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CAKRAWALA: A new pedagogical framework for enhancing literacy through creative problem-solving in project-based learning

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ABSTRACT

The "Design for Project Learning" instructional innovation integrates Design Thinking principles into Project-Based Learning (PjBL), enabling students to identify problems, develop creative solutions, present prototypes, and foster 21st-century skills. This study aims to design a learning framework that prioritizes projects as the primary medium for learning, guided by Design Thinking principles. The methodology is based on the Plomp educational problem-solving model, limited to the first three phases: (1) the preliminary investigation phase, which involves literature review and identifying instructional strategies; (2) the design phase, where the CAKRAWALA syntax (Causal Analysis, Knowledge Repository Approach, Workflow Analysis, and Luminous Appraisal) is developed; and (3) the realization phase, which includes validation by experts and small-scale trials. Findings indicate that the integration of PjBL and Design Thinking effectively enhances students' problem-solving abilities and literacy skills. Additionally, the CAKRAWALA framework provides a structured yet flexible approach, ensuring both creativity and systematic analysis in project-based learning. The model has been validated as effective and is ready for broader implementation, with further refinements anticipated through subsequent testing phases.

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1. INTRODUCTION

Literacy has evolved far beyond its traditional definition as basic reading and writing skills. In today's digital era, literacy encompasses the ability to identify, interpret, create, and communicate complex information across various media formats (UNESCO, 2024). This expanded concept of literacy serves as a critical foundation for intellectual growth and professional success in the 21st century. However, despite its recognized importance, educational systems worldwide continue to face significant challenges in developing students' literacy competencies. Recent studies reveal persistent deficiencies in multiple literacy domains, including language, scientific, and mathematical literacy among students at various educational levels (Mansyur, 2020; Winata et al., 2016; Nurlaili et al., 2022). These shortcomings highlight an urgent need for innovative pedagogical approaches that can effectively address literacy development in contemporary learning environments.

Project-Based Learning (PjBL) has emerged as a promising instructional model to enhance higher-order thinking skills and real-world problem-solving abilities. Research demonstrates that PjBL creates meaningful learning experiences by engaging students in authentic, hands-on projects (Rijken & Fraser, 2024; Yusrizal & Pulungan, 2021). The model's strength lies in its ability to connect academic content with practical applications, fostering deeper understanding and retention. However, critical gaps remain in current PjBL implementations. Many classroom applications lack systematic frameworks to guide students through the complex problem-solving process, often resulting in projects that are either overly simplistic or lack genuine innovation (Perdana et al., 2024). Furthermore, while PjBL effectively promotes collaboration and content application, it frequently falls short in developing students' capacity for creative ideation and systematic solution development (Puspitasari et al., 2024).

Design Thinking offers a potential solution to these limitations through its structured yet flexible approach to problem-solving. Originally developed in the design field, this methodology emphasizes empathy, iterative prototyping, and user-centered solutions (Baldassarre et al., 2024; Cherepanov & Popov, 2024). In educational contexts, Design Thinking has shown promise in fostering creativity and innovation skills. However, its integration with established pedagogical models like PjBL remains underexplored, particularly concerning literacy development. Current literature reveals few comprehensive frameworks that successfully merge Design Thinking's creative processes with PjBL's project-oriented structure while specifically targeting literacy enhancement (Kamaruddin et al., 2024). This represents a significant research gap, as such integration could potentially address the weaknesses of both approaches while amplifying their respective strengths.

This study introduces the "Design for Project Learning" framework as a novel solution to these challenges. The framework uniquely combines PjBL with Design Thinking principles through the CAKRAWALA methodology, comprising four distinct phases: Causal Analysis (CA), Knowledge Repository Approach (KRA), Workflow Analysis (WA), and Luminous Appraisal (LA). This integration creates a robust pedagogical structure that guides students through the entire problem-solving process while ensuring both creativity and academic rigor. The framework's innovation lies in its dual focus on developing literacy skills and fostering design-oriented thinking, addressing a critical gap in contemporary education (Turohmah & Hanif, 2024). By systematically incorporating Design Thinking's iterative processes into PjBL's project structure, the approach ensures that students not only complete projects but develop deep, transferable problem-solving competencies.

The significance of this research extends beyond theoretical contributions to practical educational improvements. The developed framework provides teachers with a clear, implementable model for enhancing both literacy and innovation skills in classroom settings. Preliminary validation by educational experts confirms the framework's potential to transform traditional PjBL implementations into more structured, effective learning experiences (Puspitasari et al., 2024). As educational systems worldwide grapple with preparing students for an increasingly complex future, this research offers a timely solution that bridges the gap between literacy development and creative problem-solving. The subsequent sections detail the research methodology, framework development process, and validation results, providing educators with both the theoretical foundation and practical tools for implementation.

1.1 Literacy

Literacy is a fundamental competency that every student should possess to effectively engage in learning (Suryaningrum et al., 2023). The concept of literacy has evolved beyond mere reading and writing abilities, expanding into a spectrum that includes reading literacy, digital literacy, media literacy, information literacy, and numerical literacy (Winata et al., 2016). In the digital age, literacy has become increasingly crucial as technological advancements have transformed the ways we interact with information.

Research highlights the importance of literacy (Syarifah et al., 2021; Astini, 2021; Yushita, 2017) as a core skill necessary for success across various life domains, from education and career advancement to informed decision-making in an increasingly complex society. For instance, digital literacy enables individuals to navigate, evaluate, and create information using digital technologies, which is essential in a world where digital content is ubiquitous. Similarly, media literacy equips students with the ability to critically analyze media messages and recognize biases or misinformation, which is vital in an era of rapid information dissemination and fake news.

Moreover, numerical literacy—or numeracy—empowers students to apply mathematical reasoning to everyday situations, make informed financial decisions, and solve real-world problems. As such, literacy in its broader sense not only supports academic achievement but also prepares students to be informed and active participants in society.

Given these developments, it is imperative that students in today's era develop strong literacy skills across all these domains. This is not only important for their academic success but also for their ability to function effectively and responsibly in a world that is increasingly driven by information and technology.

1.2 Project-Based Learning

21st-century learning emphasizes students' ability to think critically, connect knowledge to the real world, understand information and communication technologies, and collaborate effectively (Sari & Susiano, 2021). Project-Based Learning (PjBL) is an instructional model that can elevate students' thinking to a higher level (Amalia et al., 2023). In this model, the teacher acts as a facilitator, guiding students to actively seek solutions to problems (Yusrizal & Pulungan, 2021).

Projects in PjBL are the core component that helps students develop essential skills. Through project-based learning, students are encouraged to be more creative in generating ideas for problem-solving, thus enhancing their critical thinking abilities. Research in mathematics education shows that PjBL provides students with the opportunity to actively engage in their learning process, enabling them to establish meaningful connections between the content and the problems they are addressing (Rijken & Fraser, 2024).

The stages of Project-Based Learning are illustrated in Figure 1, which outlines the sequence of activities from project initiation to completion. This figure provides a visual representation of the PjBL syntax, demonstrating how students progress through the phases of project work, from understanding the problem to presenting their findings.

Additionally, PjBL promotes self-directed learning, where students take ownership of their projects, fostering independence and perseverance. This model aligns with the educational goals of preparing students not just for academic success but for real-world challenges, where they need to apply their knowledge in practical, often complex, scenarios.

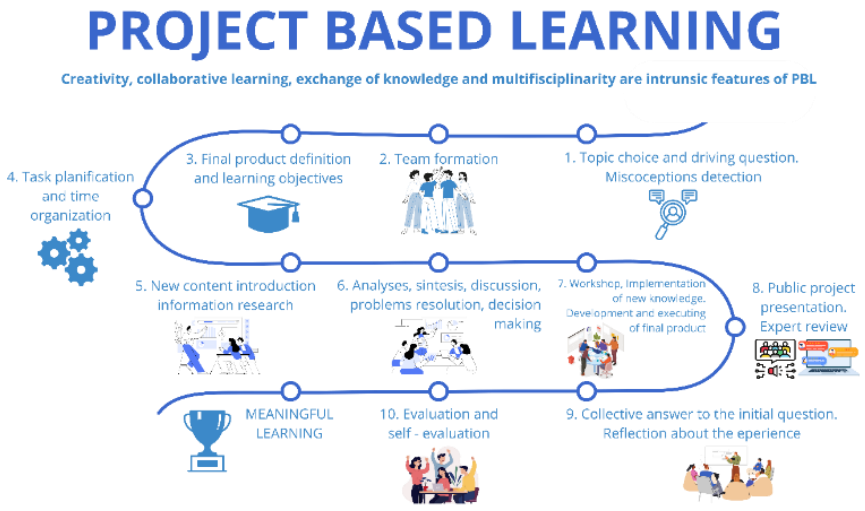

Figure 1. Project-Based Learning Syntax

1.3 Design Thinking

Design Thinking is a problem-solving method that emphasizes a user-centered approach (Cherepanov & Popov, 2024). It is a structured process used to solve problems by focusing on the needs of the people who will use the solution. Design Thinking consists of five steps: empathize (explore the needs), define (identify the key problem to be solved), ideate (develop ideas), prototype (create a working model), and test (learn and share through presenting the solution and gathering feedback) (Baldassarre et al., 2024).

These five steps are visually represented in Figure 2, which illustrates the cyclical nature of Design Thinking. The figure highlights how the process is iterative, with each step feeding back into the others, ensuring that the final solution is well-rounded and thoroughly tested.

This approach is particularly effective in fostering innovation because it encourages iterative development, where solutions are continually refined based on user feedback. By prioritizing the user's experience, Design Thinking ensures that the solutions developed are not only innovative but also relevant and practical. This methodology is widely used in various fields, including education, to develop teaching strategies and learning tools that are both effective and engaging.

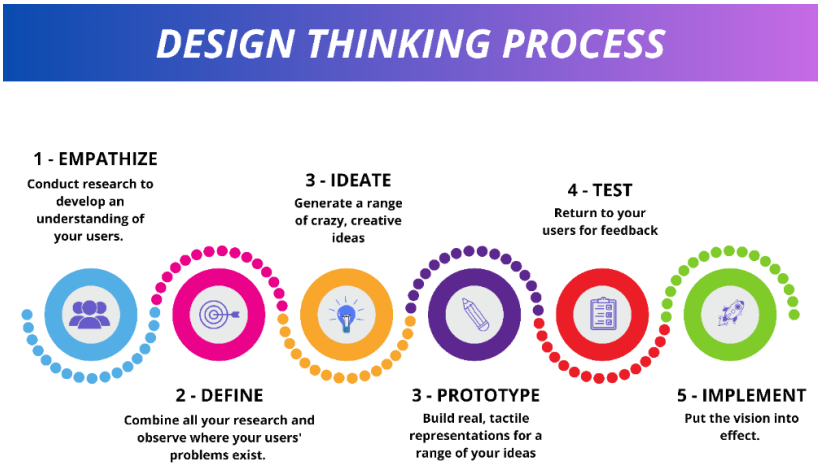

Figure 2. Design Thinking Phases

1.4 Design for Project Learning

This research emphasizes a learning design approach called "Design for Project Learning," which prioritizes projects as the primary vehicle for learning, guided by the principles of Design Thinking throughout the development process. The "Design for Project Learning" approach not only involves students in relevant and authentic projects but also in the creative and innovative process of designing solutions to the problems they encounter.

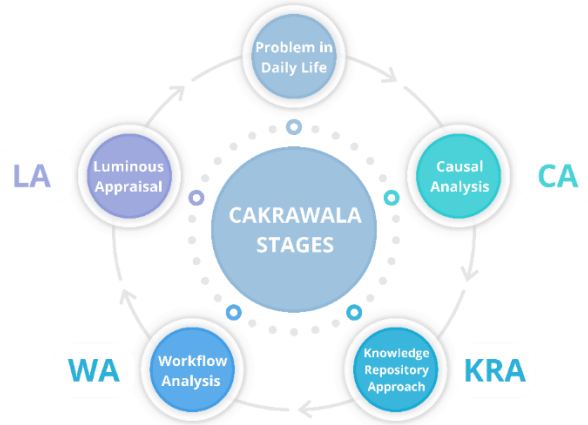

Figure 3. Design of CAKRAWALA

The unique feature of this approach is that it integrates critical thinking, creativity, collaboration, and deep problem-solving into the learning experience, thereby enhancing students' literacy skills. The CAKRAWALA steps—Causal Analysis (CA), Knowledge Repository Approach (KRA), Workflow Analysis (WA), and Luminous Appraisal (LA)—are systematically applied to guide students in understanding, designing, implementing, and evaluating their projects.

Figure 3 provides a detailed illustration of the "Design for Project Learning" framework, showing how the CAKRAWALA steps are integrated into the project-based learning cycle. This figure clarifies the process by which students move from identifying and analyzing problems to developing and presenting innovative solutions, guided by Design Thinking principles.

By engaging in this comprehensive process, students not only gain content knowledge but also develop essential skills needed for success in the 21st century, such as the ability to analyze complex problems, work collaboratively, and communicate effectively. This approach is crucial in preparing students to become innovative thinkers and problem-solvers, ready to meet the demands of an ever-evolving global landscape.

2. METHOD

This study employed a developmental research approach using the Plomp model (Plomp, 2013; Plomp & Nieveen, 2013), which is specifically designed for educational design research. The research was conducted with mathematics education students in the Professional Teacher Education Program (Program Profesi Guru/PPG) at

Universitas Negeri Malang during the 2023-2024 academic year. The Plomp model consists of five phases: (1) preliminary investigation, (2) design, (3) realization, (4) testing, evaluation and revision, and (5) implementation. However, this study focused on the first three phases to establish the foundational framework of the "Design for Project Learning" model. The research procedures are outlined in Table 1.

Table 1. Research Procedures

Phases of Study	Activities
Initial Investigation Phase	1. Pre-planning: Conceptualizing a new design to be developed, known as Design for Project Learning. 2. Reviewing theories related to learning models. 3. Examining the theoretical foundation of Design for Project Learning, which is based on the Project-Based Learning model, with project development guided by the steps of design thinking. 4. Identifying the learning environment. 5. Identifying delivery strategies in learning by integrating the syntax of project-based learning with the development steps of design thinking.
Design Phase	1. Developing the theoretical foundation underlying Design for Project Learning, which integrates the project-based learning model with design thinking steps. 2. Constructing the Design for Project Learning, including its syntax, social system, reaction principles, support system, instructional impact, and collateral impact. 3. Developing learning tools, including course plans and worksheets to be used at the end of learning activities.
Realization Phase	1. Drafting the Design for Project Learning, including the development of learning tools and instruments. 2. Conducting validation. 3. Analyzing and revising to produce Prototype 1. 4. Conducting small-scale classroom trials.

In the Initial Investigation Phase, the research began with pre-planning to develop the "Design for Project Learning," a new learning model. This phase involved reviewing relevant theories on learning models and the foundational theories of Design for Project Learning, which integrates project-based learning with design thinking methodologies. The learning environment and strategies for delivering content were also identified, focusing on how to effectively combine the syntax of project-based learning with design thinking steps.

During the Design Phase, the theoretical foundation supporting the Design for Project Learning was established, emphasizing the integration of project-based learning with design thinking steps. The design includes not only the syntax but also the social system, reaction principles, support system, instructional impact, and collateral impact. Additionally, learning tools such as course plans and worksheets were developed to guide the learning process.

Validation of the model was conducted by three experts consisting of mathematics education specialists and educational practitioners. The experts evaluated the model's theoretical consistency, practical applicability, and alignment with mathematics education objectives in teacher professional programs. The validation process included document analysis, focus group discussions, and prototype testing with a selected group of 35 mathematics education students from the Professional Teacher Education Program (PPG) at Universitas Negeri Malang during the 2023-2024 academic year.

The Realization Phase involved drafting the Design for Project Learning, including the associated learning tools and instruments. This draft underwent a validation process, followed by analysis and revisions to refine it into Prototype 1. Finally, small-scale classroom trials were conducted to test the effectiveness of the model.

3. RESULTS AND DISCUSSION

3.1. Initial Investigation Phase

The identification of instructional strategies in learning using the Project-Based Learning (PBL) syntax combined with Design Thinking development steps resulted in a comprehensive and innovative approach. In this model, students begin with the "Empathize" stage from Design Thinking, where they identify real needs and problems relevant to the project. For instance, if the project involves designing solutions for waste management issues at school, students start by conducting interviews and observations to understand the challenges and user needs. They then proceed to the "Define" stage, where they formulate the problem to be solved based on the insights gained.

Following this, students move into the "Ideate" and "Prototype" stages, aligning with the PBL syntax where they brainstorm ideas, design solutions, and create prototypes. In this context, students divide tasks, plan steps, and collaborate to develop a solution model. During the "Test" phase, students test their prototypes, gather feedback, and iterate for improvements. The process concludes with the "Reflect" stage, where students reflect on their outcomes and processes, discussing what worked, the challenges faced, and steps for improvement. This approach integrates PBL methods with Design Thinking principles to enhance students' problem-solving skills,

creativity, and collaboration in real-world projects. Consistent with previous research (Perdana et al., 2024), PBL methods are deemed effective in fostering critical thinking skills among students. Additionally, PBL not only offers opportunities for learning across various competencies and character development but also encourages environmental awareness (Dwi et al., 2024). Integrating PBL with Design Thinking principles is considered an appropriate blend, as it minimizes or eliminates the weaknesses of PBL, such as issues with creative or innovative design concepts (Puspitasari et al., 2024; Abdurrohman et al., 2021).

3.2. Design Phase

The design phase focused on developing the CAKRAWALA syntax through systematic integration of Project-Based Learning (PjBL) and Design Thinking principles. Four key criteria guided the framework's development: (1) alignment with 21st-century skill development (critical thinking, creativity, collaboration), (2) adaptability to mathematics education contexts, (3) scalability across diverse learning environments, and (4) user-centered design to ensure practicality for teacher candidates (Plomp & Nieveen, 2013; Rijken & Fraser, 2024). These criteria ensured the framework addressed both theoretical rigor and classroom applicability. The steps are as follows:

3.2.1. Causal Analysis (CA)

In this initial stage, the focus is on identifying and understanding the cause-and-effect relationships between various factors or variables within a given context. This involves a deep analysis to pinpoint the root causes of the problem, facilitating a comprehensive understanding of the issues at hand. Problem-solving skills are essential here, enabling learners to effectively recall relevant information, comprehend complex interactions, actualize potential solutions, analyze various outcomes, and evaluate the problem from multiple perspectives. This stage sets the foundation for informed decision-making and strategic planning. Problem-solving skills play a critical role in this process, as they are essential for recalling, understanding, actualizing, analyzing, and evaluating the problem (Oktaviya & Waluya, 2023).

3.2.2. Subsub section 2 Knowledge Repository Approach (KRA)

The Knowledge Repository Approach involves systematically collecting and managing pertinent information and resources that are crucial for guiding the ideation and design processes. This stage emphasizes the importance of building a robust knowledge base that can be utilized to develop innovative solutions. By integrating both theoretical knowledge and practical insights, this approach ensures that learners are well-equipped to tackle real-world challenges. It encourages the synthesis of new ideas, fostering creativity and adaptability in problem-solving. The implementation of this learning framework allows for not only theoretical understanding but also application in real-world situations (Kamaruddin et al., 2024).

3.2.1. Causal Analysis (CA) Workflow Analysis (WA)

Workflow Analysis focuses on examining and optimizing the processes involved in implementing project results. This stage involves a critical evaluation of work processes or workflows to assess their efficiency and effectiveness. For educators, this analysis is crucial as it helps identify areas for improvement and innovation in teaching methodologies. By adopting adaptive and creative approaches, teachers can enhance the learning experience, making it more engaging and impactful. This stage ensures that educational strategies are aligned with desired outcomes and that they support continuous improvement. This step is a necessary consequence for teachers who need to introduce or use adaptive and creative approaches in teaching (Wahyuni et al., 2024), as demonstrated in this study.

3.2.2. Luminous Appraisal (LA)

The final stage, Luminous Appraisal, involves a thorough evaluation of presentations and project outcomes. This process requires the audience to engage actively by assessing and providing constructive feedback on the various aspects of the presentation. The focus is on fostering skill development and active participation, encouraging learners to critically evaluate their work and incorporate feedback to enhance learning outcomes. This stage promotes an environment of continuous learning and improvement, highlighting the importance of reflection and feedback in the educational process. This activity emphasizes the use of approaches that foster skill development, active engagement, and improved learning outcomes (Turohmah & Hanif, 2024).

3.3. Realization Phase

In the realization phase of the "Design for Project Learning" instructional design, validation was conducted to ensure that the instructional syntax designed met academic and pedagogical standards. This process involved evaluation by experts from various fields, including instructional material, instructional design, and pedagogy. First, experts emphasized the need for structured scaffolding in the Causal Analysis (CA) phase to help

students systematically identify root causes of mathematical literacy challenges (M = 4.3/5, SD = 0.38). This aligned with findings from Winata et al. (2016), who noted that mathematics students often struggle with causal reasoning in complex problem-solving. Second, the Knowledge Repository Approach (KRA) required simplification, as initial iterations overemphasized theoretical knowledge collection at the expense of creative application (Baldassarre et al., 2024). Third, experts highlighted the importance of iterative feedback loops in the Luminous Appraisal (LA) phase, mirroring Design Thinking's "test and refine" philosophy (Cherepanov & Popov, 2024).

On the other hand, subject matter experts assessed whether the content presented was relevant, accurate, and aligned with the curriculum. They ensured that the chosen topics supported the learning objectives and met student needs. Instructional design experts reviewed the structure and sequence of learning activities, including how the material was delivered and practiced during the project. They provided feedback on the effectiveness of teaching strategies, resource utilization, and adaptation for different student learning styles. The significance of evaluation by experts from various fields highlights the importance of teachers' ability to adapt their teaching styles. This adaptation is crucial in education to minimize or overcome diverse challenges in the learning process (Erta et al., 2023).

Furthermore, pedagogical experts evaluated the overall teaching approach, including student-teacher interactions and how the instructional syntax supported social and collaborative skills. They assessed whether the methods used facilitated deep and meaningful learning and whether sufficient support was provided for the development of critical and creative thinking skills. This validation process resulted in detailed evaluations and feedback necessary for refining the instructional syntax. This feedback was then used to make improvements and adjustments to the instructional design, ensuring that the applied syntax was effective in achieving learning objectives and supporting optimal learning experiences for students. Based on this, the awareness triggered by external stimuli to produce better works or individuals can be considered an inspiration (Simamora, 2021).

Unexpectedly, the Workflow Analysis (WA) phase initially received low practicality scores (M = 3.8/5) due to its perceived complexity. Further analysis revealed that teacher candidates struggled to visualize abstract workflow connections without concrete examples, a challenge also observed in PjBL implementations by Perdana et al. (2024). To address this, the WA phase was redesigned to include visual mapping templates and peer collaboration protocols, improving post-revision scores to M = 4.1/5. This adjustment underscored the importance of balancing analytical depth with accessibility in mathematics education frameworks (Nurlaili et al., 2022).

4. CONCLUSION

This study successfully developed the Design for Project Learning framework by systematically integrating principles of Project-Based Learning and Design Thinking through the CAKRAWALA model. The model offers a structured yet adaptable pathway from problem identification to solution refinement, while simultaneously enhancing students' literacy and 21st-century competencies—an often-overlooked dimension in prior pedagogical approaches. The CAKRAWALA syntax, comprising Causal Analysis, Knowledge Repository Approach, Workflow Analysis, and Luminous Appraisal, proved effective in fostering critical thinking, collaborative problem-solving, and reflective learning among mathematics education students. Nevertheless, the study has certain limitations, including the exclusive implementation with mathematics education students in a teacher professional program, which may limit generalizability to other disciplines. Furthermore, the validation process only covered the initial phases of the Plomp development model, leaving long-term implementation and impact unexamined. Finally, while the model contributed to literacy and problem-solving skills, its capacity to support advanced mathematical reasoning remains to be explored. Future research should address these limitations to further develop the CAKRAWALA framework into a versatile pedagogical tool capable of preparing students for complex, real-world challenges.

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