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Applied learning innovation: Evaluating the effects of self-efficacy and Project-based blended learning on computational thinking skills

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Abstract: In today's digital age, it is crucial to equip future elementary teachers with computational thinking skills to address the educational needs of the 21st century. This research examines how project-based blended learning and self-efficacy influence students' computational thinking abilities within the realm of primary teacher education. A quasi-experimental 2×2 factorial design was utilized, involving 74 undergraduate students from Universitas PGRI Madiun, Indonesia. Participants were divided into either a project-based blended learning group or a non-blended project-based learning group and further classified based on high or low self-efficacy levels. Data collection involved validated self-efficacy questionnaires and computational thinking assessments, with analysis conducted using two-way ANOVA. The results indicate a significant main effect of project-based blended learning ($p = 0.02$) and self-efficacy ($p = 0.00$) on computational thinking skills, while no significant interaction was found between the two variables ($p = 0.431$). These findings underscore the individual effectiveness of blended, project-based methods and learner confidence in enhancing computational thinking. The study adds to the growing body of evidence supporting technology-integrated teaching methods in teacher education programs and provides practical insights for curriculum developers aiming to cultivate computational skills in future educators.
Keywords: *Computational thinking skills, Primary teacher education, Project-based blended learning, Self-efficacy.*

1. Introduction

The swift progression of digital technologies is transforming the educational field, necessitating that educators adopt teaching methods that prepare students with skills suited to the demands of the 21st century [1, 2]. Effectively integrating technology into education has shown the potential to greatly enhance learning outcomes and encourage innovation in teaching practices [3]. For nations such as Indonesia, these changes present both challenges and opportunities, especially in developing a teaching workforce that is ready for the future and capable of meeting global educational standards [4].

In contemporary education, essential skills such as problem-solving, critical thinking, collaboration, and digital literacy are heavily emphasized [5, 6]. These abilities are crucial for engaging in knowledge-based societies and are vital for maintaining professional development in an increasingly digital world. Teachers, as key drivers of change, need to not only have these skills but also be proficient in nurturing them in their students. As a result, incorporating technology into teacher education programs has become increasingly important, especially through approaches that encourage active learning and self-regulation [7]. Consequently, educators must incorporate technology into their pedagogical methods to

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address the needs of students in accordance with contemporary developments.

Computational thinking (CT) has become a vital skill for the 21st century, particularly important for pre-service elementary teachers who need to develop systematic and logical problem-solving skills in young students [8, 9]. Nonetheless, research indicates that future teachers in various countries, such as Indonesia and Ukraine, do not possess adequate understanding of CT concepts and teaching methods [10, 11]. Given that CT underpins higher-order thinking and digital literacy, its early integration into teacher education programs is essential. Experts suggest that the primary school stage is optimal for introducing computational thinking, as it forms the foundation for children's cognitive abilities, reasoning skills, and creativity. The thought processes developed during this foundational period are expected to guide students toward more advanced stages of learning [12].

Although there is increasing interest in incorporating computational thinking, there is a scarcity of empirical studies examining how instructional models like Project-Based Blended Learning (PBBL) and learner-related factors such as self-efficacy together influence the development of CT skills. Previous research has looked at these variables individually, but their combined and interactive effects, especially in the context of teacher education in developing nations, have not been thoroughly investigated. This study seeks to fill this gap by exploring both the individual and interactive impacts of PBBL and self-efficacy on the computational thinking abilities of pre-service elementary teachers.

The study specifically aims to (1) analyze the influence of project-based learning, with and without blended integration, on CT skills; (2) assess the effects of varying levels of self-efficacy (high versus low); and (3) determine if there is an interaction between PBBL and self-efficacy that affects CT outcomes. By shedding light on these dynamics, the study enhances the understanding of how pedagogical innovations and learner characteristics work together to promote computational skills in teacher education.

2. Theoretical Framework

This research is based on the theoretical interaction among three essential elements: Project-Based Blended Learning (PBBL), self-efficacy, and computational thinking (CT) skills. Each of these aspects plays a distinct role in fostering 21st-century educational skills, and their combination offers a strategic teaching method to improve learning outcomes in teacher education.

2.1. Project Based Blended Learning

Project-based learning empowers students to cultivate innovative thinking, creativity, critical analysis, and learning abilities. By incorporating suitable technology-driven educational approaches, students can develop problem-solving and creative thinking skills relevant to their future careers [13]. This innovative and methodical teaching strategy enhances student involvement through complex enquiries that demand thorough investigation [14]. It allows students to organize learning activities, collaborate on projects, and generate creative outcomes [15]. Furthermore, it encourages students to research, work together, and find solutions to real-world issues and challenges [16, 17]. The dynamic nature of project-based learning helps students reach Bloom's highest cognitive level (C6) [18]. As noted by Santyasa, et al. [19] this approach involves substantial learning that combines various knowledge and concepts from multiple academic disciplines.

Blended learning is a cutting-edge educational strategy that combines conventional classroom instruction with online learning in a digital setting, taking into account each approach's inherent advantages and disadvantages [20]. This method encompasses a learning process that employs digital tools and direct personal interaction to seek creative and innovative problem-solving techniques [21-24]. Blended learning encourages students to use learning resources in accordance with the characteristics of their learning style. This is because in the blended learning process, the lecturer provides varied learning resources to be used as a source of information in the learning process [25].

The integration of project-based and blended learning can increase student motivation and communication skills. The aim of combining face-to-face learning with online-based learning in an

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effective project-based learning model is to increase student activity; educators and students can communicate and interact directly anytime and anywhere, and students can also search for project materials from various sources without any restrictions [26]. Integrating blended learning into project-based learning corresponds with modern learning scenarios where students utilize technology in their academic pursuits [27]. A study by Nurbekova, et al. [28] found that incorporating blended learning within project-based instruction can significantly impact informatics students' ability to develop project-based digital technology applications, programming skills, collaborative work capabilities, and digital educational content. This study integrates project-based learning with blended learning as an innovative learning strategy for prospective elementary school teachers to develop learning media and digital learning resources.

The following are the phases in the integration of project-based learning with blended learning adopted from [29].

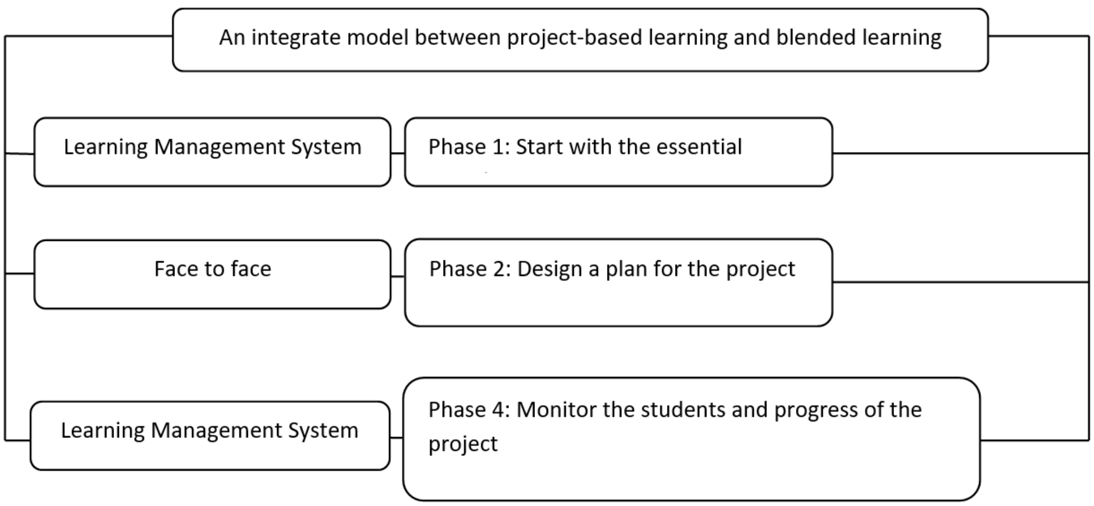

Figure 1.
Learning Phases Combining Project Based Learning and Blended Learning Models.

2.2. Self Efficacy

According to Bandura [30] self-efficacy primarily results from a cognitive process involving comprehension, awareness, or insight into one's ability to perform tasks that require effort to achieve desired outcomes. In digital education, students' self-efficacy instills confidence in their capacity to engage in e-learning as effectively as traditional classroom instruction [31, 32] assert that students with strong self-belief and well-developed self-efficacy typically invest more effort and complete tasks more consistently. Conversely, those lacking confidence in their abilities and possessing low self-efficacy often struggle to complete their tasks satisfactorily.

Self-confidence is essential for an individual to execute tasks effectively. If an individual possesses a skill or potential but lacks the confidence to implement and apply it, that ability becomes ineffective. In the absence of confidence in performing a task, there is inevitably a discrepancy between expectations and outcomes [33]. Self-efficacy significantly influences the outcome of an action or endeavor. Individuals with strong self-efficacy tend to generate diverse solutions to problems. Those with high levels of self-efficacy demonstrate increased motivation to accomplish goals. Conversely, individuals with low self-efficacy may impede progress and adopt a passive stance [34]. High self-efficacy and positive self-regulatory behaviors are significant predictors of academic success in learning [35].

Research conducted by Saienko, et al. [36] suggested that online self-efficacy can be enhanced by integrating technology into learning by focusing on key aspects of the educational process. These aspects include student interaction, instructional design, evaluation methods, learner engagement, classroom management, implementation of various learning strategies, language proficiency, and the development of twenty-first-century skills.

2.3. Computational Thinking Skills

Computational thinking abilities are essential competencies applicable to all individuals, encompassing the analysis of problems, design of systems, and comprehension of human conduct based on fundamental information technology principles. Wing [37] asserted that computational thinking is crucial for everyone, not just computer scientists, and that it should be taught alongside reading, writing, and arithmetic. In the contemporary digital era, individuals must possess computational thinking skills [38]. This cognitive ability enables learners to address problems in a systematic manner using computer programs or technology [39].

Computational thinking comprises four primary components: decomposition, pattern recognition, abstraction, and algorithms [40]. Decomposition involves breaking down complex issues into manageable parts for more efficient resolution. Pattern recognition entails identifying similarities or differences within a problem, potentially enhancing critical and creative thinking efficiency if applied consistently. Abstraction involves viewing the problem holistically or reducing the complexity of non-essential attributes in an entity and substituting attributes with similar functions with a single construct, thereby simplifying the problem-solving process. The algorithmic component focuses on developing alternative and effective steps to address a problem [34]. Despite the undeniable significance of students' computational thinking skills in completing learning projects, a challenge arises, as prospective primary school teachers have not yet mastered these skills for implementation in the primary school curriculum. This is corroborated by evidence suggesting that primary education in Indonesia has not yet incorporated computational thinking skills into its learning approach.

A study by Killen, et al. [41] suggests that integrating computational thinking into learning can assist elementary school educators in developing improved lesson plans for exploring project-based learning. This finding aligns with research by Nouri, et al. [42] which proposes that student-centered computational thinking can enhance understanding and knowledge in the 21st century. To address this challenge, computational thinking and project-based learning models are necessary to overcome learning difficulties across various subjects [43]. From a simulation modeling perspective, computational thinking focuses on five aspects: (CT1) breaking down problems for computational solutions; (CT2) developing computational artifacts through algorithmic thinking; (CT3) producing, arranging, and interpreting data; (CT4) identifying and rectifying errors; and (CT5) implementing iterative enhancements [44].

The variables of Project-Based Blended Learning (PBBL), Self-Efficacy, and Computational Thinking Skills in this study is predicated on their relevance to 21st-century educational requirements, wherein computational thinking is deemed a critical competency for prospective educators. PBBL was selected for its capacity to integrate the advantages of Project-Based Learning (PBL) and Blended Learning (BL) in enhancing computational thinking skills, while self-efficacy was considered due to its role in motivating students in technology-based learning. This study addresses the lacunae in previous research that has not extensively examined the interaction between PBBL and self-efficacy in developing CT. The findings indicated that PBBL significantly improved CT skills, and self-efficacy positively contributed to this achievement, although no significant interaction was observed between these two variables.

The implications of this study underscore the necessity of integrating PBBL into teacher education curricula, implementing pedagogical strategies that support the enhancement of student self-efficacy, and utilizing adaptive digital-based learning to ensure optimal benefits for all the students. Furthermore, future research should investigate other moderating factors, such as digital literacy and cognitive load, and conduct longitudinal studies to elucidate the long-term impact of PBBL on computational thinking development in the context of the teaching profession.

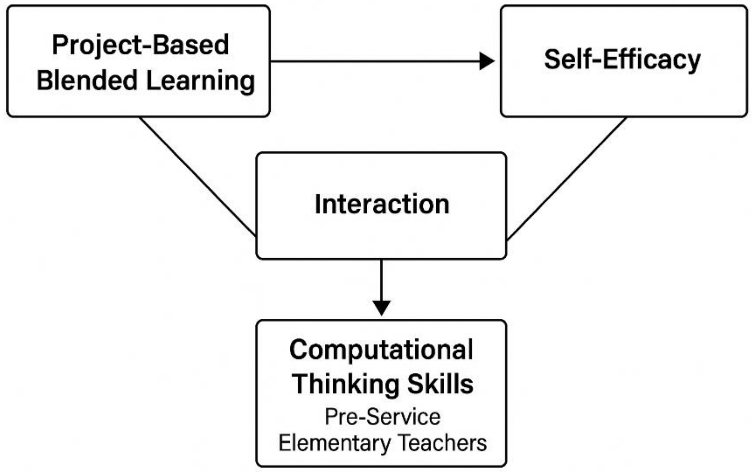

Figure 2.
Research Conceptual Framework

3. Methodology

3.1. Research Design

This investigation employed a quasi-experimental approach utilizing a 2 × 2 factorial design. The study incorporated a pretest-posttest method to assess the impact of project-based learning, which integrates blended learning and self-efficacy, on students' computational thinking skills in for primary teacher education students.

The experimental setup compared the computational thinking abilities of two groups: one that received project-based learning combined with blended learning, and a control group that underwent project-based learning without blended learning integration. Both groups were evaluated for self-efficacy levels.

3.2. Participants and Research Procedures

The participants in this study were fourth-semester primary teacher education students at Universitas PGRI Madiun, Indonesia, enrolled in the Media and Teaching Materials Development course. The sample was divided into an experimental group and a control group. The experimental group consisted of 37 students (18 males and 19 females) who were subjected to project-based learning strategies with blended learning through UNIPMA eLearning (eLMA) and face-to-face to complete a google site learning media development project. Conversely, the control group comprised 37 students (17 males and 20 females) who were exposed to project-based learning strategies without blended learning, relying solely on face-to-face to complete the google site learning media development project assignment.

The research methodology commenced with the allocation of students into experimental and control groups. Both cohorts were administered a pretest to assess their initial computational thinking skills. Additionally, a self-efficacy questionnaire was administered to both groups to determine the level of student self-efficacy, categorizing participants into high or low self-efficacy groups. Over a period of approximately four months, both groups engaged in a google site learning media development project as a culminating course assignment.

Following the completion of all stages of project-based learning with blended learning in the experimental group and project-based learning without blended learning in the control group, both cohorts were administered a posttest to evaluate the level of students' computational thinking skills in relation to their self-efficacy. The pretest and posttest instruments utilized in this study were adapted from validated instruments for assessing computational thinking skills developed by Hooshyar, et al. [45].

Table 1.
Design Experiment 2 × 2.

Group	Instructional Strategy	Self-Efficacy Level	Number of Students
Experimental Group	Project-Based Blended Learning	High	19
	Project-Based Blended Learning	Low	18
Control Group	Project-Based Learning	High	17
	Project-Based Learning	Low	20

4. Result and Discussion

Prior to the analysis, tests were conducted to assess whether the data followed a normal distribution and originated from a uniform group. The normality test aimed to evaluate whether the sample accurately reflected the distribution of the entire population. The following normality test results are presented in the table below:

Table 2.
Test of Normality.

Kolmogorov-Smirnov[a]			
	Statistic	**df**	**Sig.**
Standardized Residual for CT	0.093	74	0.187

Based on the table above, the study's normality test used Kolmogorov-Smirnov, with a value of 0.187>0.05, meaning the sample data is normally distributed. Once it is known that the data is normally distributed, a homogeneity test is then carried out to determine whether the data comes from homogeneous variants or not, which is presented in the table below:

Table 3.
Test of Homogeneity.

		Levene Statistic	df1	df2	Sig.
CT	Based on Mean	3.657	3	70	0.016
	Based on Median	2.803	3	70	0.046
	Based on Median and with adjusted df	2.803	3	64.313	0.047
	Based on trimmed mean	3.616	3	70	0.017

The homogeneity test in this study used Leven's test with a value of 0.016>0.05, which means the variance is homogeneous. Initial tests were performed to verify that the data satisfied the requirements for parametric analysis. The Kolmogorov-Smirnov test produced a significance value of 0.187, which is greater than 0.05, indicating normal distribution of the data. On the other hand, Levene's test for homogeneity showed a significance value of 0.016, less than 0.05, suggesting unequal variances among groups. Despite this, the data is still suitable for factorial ANOVA due to its ability to handle minor violations.

Table 4.
Two-Way ANOVA Summary: Effects on Computational Thinking Skills.

Source	F	Sig. (p)
Learning Strategy (Project-Based Blended Learning vs Project-Based Learning)	9.01	0.002
Self-Efficacy (High vs Low)	16.10	0.000
Interaction (Strategy x Self-Efficacy)	0.63	0.431

The findings suggest that both the teaching approach and self-efficacy had notable main effects on computational thinking (CT) scores. Students who learned through PBBL achieved significantly higher average CT scores compared to those who were instructed using traditional PBL. Likewise, students with high self-efficacy scored better than those with low self-efficacy, irrespective of the teaching method used. Nonetheless, the interaction between these two factors did not reach statistical significance.

Table 5.
Descriptive Statistics.

Project-Based Blended Learning – High Self-Efficacy Mean = 23.76
Project-Based Blended Learning – Low Self-Efficacy Mean = 21.12
Project-Based Learning – High Self Efficacy Mean = 21.60
Project-Based Learning – Low Self Efficacy Mean = 19.84

Two-way ANOVA revealed a notable distinction between the test group, which utilized project-based learning integrated with blended learning, and the comparison group, which employed project-based learning without integration. This analysis demonstrated a statistically significant difference between the two approaches. The results indicate that in the experimental group, students exhibiting high self-efficacy achieved a mean score of 23.76, whereas those with low self-efficacy scored a mean of 21.12.

In contrast, within the control group, students demonstrating high self-efficacy attained a mean score of 20.6, whereas those with low self-efficacy scored a mean of 19.84. A p-value of 0.02, which is less than 0.05, suggests that integrating blended learning with project-based learning enhances students' computational thinking skills more effectively than project-based learning alone. The analysis revealed a p-value of 0.00, below 0.005, indicating a substantial difference in computational thinking skills between students with high and low self-efficacy, regardless of the learning approach employed.

However, when examining the interaction between project-based blended learning and self-efficacy, the p-value of 0.431, exceeding 0.05, implies no significant interaction between these two factors in enhancing the computational thinking skills of primary teacher education students.

The findings of this study demonstrate that the integration of project-based learning with blended learning significantly enhances students' computational thinking skills compared to project-based learning without blended learning. The flexibility of blended learning enables students to access educational content both online and offline, fostering a more comprehensive and continuous learning experience [46]. In the context of learning media development, the superior computational thinking skills exhibited by students engaged in blended learning support the notion that this approach promotes more systematic, analytical, and creative problem-solving [47].

The notable disparity between the experimental and control groups, evidenced by a significance value of $0.02 < 0.05$, suggests that incorporating technology into project-based learning facilitates deeper engagement and enhances higher-order thinking skills [48]. This is particularly relevant in the education of prospective teachers, who are expected to develop competence in creating innovative and effective learning media.

Furthermore, this study revealed that self-efficacy is crucial in shaping students' computational thinking skills regardless of the instructional approach employed [49]. Students with high self-efficacy consistently demonstrated superior computational thinking skills compared to their low-self-efficacy counterparts in both the experimental and control groups [50]. Elevated self-efficacy enables students to be more proactive and self-reliant in creating learning materials that demand computational thinking skills, including planning, problem-solving, and coding [34]. Within the experimental group, students with high self-efficacy attained a mean score of 23.76, substantially higher than the 21.12 average achieved by those with low self-efficacy. Similarly, a notable difference was observed in the control group, where high self-efficacy students scored 21.6 on average, compared to 19.84 for those with low self-efficacy. These findings support the notion that computational thinking skills is influenced by both instructional strategies and internal student factors [51], such as self-confidence in one's abilities [52]. Consequently, fostering students' self-efficacy in teacher preparation programs should be considered a vital component of curriculum development to enhance their proficiency in creating technology-based educational resources [53].This study demonstrates that there is no significant interaction between blended-learning-based project learning and self-efficacy in enhancing students' computational thinking skills, as evidenced by a significance value of 0.431 > 0.05. This finding indicates that although these factors independently influence computational thinking skills, their combined effects do not produce mutually reinforcing results. This outcome contradicts various studies showing synergistic effects of the interaction of innovative learning approaches and self-efficacy in enhancing student capabilities [54]. Several factors may elucidate this result, including the relatively homogeneous characteristics of the sample population in terms of initial competence and technological experience.

Primary teacher education students may already possess a certain level of foundational skills and knowledge in the development of digital learning technology and media [55]. Consequently, blended learning strategies in experimental classes, particularly for students with high levels of self-efficacy, do not have a significant impact [56]. Furthermore, limitations on the intervention duration or intensity of blended learning implementation could have influenced these findings, suggesting that a more extended or intensive approach might be necessary to observe significant interactions.

5. Conclusion

This research explored the impact of Project-Based Blended Learning (PBBL) and self-efficacy on the enhancement of computational thinking (CT) skills in pre-service elementary teachers. The study led to three main conclusions:

1) PBBL notably improves computational thinking skills more effectively than traditional project-based learning, highlighting the educational benefits of combining digital tools with collaborative, real-world projects in teacher training environments.
2) Self-efficacy emerges as a vital predictor of students' computational success, showing that learners' confidence and self-regulation abilities greatly affect their capacity to tackle complex, technology-based tasks.
3) No significant interaction was observed between PBBL and self-efficacy, indicating that their effects on CT development function independently rather than in conjunction.

These findings add to the expanding research supporting blended teaching models as effective approaches for developing 21st-century skills. They also emphasize the need to address learners' motivational and psychological preparedness—especially self-efficacy—when designing effective teaching strategies. From a practical perspective, teacher education programs should consider incorporating structured blended project-based learning into their curricula while also including interventions that boost learner self-confidence and metacognitive awareness. Though the study employed a robust factorial design, several limitations should be noted. The sample was confined to a single institutional setting, and the self-efficacy measurement relied on self-report tools, which may introduce bias. Future studies should investigate longitudinal effects, include varied institutional settings, and explore additional moderating factors such as digital literacy and prior technological experience.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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