducted within a limited timeframe, restricting the ability to assess long-term impacts on students' learning outcomes and teacher effectiveness. A longitudinal study would provide deeper insights into the sustained improvements and ongoing challenges of implementing this approach.

Technological disparities among the schools also posed a challenge, as some institutions had access to modern facilities while others lacked adequate digital tools and infrastructure. This variation in

resources affected the effectiveness of PjBL-CT implementation. Additionally, the assessment of learning outcomes was primarily qualitative, relying on interviews and observations rather than quantitative metrics such as standardized test scores or comparative pre- and post-assessments. The absence of such quantitative measures limits the ability to evaluate the direct academic impact of PjBL-CT.

Lastly, external factors such as students' socioeconomic backgrounds, levels of motivation, and parental or community support were not extensively analyzed. These elements could significantly influence the effectiveness of PjBL-CT, and further research should consider their role in shaping learning outcomes. To address these limitations, future studies should expand the scope of research to include a broader range of schools, incorporate quantitative performance metrics, conduct longitudinal assessments, and engage with a wider array of stakeholders. By overcoming these challenges, a more comprehensive understanding of the effectiveness and scalability of PjBL-CT can be achieved, ultimately contributing to its refinement and broader adoption in educational settings

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