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Design of STEAM-Integrated PjBL Learning Model Based on Interdisciplinary Learning: A Literature Review on Developing Critical and Creative Thinking Skills of Mathematics Students

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Abstract: This literature review explores the design of a Project-Based Learning (PjBL) model integrated with STEAM (Science, Technology, Engineering, Arts, and Mathematics) within the framework of interdisciplinary learning, aiming to enhance university students' critical and creative thinking abilities in mathematics. As 21st-century education demands higher-order thinking skills, integrating PjBL and STEAM has emerged as a promising pedagogical approach to foster deeper understanding, innovation, and problem-solving capabilities. This study examines previous research and theoretical perspectives on the implementation of interdisciplinary STEAM-based PjBL models, highlighting their impact on students' engagement and cognitive development. The review also identifies key components and design principles necessary for effectively applying this model in mathematics education. Findings suggest that such an integrated approach not only enriches the learning experience but also significantly contributes to the development of students' critical and creative mathematical thinking skills.

Keywords: Project-Based Learning, STEAM, Interdisciplinary Learning, Critical Thinking, Creative Thinking.

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A. INTRODUCTION

In the era of the Fourth Industrial Revolution (Industry 4.0) and Society 5.0, education is increasingly expected to produce human resources who not only master theoretical knowledge but also possess critical and creative thinking skills, especially in the fields of science and mathematics. Critical thinking enables students to analyze information logically, evaluate arguments, and make sound decisions. Meanwhile, creative thinking is essential for generating new ideas, innovative solutions, and addressing complex problems in a flexible manner (Facione, 2015; Torrance, 2000).

However, several studies have shown that mathematics instruction in higher education still tends to be conventional, focusing primarily on memorization and procedural knowledge, with limited emphasis on exploration or meaningful problem-solving (Suryani & Wahyudin, 2020). To respond to this challenge, integrative and contextual approaches such as Project-Based Learning (PjBL) integrated with STEAM (Science, Technology, Engineering, Arts, and Mathematics) offer promising alternatives. PjBL emphasizes complex and authentic project activities that encourage collaboration, critical thinking, and the application of interdisciplinary knowledge (Krajcik & Blumenfeld, 2006).

The integration of STEAM in PjBL can strengthen the connections between disciplines through interdisciplinary learning, thereby creating a more holistic and relevant learning experience that mirrors real-world challenges (Beers, 2011). This approach has been shown to enhance students' higher-order thinking skills, particularly in the context of solving open-ended and complex mathematical problems (Henriksen, 2014). Furthermore, STEAM-based project learning provides students with opportunities to develop their creativity through exploration, reflection, and the creation of meaningful, tangible products (Mehta et al., 2019).

Considering the importance of critical and creative thinking skills in 21st-century mathematics education, there is a growing need for instructional models that effectively integrate the principles of PjBL, STEAM, and interdisciplinary learning. This literature review aims to examine relevant research as a foundation for designing a learning model that supports the development of these essential competencies among mathematics education students. In the field, the mathematics learning process at the university level still faces many obstacles in developing students' critical and creative thinking skills. Generally, learning is still teacher-centered, oriented towards material and procedural mastery, not on in-depth concept exploration or complex and contextual problem solving (Suryani & Wahyudin, 2020). Students tend to be passive, only following the lecturer's instructions, without being given space to develop creative ideas or formulate alternative solutions to real mathematical problems.

Thereare not many learning models used that integrate various disciplines holistically. Learning is still separated by course or topic, making it difficult for students to see the connection between mathematics and other fields such as science, technology, art, and engineering (Beers, 2011). This has an impact on the low relevance and motivation of students to learn because the material feels separated from the reality of life. Meanwhile, the application of Project-Based Learning (PjBL) in some institutions is still not optimal. The projects given are often artificial and decontextualized, and do not involve integrative elements between disciplines (Krajcik et al., 2006). In addition, not all lecturers have sufficient understanding of the STEAM approach based on interdisciplinary learning, so that its implementation is not maximized (Mehta et al., 2019).

Research by Hersiyati et al. (2024) implementation of PjBL integrated with ethnomathematics significantly enhances students' mathematical problem-solving skills and mathematical communication compared to conventional teaching methods. Furthermore, students involved in project-based learning within a local cultural context were better able to relate mathematical concepts to real-life situations, fostering conceptual understanding and creativity. This study concludes that the integration of ethnomathematics in the PjBL model effectively improves the quality of mathematics education in higher education institutions. Research by Utami and Jailani (2019) shows that project-based mathematics learning applied without integration with STEAM only has a moderate impact on students' critical thinking skills, because the projects designed do not encourage multidisciplinary collaboration. The study suggested the need for a more complex and unified approach between STEAM fields.

Furthermore, Suciati et al. (2021) revealed that although the STEAM approach has begun to be applied in several vocational colleges, most of them are only partial and not designed in

a systematic learning model. This causes the development of student creativity is still not significant. Research by Henriksen (2014) also emphasizes the importance of creativity development in STEM learning through artistic approaches as a component of STEAM. He found that a strong interdisciplinary approach tends to produce deeper and more meaningful learning outcomes. From these studies, it appears that there is no learning model that comprehensively integrates PjBL, STEAM, and interdisciplinary approaches to develop students' critical and creative thinking skills, especially in the context of mathematics education. This is an important research gap to be studied further.

To address the challenges identified in the current state of mathematics education—particularly the lack of critical and creative thinking development and the suboptimal implementation of project-based learning, this study proposes the design of an instructional model that integrates Project-Based Learning (PjBL) with the STEAM approach through the lens of interdisciplinary learning. The proposed solution involves the structured development of a learning model that explicitly blends elements of science, technology, engineering, arts, and mathematics within project-based tasks that are relevant to real-world problems. This integration is aimed at creating a holistic and meaningful learning experience that stimulates students' higher-order thinking abilities. By engaging in authentic, contextualized projects, students are encouraged to think critically in identifying and solving problems while simultaneously nurturing their creative capacities through innovation and exploration.

Interdisciplinary learning plays a key role in this model, where the boundaries between subjects are intentionally blurred to foster deeper understanding and application of knowledge. Collaboration among instructors from different disciplines is also essential to ensure that the learning design is rich, coherent, and effectively integrates diverse perspectives. Moreover, the success of this model depends on adequate training and ongoing support for lecturers so that they are well-equipped to implement interdisciplinary STEAM-based projects in a project-based learning environment. In terms of assessment, the model emphasizes authentic and reflective evaluation, including the use of portfolios, project outcomes, rubrics for creativity and critical thinking, and self-assessment practices. These assessment strategies are intended not only to measure students' final products but also to capture the depth of their thinking processes and personal growth throughout the learning journey.

Through this integrated instructional design, it is expected that mathematics education will become more engaging, applicable, and empowering for students, thereby enhancing their readiness to face the challenges of the 21st century. This study aims to explore and conceptualize a learning model that integrates Project-Based Learning (PjBL), STEAM, and interdisciplinary learning to support the development of critical and creative thinking skills in mathematics education students through a comprehensive literature review. Therefore, the author is interested in conducting this literature review to investigate relevant research findings and theoretical foundations that can support the development of an integrated instructional model aimed at enhancing students' critical and creative thinking in mathematics.

B. METHOD

This study employs a qualitative research method in the form of a systematic literature review. The literature review aims to collect, analyze, and synthesize relevant scholarly articles and academic sources related to the integration of Project-Based Learning (PjBL), STEAM education, and interdisciplinary learning in mathematics education, particularly concerning the development of students' critical and creative thinking skills. The stages of the literature review follow a systematic approach: (1) Identification of keywords and research questions; (2) Selection of relevant literature through inclusion and exclusion criteria; (3) Data extraction from selected journals and academic publications; and (4) Analysis and synthesis of findings to construct a conceptual understanding of the proposed instructional model.

Data were obtained from reputable academic databases such as Scopus, ERIC, Google Scholar, and ScienceDirect, with a focus on peer-reviewed journals published within the last ten years (2014–2024). The inclusion criteria included articles discussing PjBL, STEAM integration, interdisciplinary learning, and their effects on critical and/or creative thinking in mathematics education. The analysis was conducted using thematic coding to identify common patterns, theoretical frameworks, teaching strategies, and empirical findings that support the integration of the three approaches. The review was guided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to ensure transparency and comprehensiveness throughout the process.

Table 1. Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Publication Year	2014–2024	Articles published before 2014
Language	English or Indonesian	Other languages without translation
Type of Publication	Peer-reviewed journal articles, conference papers	Non-academic sources, blogs, opinion pieces
Research Focus	PjBL, STEAM integration, interdisciplinary learning in math education	Studies not related to mathematics or not integrating STEAM/PjBL
Skill Outcomes	Critical thinking, creative thinking	Studies focusing only on knowledge recall or procedural learning
Target Participants	University students or preservice mathematics teachers	Studies focusing on elementary/secondary students (if not comparable)

C. RESULTS AND DISCUSSION

1. The Pedagogical Impact of Project-Based Learning (PjBL)

Several studies confirm that PjBL supports the development of critical thinking by engaging students in inquiry, problem-solving, and real-world applications. Krajcik and Blumenfeld (2006) assert that PjBL provides a flexible framework that promotes student autonomy and reflective thinking. Similarly, Utami and Jailani (2019) found that mathematics students involved in project-based tasks demonstrated improved argumentation and analytical reasoning compared to those taught using traditional methods. However, the

impact of PjBL is highly dependent on the quality and authenticity of the projects, as well as the facilitation skills of the instructor.

2. STEAM Integration and Its Role in Creativity

The integration of STEAM elements—particularly the inclusion of the arts—has shown to enhance students' creativity in problem-solving and representation of mathematical ideas. Henriksen (2014) emphasizes that creativity is not limited to artistic expression but is crucial in developing original mathematical models and multiple solution strategies. STEAM-based learning encourages students to approach mathematics through design thinking, modeling, and visualization techniques that are often absent in conventional curricula. This multidimensional approach is especially effective when paired with PjBL, which provides a meaningful context for integrating different disciplines.

3. Interdisciplinary Learning as a Catalyst for Deeper Mathematical Understanding

Interdisciplinary learning facilitates the connection between mathematics and other fields, allowing students to see the relevance of mathematical concepts beyond abstract theory. Studies by Mehta et al. (2019) and Beers (2011) suggest that interdisciplinary tasks—when thoughtfully designed—promote conceptual transfer, collaborative learning, and innovation. These tasks enable students to approach complex problems from multiple perspectives, which is essential in cultivating both critical and creative thinking. Moreover, the literature highlights the importance of instructional design and institutional support in implementing this integrated approach effectively. Suciati et al. (2021) report that without proper training, educators may struggle to design and facilitate interdisciplinary STEAM projects. Hence, professional development and collaborative curriculum planning are crucial to the success of such pedagogical innovations.

In conclusion, the synthesis of the literature indicates that a learning model combining PjBL, STEAM, and interdisciplinary learning has significant potential to enhance critical and creative thinking in mathematics education. However, successful implementation requires well-structured project tasks, collaboration among educators from various disciplines, and alignment with learning objectives.

D. CONCLUSIONS AND SUGGESTIONS

Based on the results of the systematic literature review, it can be concluded that the integration of Project-Based Learning (PjBL), STEAM, and interdisciplinary learning holds great potential in enhancing students' critical and creative thinking in mathematics education. PjBL provides authentic learning experiences that promote inquiry and reflection, while the STEAM approach encourages multidimensional thinking and creativity. Interdisciplinary learning connects mathematics to real-world contexts and other disciplines, enabling deeper conceptual understanding and problem-solving abilities. The synthesis of these three components offers a robust instructional model that aligns with the needs of 21st-century education. However, the successful implementation of this integrated model requires well-designed projects, professional collaboration among educators, and institutional support in

terms of training and curriculum development. Without these supports, the integration may become fragmented and fail to achieve its intended outcomes.

Future research should focus on designing and validating a concrete instructional model based on the integration of PjBL, STEAM, and interdisciplinary learning, particularly within the context of mathematics education at the university level. It is also recommended that teacher training programs incorporate modules on interdisciplinary curriculum design, STEAM pedagogy, and project-based assessment. Furthermore, educational institutions should encourage collaborative teaching practices and provide platforms for cross-disciplinary innovation to ensure the sustainability and scalability of such integrated approaches.

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