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The Role of STEM-Based Project-Based Learning in Developing Future Competencies: A Systematic Review

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Abstract: The STEM project-based learning technique (STEM-PjBL) is acknowledged as an effective educational instrument for cultivating 21st-century competencies, including critical thinking, creativity, and problem-solving. This study seeks to evaluate the efficacy, obstacles, and potential of executing STEM-PjBL by a systematic literature evaluation of publications from 2019 to 2023 in the Scopus database. The evaluation identified 14 papers that fulfilled the inclusion requirements, analyzed via a qualitative descriptive technique, concentrating on learning outcomes, innovative solutions, and implementation issues. The findings indicate that STEM-PjBL consistently improves students' skills across different educational levels, with the integration of methodologies like Ethno-STEM and STEAM enriching the learning experience. Nonetheless, challenges like as constrained resources, teacher preparedness, and the lack of a standardized framework persist as significant impediments. This study promotes ongoing teacher training, equitable allocation of resources, and supporting educational policies to enhance the efficacy of STEM-PjBL. This technique can establish a basis for educational reforms that meet the requirements of the 21st century by mitigating these constraints.

Keywords: STEM, Project-Based Learning, 21st Century Skills, Creativity, Problem Solving

Abstrak: *Metode pembelajaran berbasis proyek STEM (STEM-PjBL) diakui sebagai alat pendidikan yang sangat baik untuk menumbuhkan keterampilan abad ke-21 seperti berpikir kritis, kreativitas, dan pemecahan masalah. Studi ini berupaya untuk menilai kemanjuran, hambatan, dan prospek penerapan STEM-PjBL melalui penilaian sistematis terhadap materi yang diterbitkan dari tahun 2019 hingga 2023 dalam basis data Scopus. Hasil review berhasil terpilih sejumlah 14 paper yang memenuhi kriteria inklusi diperiksa melalui metodologi deskriptif kualitatif, dengan berkonsentrasi pada hasil pembelajaran, solusi kreatif, dan tantangan implementasi. Hasilnya menunjukkan bahwa STEM-PjBL secara konsisten meningkatkan keterampilan siswa di berbagai tingkat pendidikan, dengan penggabungan pendekatan seperti Etno-STEM dan STEAM yang menambah signifikansi pembelajaran. Meskipun demikian, hambatan seperti sumber daya yang terbatas, kesiapan guru, dan tidak adanya kerangka kerja standar tetap menjadi hambatan substansial. Studi ini menganjurkan pelatihan guru yang berkelanjutan, distribusi sumber daya yang merata, dan kebijakan pendidikan yang mendukung untuk mengoptimalkan kemanjuran STEM-PjBL. Dengan mengurangi batasan-batasan ini, strategi ini dapat berfungsi sebagai landasan bagi perubahan pendidikan yang selaras dengan tuntutan abad ke-21. Riset ini diharapkan dapat memberikan implikasi positif terhadap wawasan kepada pendidik dalam penggunaan metode pembelajaran inovatif.*

Kata Kunci: *STEM, Pembelajaran Berbasis Proyek, Keterampilan Abad 21, Kreativitas, Pemecahan Masalah*

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INTRODUCTION

In the 21st century, society is experiencing significant transformations in socio-cultural, economic, demographic, and political values. These developments necessitate modifications in the education system to adequately prepare students to become adaptable, innovative, and competitive individuals in the face of increasingly complex global issues. The conventional education system, which prioritizes academic achievement, is insufficient to address these requirements. Students must acquire 21st-century competencies, including critical thinking, creativity, problem-solving, and digital literacy, to effectively compete in the context of globalization and digitalization.

A significant learning process necessitates reciprocal contact between teacher and student, rather than a unilateral transmission of knowledge. Numerous learning models and strategies exist to establish an effective learning environment, including Project-Based Learning (PjBL). PjBL is an approach that enables students to collaboratively address real-world problems, fostering critical and creative thinking, thereby enhancing its relevance to their lives. Moreover, multidisciplinary techniques like STEM (Science, Technology, Engineering, and Mathematics) are deemed capable of motivating students to amalgamate these fields to address intricate challenges through innovative solutions. The integration of Project-Based Learning (PjBL) and STEM has demonstrated efficacy in enhancing 21st-century competencies, including digital literacy, creativity, and problem-solving, as indicated by (Ndiung & Menggo, 2024) and (Sumarni & Kadarwati, 2020). This integration enables students to comprehend theory and use it practically, leading to enhanced motivation, engagement, and advanced cognitive skills, including computational thinking (Chang et al., 2023). This collaboration equips students to be adaptable, innovative, and effective in addressing the increasing global concerns.

The integration of the STEM (Science, Technology, Engineering, and Mathematics) framework with Project-Based Learning (PjBL) has emerged as a novel and efficient educational model to address these requirements. Project-based learning (PjBL) is student-centered, promoting the resolution of real-world issues through collaborative projects and the integration of knowledge across multiple disciplines. Research conducted by (Sumarni & Kadarwati, 2020) shown that the project-based Ethno-STEM methodology enhanced high school students' critical and creative thinking abilities. This strategy has been demonstrated at the university level to enhance students' creativity, motivation, and academic performance, as indicated by (Yustina et al., 2020) and (Wahono et al., 2020). Nonetheless, the execution of STEM-PjBL in Indonesia continues to encounter considerable obstacles. A primary hurdle is the scarcity of resources, including insufficient manipulative instruments and supporting technologies, particularly in schools with constrained budgets (Saad & Zainudin, 2022). Moreover, teacher preparedness is an essential element. A considerable number of educators lack confidence or have not received sufficient training to incorporate this methodology into their instructional methods (Li & Tu, 2024).

This research is significant as it addresses the critical gap in integrating digital media into Problem-Based Learning (PBL) to enhance critical thinking and engagement in STEM education, a domain that remains underexplored in current literature. Its novelty lies in the development and evaluation of tailored digital tools that combine real-world problem-solving with interactive learning features, offering an innovative framework to bridge theoretical knowledge and practical applications in education.

Alongside constrained resources and teacher preparedness, assessing the efficacy of STEM-PjBL-based education is a significant difficulty. The absence of a comprehensive framework to assess student competencies restricts the widespread adoption of this strategy. (Saad & Zainudin, 2022)

emphasized the necessity for a more cohesive approach to connect Project-Based Learning (PjBL) with computational thinking skills to get best results. In Indonesia, initiatives like the Merdeka Curriculum have facilitated a more adaptable and project-based methodology. The efficacy of this approach hinges on the ability of educators and institutions to capitalize on these chances to cultivate 21st-century capabilities. The STEM-PjBL methodology, with its numerous benefits, presents a significant chance to transform education in Indonesia. This study seeks to examine the efficacy of the STEM-PjBL strategy in enhancing 21st-century abilities across different educational levels and to suggest ways for overcoming implementation obstacles. This study aims to deliver actionable recommendations for educators, policymakers, and academics by examining literature and educational trends, thereby facilitating the optimal and relevant implementation of the STEM-PjBL strategy for Indonesian students.

The STEM project-based learning technique (STEM-PjBL) is acknowledged as an effective educational instrument for cultivating 21st-century competencies, including critical thinking, creativity, and problem-solving. This study seeks to evaluate the efficacy, obstacles, and potential of executing STEM-PjBL by a systematic literature evaluation of publications from 2019 to 2023 in the Scopus database. The review identified 14 papers that fulfilled the inclusion criteria, analyzed using a qualitative descriptive technique, concentrating on learning outcomes, innovative solutions, and implementation issues. The findings indicate that STEM-PjBL consistently improves students' skills across different educational levels, with the integration of methodologies like Ethno-STEM and STEAM enhancing the learning experience. Nonetheless, challenges like as constrained resources, teacher preparedness, and the lack of a standardized framework persist as significant impediments. This study promotes ongoing teacher training, equitable allocation of resources, and supporting educational policies to enhance the efficacy of STEM-PjBL. This technique can establish a basis for educational reforms that meet the requirements of the 21st century by alleviating these constraints.

This study aims to systematically analyze existing literature to evaluate the effectiveness of STEM-based Project-Based Learning (PjBL) in fostering 21st-century skills across various educational levels. The objectives of this research are threefold: (1) to identify key trends, successes, and challenges in the implementation of STEM-PjBL; (2) to highlight innovative teaching strategies that enhance critical thinking, creativity, and problem-solving; and (3) to provide evidence-based recommendations for improving STEM-PjBL practices, with a focus on addressing resource and teacher-readiness gaps. By synthesizing these findings, this study seeks to contribute to the growing body of knowledge on STEM education and support its integration into modern educational systems.

RESEARCH METHODS

The proposed research endeavour will conduct a comprehensive examination of all previously published scientific papers related to this topic, as well as identify new sources through the implementation of a systematic literature review approach. This methodology is recognised as systematic, transparent, and reproducible in identifying, locating, and synthesising studies pertinent to specified research question(s) (Snyder, 2019). In conjunction with a more rigorous analysis, the study aims to elucidate trends, identify gaps, and discern potential fragmentation within the literature to facilitate the investigation. The entire process adheres to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure strict compliance with each stage, from identification to the filtration of relevant articles.

The material for this study was obtained solely from Scopus (https://www.scopus.com), a distinguished and extensive library of peer-reviewed research articles. The search technique

concentrated on locating articles published from 2019 to 2023, thereby including just the most recent and pertinent studies. The search employed targeted keywords aligned with the research objectives, including "Project-based learning," "PJBL," "STEM," and "Creative Skills." Boolean operators (e.g., AND, OR) were utilized to enhance the search outcomes and guarantee a focused yet thorough compilation of content.

The inclusion and exclusion criteria used to select studies were designed to ensure the relevance and quality of the research analyzed. These criteria are outlined in Table 1 below:

Table 1. Inclusion and Exclusion Criteria

Criteria	**Inclusion**	**Exclusion**
Publication Year	2019–2023	Published before 2019
Language	English	Non-English publications
Publication Type	Peer-reviewed journal articles	Grey literature (e.g., reports, theses, blogs)
Research Relevance	Aligned with keywords and research objectives	Irrelevant based on title and abstract screening
Availability	Full text accessible	Inaccessible or incomplete studies

The screening and selection process commenced with an initial search in Scopus, which yielded a total of 388 articles. These articles underwent a systematic screening process to ensure their relevance and quality. The first stage involved reviewing the titles and abstracts of all identified articles to assess their alignment with the research objectives. Articles deemed irrelevant based on this initial review were excluded from further analysis. In the second stage, the full-text versions of the remaining articles were thoroughly evaluated against the predefined inclusion and exclusion criteria. This eligibility assessment ensured that only studies meeting the research standards and objectives were retained. Subsequently, a detailed assessment of the eligible articles resulted in the selection of 14 studies for qualitative analysis. To facilitate organised data management and referencing, all selected articles were systematically imported into Mendeley, a reference management tool.

The chosen papers were examined utilizing a qualitative descriptive methodology (Lassoued et al., 2020). Essential information, including authorship, publication year, research methods, findings, and implications, was carefully extracted utilizing a predetermined documentation guide. The retrieved data were further synthesized thematically, emphasizing commonalities, contrasts, and distinctive contributions among the research.

The systematic PRISMA approach employed in this study involved four main stages to ensure a comprehensive and structured review process. The first stage comprised the identification of research objectives and the formulation of relevant keywords, which guided the subsequent search strategy. In the second stage, a database search was conducted exclusively in Scopus utilising a structured query to retrieve articles aligned with the research objectives. The third stage involved the screening and selection of articles based on predefined inclusion and exclusion criteria, ensuring that only high-quality and relevant studies were retained. Finally, the fourth stage focused on data extraction, synthesis, and qualitative analysis, wherein the selected articles were meticulously analysed to identify patterns, trends, and key insights relevant to the research topic. As illustrated in Figure 1 below.

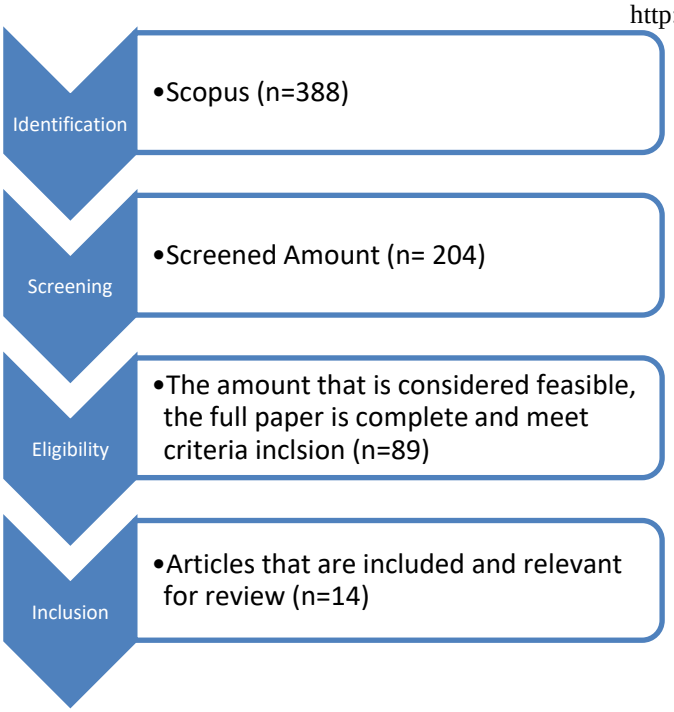

Figure 1. Analysis Using PRISMA Flow

RESULTS AND DISCUSSION

Overview of Reviewed Studies

A total of 14 studies were considered in this evaluation based on the search done in Scopus from 2019 to 2023. The studies concentrated on the execution of STEM-oriented Project-Based Learning (PjBL) and its effects on diverse learning outcomes. The analyzed papers were published in prestigious journals, underscoring their scientific validity. The results of the review of 14 papers will be presented in table 2 below.

Table 2. Review Results

Authors	Main Findings	Skills Measured	Research Design	Research Subject / Educationl Level
(Sumarni & Kadarwati, 2020)	The ethno-STEM project-based learning approach improved students' critical and creative thinking skills, with the improvements ranging from low to medium categories.	critical thinking skills and creative thinking skills	Quantitative (Quasi Experiment Design)	Senior High School
(Khalil et al., 2023)	The STEM-based	creative thinking	Quantitative (Quasi	Senior High

	curriculum did not have a significant impact on the elaboration component of creative thinking.	skills	Experiment Design)	School
(Chang et al., 2023)	The study highlights the potential benefits of integrating STEAM into PBL as a transdisciplinary teaching approach for enhancing students' creativity and computational thinking skills.	Creativity and Computation Thinking	Quantitative (Quasi Experiment Design)	Junior High School
(Li & Tu, 2024)	The students themselves also reported perceiving improvements in all aspects of their creativity after completing the PjBL-TPS course.	creative thinking skills	Research and Development	University
(Sari et al., 2023)	Project-based learning was beneficial in developing students' creative thinking, despite some obstacles faced by the students during the process.	creative thinking skills	Qualitative	University
(Yustina et al., 2020)	The average creative thinking score of pre-service teachers in the experimental group using Blended Learning and Project-Based Learning was 91, with an N-gain index of 0.62, which was higher	creative thinking skills	Quantitative (Quasi Experiment Design)	University

	than the control group using a conventional approach (score of 76, N-gain of 0.51).			
(Saad & Zainudin, 2022)	There is a lack of explicit frameworks or models for integrating Project-Based Learning (PBL) and Computational Thinking (CT) in teaching and learning.	Computational Thinking	Literature Review	-
(Khoiri et al., 2023)	The PjBL model improved students' creative thinking skills across various indicators, including improvisation, elaboration, creativity, vision, effectiveness, and efficiency	Critical Thinking, Creative Thinking, and Collaborative Skills	Quantitative (Pre-Experimental Design)	Senior High School
(Karan & Brown, 2022)	PBL improved individual students' problem-solving skills compared to traditional instruction	Problem-solving Skills	Quantitative (Quasi Experiment Design)	University
(Rehmat & Hartley, 2020)	The PBL group showed significantly greater gains in critical thinking skills compared to the traditional learning group.	content knowledge and critical thinking	Quantitative (Quasi Experiment Design)	University
(Ndiung & Menggo, 2024)	The project-based learning model had a significant positive impact on elementary school children's creative thinking and mathematics	Fostering Creative Thinking and Mathematical Problem-Solving Skills	Quantitative (Quasi Experiment Design)	Elementary School

	problem-solving skills.			
(Yaki, 2022)	The integrated STEM approach used in the experimental group was effective in significantly improving students' critical thinking skills compared to the control group	Critical Thinking	Quantitative (Quasi Experiment Design)	Senior High School
(Pramasdyahsari et al., 2023)	The implementation of the digital book STEM-PjBL showed a significant gain in fostering students' critical thinking skills.	mathematical critical thinking	Research and Development	Senior High School
(Wahono et al., 2020)	The effectiveness of STEM enactment was observed in the following order: higher-order thinking skills, academic achievement, and motivation.	academic learning achievement, higher-order thinking skills (HOTS), and motivation	Quantitative (Quasi Experiment Design)	University

Paper and Citation Distribution

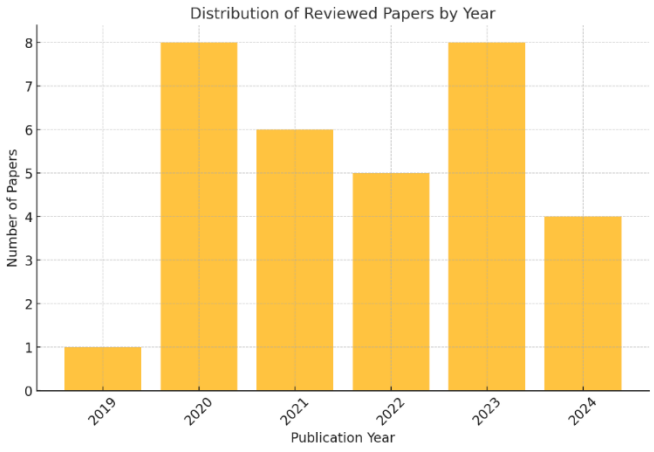

Figure 2. Publication Year

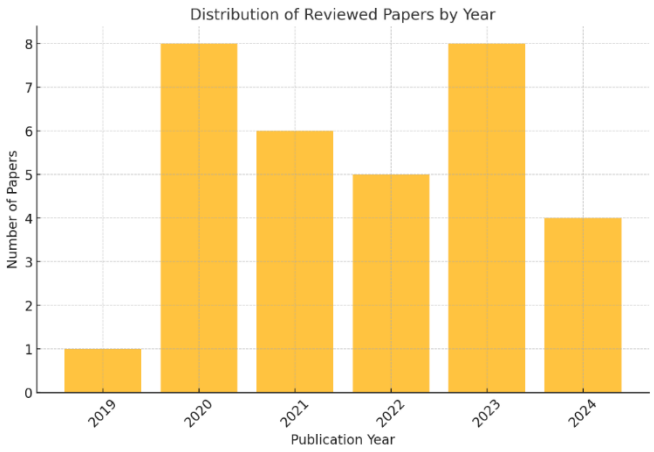

Figure 3. Citation per year

This citation graph illustrates the total number of citations per year for the reviewed articles. Generally, articles published in earlier years, such as 2019 and 2020, have received a relatively higher number of citations in their DOIs compared to articles appearing in recent years, such as 2023. This demonstrates the expected pattern in citation accumulation, wherein articles published earlier are associated with more research for recognition and reference. Furthermore, the high citation counts in certain years may be attributed to the significant relevance of the topic to current times or the substantial contributions these articles have made to the field of study. The distribution graph examining the topic of STEM-based Project-Based Learning (PjBL) post is also depicted by a graph showing the progression in the number of publications over the years in question. Potentially, researchers' interest in this field serves as a significant indicator of the development of educational innovations in STEM. These years demonstrate an increase in publications due to new educational policies or specific academic trends. Upon examination of this phenomenon, the decline in the number of publications in recent years, such as 2023, may be attributed to incomplete data accumulation processes or insufficient time. This tool can provide new insights (or reinforce existing knowledge) regarding the impact of developments in the field currently under study and how this topic is received and applied within the scientific community.

The Advantages of STEM-PjBL in Developing 21st Century Skills

STEM-oriented Project-Based Learning (PjBL) has continuously proven helpful in cultivating a diverse array of 21st-century competencies, such as critical thinking, creativity, problem-solving, and computational thinking. This educational method compels students to study, evaluate, and synthesize material while participating in real-world problem-solving situations, enhancing both cognitive and creative abilities. PjBL has been demonstrated to markedly enhance problem-solving skills in physics (Purwaningsih et al., 2020) and to foster critical thinking and creativity in chemistry (Rahmawati et al., 2021) (Sumarni & Kadarwati, 2020). Furthermore, the amalgamation of Project-Based Learning (PjBL) with methodologies like Design Thinking has enhanced critical thinking (Ananda et al., 2023) and computational thinking abilities (Chang et al., 2023), illustrating its versatility across diverse fields.

Research repeatedly demonstrates the beneficial effects of STEM-PjBL across many educational tiers, from elementary institutions to universities. Students engaged in Project-based Learning (PjBL) activities demonstrate notable enhancements in creativity, namely in fluency, flexibility, and originality (Ndiung & Menggo, 2024)(Yustina et al., 2020). Likewise, research such as (Karan & Brown, 2022) shown the significance of PjBL in cultivating proficient problem-solving abilities, an essential skill for

tackling intricate, interdisciplinary issues. Nonetheless, although the cumulative evidence endorses the efficacy of PjBL, certain research, such those by (Pritasari et al., 2021), have identified no substantial differences between PjBL and alternative active learning methodologies in fostering critical and creative thinking. Notwithstanding its favorable results, discrepancies in the conceptualization and measurement of critical thinking in PjBL research have been observed, as emphasized by (Marnewick, 2023). These disparities highlight the necessity for more stringent study designs and defined measurements to enhance comprehension and optimize the potential of PjBL. Nonetheless, the substantial evidence supporting its positive impact makes STEM-PjBL a transformative approach in modern education, equipping students with essential skills for success in an increasingly complex world.

Innovative Teaching Approaches to Enhance 21st-Century Skills

Innovative pedagogical strategies have demonstrated efficacy in enhancing 21st-century skills through the integration of methodologies such as Project-Based Learning (PjBL), interdisciplinary approaches, and technology. PjBL cultivates critical thinking, creativity, and problem-solving through real-world problem-solving tasks (Sumarni & Kadarwati, 2020)(Rahmawati et al., 2021), while interdisciplinary methods such as STEAM and Ethno-STEM contextualise learning by incorporating the arts and cultural relevance, thereby enhancing creativity and engagement (Aguilera & Ortiz-Revilla, 2021). Design Thinking complements these strategies by promoting iterative problem-solving and user-focused solutions, further enhancing critical and creative thinking (Ananda et al., 2023). Additionally, digital tools such as STEM-PjBL e-books and virtual laboratories augment learning outcomes by improving critical thinking and providing access to practical experiences (Pramasdyahsari et al., 2023). Inquiry-based and collaborative learning approaches foster autonomy and teamwork, which are critical for 21st-century competencies, while inclusive practices address equity by supporting underrepresented groups, such as girls in STEM and marginalised communities, ensuring broader participation and engagement. Collectively, these strategies form a cohesive framework for preparing students to thrive in an increasingly complex world.

Teachers' capacity to implement integrated STEM methods is significantly influenced by their self-efficacy, attitudes, and knowledge, which is why they are crucial to the success of these approaches (Karan & Brown, 2022). Student engagement is improved in the cognitive, affective, and operative domains through inquiry-based learning, industry partnerships, and localized curricula ((Wannapiroon et al., 2021). Nevertheless, professional development is essential for the effective implementation of such strategies. Teachers can align their teaching methods with STEM objectives and adjust to changing demands through ongoing training (Giang, 2021). (Haser et al., 2022) have demonstrated that teachers' attention to the affective needs of learners is essential during challenging periods, such as the COVID-19 pandemic.

Additionally, the promotion of diversity and equity in STEM is significantly influenced by innovative pedagogies. (Nithyanantham et al., 2019) have demonstrated that emancipatory pedagogies have effectively engaged marginalized groups, including Black and Latinx students, by making STEM more pertinent to their lives. STEM education can help students prepare for real-world challenges and create equitable and inclusive learning environments by integrating these strategies with real-world applications through industry partnerships and contextualized projects.

Challenges in Implementation Based on Education Level

Despite its demonstrated success in fostering 21st-century skills, such as critical thinking, problem-solving, creative thinking, and higher-order thinking skills, challenges in the implementation of STEM-based Project-Based Learning (PjBL) frequently arise (Sumarni & Kadarwati,

2020)(Pramasdyahsari et al., 2023). These challenges are often the result of the complexities of integrating innovative pedagogical approaches into existing curricula, insufficient teacher preparation, and limited resources. For example, numerous educational institutions encounter obstacles in supplying the materials, technological tools, and infrastructure that are essential for the successful implementation of STEM-PjBL activities (Prayogi et al., 2024). The scope of student-centered, inquiry-based projects is frequently restricted by this inadequate resource allocation, which may impede students' engagement with real-world STEM applications.

Teacher readiness is another significant barrier to successful implementation. Many educators experience a lack of preparedness to adopt STEM-PjBL approaches due to deficiencies in professional training, limited experience in interdisciplinary teaching, or insufficient confidence in integrating digital tools into instruction (Purwaningsih et al., 2020). These challenges are exacerbated by the necessity to balance innovative methods with traditional assessment requirements, which may not fully capture the breadth of skills developed through STEM-PjBL (Khalil et al., 2023). In the absence of adequate professional development opportunities, teachers may encounter difficulties in adapting to the demands of facilitating collaborative, technology-enhanced, and culturally contextualised projects. Research demonstrates the flexibility of STEM-based Project-Based Learning (PjBL) across various educational levels. At the primary school level, this approach effectively enhances creative thinking skills and mathematical problem-solving abilities (Ndiung & Menggo, 2024). In secondary education, the primary focus is on developing critical thinking, creative thinking, and Higher Order Thinking Skills (HOTS) (Yaki, 2022). The integration of Ethno-STEM at this level also increases student relevance and engagement in learning. At the tertiary level, STEM-PjBL has been shown to not only enhance creativity but also improve motivation and academic achievement (Yustina et al., 2020)(Wahono et al., 2020).

However, the implementation of STEM-PjBL faces challenges at every level of education. In elementary schools, limited resources such as manipulative tools and technology are major barriers (Saad & Zainudin, 2022). In secondary schools, curriculum pressures and the difficulty of managing collaborative projects in large classes limit implementation (Li & Tu, 2024). In universities, constraints include the lack of infrastructure and standard guidance for complex projects. These challenges emphasize the importance of teacher training, resource provision, and supportive policies to ensure the successful implementation of STEM-PjBL at all levels of education.

Implications for Educational Practice

Despite the numerous benefits offered, the implementation of STEM-PjBL faces significant challenges, particularly concerning resource limitations and teacher preparedness. A primary constraint is the inadequacy of STEM tools and facilities, especially in schools with budgetary restrictions (Li & Tu, 2024)(Saad & Zainudin, 2022). Furthermore, many educators lack confidence or sufficient training to effectively adopt this approach. Consequently, greater support is necessary, such as professional development focused on interdisciplinary teaching, digital tool integration, and inquiry-based learning (Yustina et al., 2020). Mentorship programmes and peer learning initiatives may also foster sustained innovation and engagement in the classroom.

Proper resource allocation and governmental support are crucial to mitigate these limitations. Educational institutions require adequate financial resources to supply learning materials, technology, and adaptable learning environments (Pramasdyahsari et al., 2023). Education policies must facilitate the incorporation of STEM-PjBL into the curriculum by granting schools the autonomy to implement novel pedagogical methods unencumbered by inflexible evaluation frameworks (Rahmawati et al., 2021). A prominent trend identified in the literature is the extensive implementation of cross-disciplinary approaches, including the incorporation of arts and cultural components, which have proven effective in

enhancing student engagement and the relevance of learning (Sumarni & Kadarwati, 2020). Moreover, STEM-PjBL has demonstrated superior efficacy in enhancing critical thinking, creativity, and problem-solving abilities relative to conventional educational methods.

This trend corresponds with global priorities, notably Sustainable Development Goal (SDG) 4, which underscores the importance of inclusive, adaptive, and practical education. With robust teacher support, equal resources, and progressive policies, STEM-PjBL may revolutionize education and provide children with vital 21st-century competencies. This study underscores the transformative potential of STEM-PjBL; nevertheless, constraints in secondary data coverage and access to particular literature restrict its generalizability. Nonetheless, the results offer actionable recommendations for enhancing STEM education and establish a foundation for future study investigating underrepresented situations and their enduring effects.

However, this study is limited by the reliance on secondary data and the restricted availability of literature from diverse educational contexts, which may affect the generalizability of the findings. Expanding the scope to include primary data and underrepresented contexts could provide a more comprehensive understanding of STEM-PBL's impact.

CONCLUSIONS AND RECOMMENDATIONS

This research illustrates that the incorporation of digital resources into STEM-oriented Problem-Based Learning (PBL) efficiently corresponds with the study's goals of promoting critical thinking, problem-solving, and student involvement, underscoring its significance and application. The results validate that STEM-PBL is an effective educational method for imparting critical 21st-century abilities to students, however obstacles such as resource scarcity, inadequate teacher training, and absence of standardized frameworks remain. Addressing these issues necessitates systemic initiatives, encompassing professional development for educators to improve their interdisciplinary instruction and proficient utilization of digital tools, alongside appropriate allocation of resources to assist schools in underprivileged regions. Future study must concentrate on enhancing metrics for assessing the impact of PBL, investigating various educational contexts, and performing longitudinal studies to evaluate its enduring effectiveness, so assuring that STEM-PBL considerably advances worldwide educational excellence.

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