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EXPLORING THE MODERATING ROLE OF DIGITAL TECHNOLOGY IN PROJECT-BASED LEARNING FOR TEACHING SKILL ENHANCEMENT

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Abstract
This research examines the moderating role of digital technology in the relationship between Project-Based Learning (PjBL) and teaching skills within microteaching programs for pre-service teachers. Grounded in Experiential Learning Theory (ELT), the study adopts a quantitative survey approach and is analyzed using Partial Least Squares–Structural Equation Modeling (PLS-SEM). The sample consists of 120 pre-service teachers from three universities in Malang, Indonesia, who participated in the implementation of a Teaching Skill Strengthening Model integrating PjBL with digital technology. The findings reveal that PjBL significantly improves teaching skills, while digital technology also contributes directly to teaching competence. More importantly, technology amplifies the positive effect of PjBL, suggesting that the integration of digital tools enhances learning outcomes when aligned with project-based pedagogy. These results demonstrate that combining PjBL with digital support can create richer and more reflective microteaching experiences. Theoretically, this research extends ELT by providing empirical evidence on how digital mediation strengthens the experiential learning cycle in teacher education. Practically, it offers guidance for universities to design technology-supported microteaching models that build teaching competence, reflection, and digital readiness among pre-service teachers. Furthermore, the findings emphasize the importance for educational institutions to synchronize technological transformation with instructional innovation as a strategy to equip future teachers with the competencies required in 21st-century learning environments.
Keywords: Experiential Learning, Teaching Skill, Project-Based Learning, Digital Technology, Microteaching

INTRODUCTION

The quality of teacher education plays a determining role in preparing future educators who are professionally competent. Among various approaches used in teacher training, microteaching remains a fundamental element due to its structured design that allows pre-service teachers to practice teaching skills in a controlled setting. Microteaching was first proposed by [1] as a structured training approach designed to help prospective teachers develop specific teaching competencies through short, focused practice sessions accompanied by feedback. Since its introduction, microteaching has gradually evolved into a fundamental element of teacher preparation programs around the world. It allows student teachers to explore teaching strategies, receive systematic feedback, and develop their instructional abilities in simulated settings before teaching in actual classrooms. Recent reviews continue to highlight its benefits for professional competence, reflective practice, and self-confidence among pre-service teachers [2]. However, in many contexts, microteaching is still implemented in a rather limited way—often centered on basic lesson delivery and evaluation—with little emphasis on innovation or digital integration [3], [4]. To meet the expectations of 21st-century education, scholars have suggested that microteaching should evolve into more authentic, collaborative, and technology-enhanced learning experiences [5].
One promising pedagogical approach that aligns with this vision is Project-Based Learning (PjBL). Rooted in constructivist theory, PjBL encourages learners to engage in meaningful projects that integrate knowledge, skills,

and collaboration. Through the stages of designing, exploring, and presenting project outcomes, learners enhance their analytical thinking, creative capacity, and ability to solve problems [6], [7]. In teacher education, recent studies have shown that PjBL promotes professional readiness and pedagogical insight among pre-service teachers [8], [9]. When applied in microteaching, PjBL provides opportunities for student teachers to experience authentic teaching cycles: they plan lessons, implement instructional strategies, receive feedback, and refine their approaches. This process encourages deeper reflection and fosters teaching skills that extend beyond theoretical knowledge.

Digital technology can further strengthen the benefits of both microteaching and PjBL. Technology tools allow for collaboration, access to diverse resources, and structured opportunities for feedback and reflection. In microteaching, digital platforms such as video-based observation, virtual teaching spaces, and online reflection tools help pre-service teachers review their performance and recognize aspects that need enhancement [10], [11]. Technology not only improves the delivery of instruction but also functions as a mediating element that enhances the impact of learner-centered pedagogical approaches [12]. In the context of teacher preparation, developing digital competence alongside pedagogical expertise is essential for creating adaptive and reflective educators who can navigate complex classroom realities.

The theoretical foundation connecting PjBL, technology, and microteaching is grounded in [13] Experiential Learning Theory (ELT), which posits that learning progresses through four continuous stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation. Within microteaching, PjBL projects provide concrete experiences; reflection and discussion represent observation and conceptualization; and repeated teaching sessions enable active experimentation. Digital tools enhance each phase by offering ways to capture experience, support reflection, and provide data-driven feedback. This alignment shows how technology can enrich experiential learning by creating a more iterative and evidence-based learning cycle for teacher development.

Despite these theoretical advancements, several gaps remain in current research. Many studies focus on developing pedagogical models or validating them conceptually, but relatively few examine their implementation through empirical testing. Additionally, although PjBL and digital technology have been widely studied separately, their combined impact within microteaching—especially with technology as a moderating factor—has not been adequately explored. Previous research has also tended to rely on descriptive or qualitative methods, which limits generalization and inferential strength.

To bridge the identified research gaps, this study explores the application and effectiveness of a Teaching Skill Strengthening Model that integrates PjBL with digital technology as a moderating construct. It specifically analyzes: (1) the impact of PjBL on teaching skill, (2) the influence of digital technology as an independent factor on teaching skill, and (3) how digital technology moderates the association between PjBL and teaching skill. A Partial Least Squares–Structural Equation Modeling (PLS-SEM) approach is applied in the analysis to ensure robust empirical testing of the hypothesized relationships.

This research adds value to scholarly discussions in the field of teacher education through the integration of experiential, project-based, and digital approaches within a single empirical framework. Theoretically, it extends Experiential Learning Theory (ELT) by demonstrating how digital mediation reinforces experiential processes in teacher learning. Practically, it offers a framework for integrating PjBL and technology into microteaching to strengthen professional competence and reflective practice. This unique integration provides new empirical evidence for how digital technology mediates experiential learning mechanisms within teacher education contexts.

Beyond its pedagogical focus, the study also has implications for educational management and policy. Integrating PjBL and digital technology into microteaching can serve as a strategic model for improving institutional training systems. By embedding technology-supported experiential learning, universities can foster innovation, reflection, and digital readiness among pre-service teachers—competencies that are essential for modern educational management. Consequently, the findings from this research can provide valuable insights for educational policymakers and institutional decision-makers in formulating evidence-based initiatives aimed at improving instructional effectiveness and strengthening teacher readiness within higher education settings.

LITERATURE REVIEW

Experiential Learning Theory

Experiential Learning Theory (ELT), formulated by [13], conceptualizes learning as a continual process consisting of four interconnected phases: experiencing phenomena directly, reflecting on those experiences, forming abstract concepts, and applying them through experimentation. This framework posits that effective learning occurs when individuals actively participate in real situations, critically evaluate their experiences, transform them into conceptual understanding, and apply the insights gained in new contexts. In contrast to traditional transmission-based learning views, ELT emphasizes that knowledge is progressively built through active engagement and reflection.

In the context of teacher education, ELT provides a strong theoretical foundation for practice-based learning because it explains how pedagogical competence can be cultivated systematically through repeated cycles of teaching, reflection, and feedback. Recent studies have re-examined ELT's relevance in higher education. [14] argued that while ELT remains robust, learning does not occur automatically unless reflection is deliberately

scaffolded and opportunities for re-practice are intentionally designed. Similarly, [15] found that courses structured around authentic experience, reflection, and simulation aligned with the ELT cycle significantly improved professional readiness. These findings affirm that ELT continues to serve as a relevant model for designing teacher education curricula that bridge theory and practice.

When applied to microteaching, ELT supports structured environments in which pre-service teachers can experience teaching practice, engage in guided reflection, and refine their approaches through repetition. Mechouat (2024) demonstrated that integrating Kolb's model into teacher training improved instructional attitudes and classroom performance. [17], [18] found that digital portfolios and technology-mediated reflection enhanced iterative improvement consistent with the ELT stages. Digital technology, therefore, acts as a facilitator of ELT by making reflection more evidence-based and accessible. Tools such as video feedback and online platforms enable pre-service teachers to revisit their performances and enact improvements across teaching cycles [10], [19]. Taken together, these studies establish ELT as a strong theoretical basis to support the integration of Project-Based Learning (PjBL) and digital technology in microteaching, where authentic projects and digital reflection tools jointly reinforce experiential learning and teaching competence.

Project-Based Learning (PjBL)

Project-Based Learning (PjBL) represents an instructional model that positions learners as active participants in the learning process and is grounded in the principles of constructivism. This approach involves engaging learners in exploration-based project activities that simulate authentic situations, thereby promoting analytical thinking, teamwork, creativity, and the ability to solve problems [6], [7]. PjBL allows learners to construct knowledge actively through the planning, investigation, and presentation of projects, providing authentic contexts that promote the transfer of skills to professional practice. Compared with conventional instruction, PjBL assigns learners more agency and responsibility for their learning—features that align closely with contemporary educational reforms emphasizing learner autonomy and innovation.

Within teacher education, PjBL has been shown to effectively equip prospective teachers to meet the multifaceted challenges of modern educational environments. Systematic reviews highlight that PjBL enhances higher-order thinking, communication, creativity, and reflective habits essential for professional growth [6], [9]. Its flexibility also allows integration into microteaching settings, where pre-service teachers can design instructional projects, deliver lessons in simulated environments, and refine their practices through feedback and re-teaching.

Empirical findings support the effectiveness of PjBL-based microteaching. [20] reported that microteaching modules grounded in PjBL significantly improved the instructional competence of teacher candidates, reflection, and creativity in lesson design. Similar evidence from international contexts confirms that PjBL strengthens professional readiness and deepens pedagogical understanding [21], [22]. Successful PjBL implementation, nevertheless, depends on aligning project-based learning activities with targeted learning outcomes and embedding formative assessment throughout the project cycle. Formative feedback ensures continuous improvement rather than relying solely on final evaluation [23], [24].

Overall, PjBL not only supports the development of pedagogical competence but also reflects the principles of experiential learning. When integrated with digital technologies, PjBL enhances authenticity, collaboration, and reflection—three dimensions that together strengthen pre-service teachers' teaching skills and professional competence.

Digital Technology and Teacher Education

The adoption of digital tools has significantly influenced the landscape of teacher preparation programs by transforming how future educators build, assess, and refine their instructional capabilities. Rather than functioning solely as instructional tools, digital platforms now serve as interactive learning environments that facilitate collaboration, feedback, and iterative practice—core processes of both microteaching and experiential learning. When strategically embedded, technology amplifies the experiential and project-based dimensions of teacher education, enabling data-driven reflection and authentic engagement.

Research consistently demonstrates that digital tools enhance reflective practice in microteaching. [10] found that technology-supported microteaching improves continuous feedback, promotes deeper self-assessment, and enables multiple teaching iterations. Similarly, [17] showed that digital portfolios allow prospective teachers to record their developmental progress and participate in systematic reflection aligned with learning goals. These tools strengthen reflective and evaluative dimensions of teaching, making learning cycles more visible and evidence-based. Furthermore, well-designed digital interfaces enhance usability and cognitive engagement by reducing cognitive load, which in turn increases learning effectiveness [25].

At the institutional level, digital capacity and teacher digital competence significantly influence how effectively pedagogical innovations are implemented. [26] found that universities with developed digital ecosystems foster richer pedagogical interactions and smoother technology integration. Similarly, [27] showed that digital readiness and ongoing professional development moderate the relationship between pedagogical design and technology adoption. Together, these studies indicate that digital preparedness magnifies the effects of experiential and project-based approaches by enhancing feedback, reflection, and instructional adaptability.

However, the presence of technology alone does not guarantee effective learning. Its impact depends on pedagogical alignment and teacher readiness. Without adequate digital literacy and reflective scaffolding, technology integration may remain superficial [28]. Effective implementation thus requires designing digital experiences that complement, rather than replace, authentic teaching and reflection. In this study, digital

technology is positioned as an interaction variable that enhances the linkage between PjBL and teaching competence. By supporting continuous feedback loops, enabling data-informed reflection, and extending experiential learning cycles, technology operationalizes the mechanisms predicted by both PjBL and ELT.

Furthermore, recent studies emphasize that the integration of digital technology can enhance the implementation of Project-Based Learning, particularly in microteaching environments where collaborative planning, feedback, and iterative instructional improvement are required. Digital platforms such as learning management systems and online assessment tools provide structured learning support that aligns with the reflective and experiential nature of PjBL. When used effectively, digital tools do not merely serve as instructional aids but act as pedagogical enhancers that strengthen teaching competence development in pre-service teacher education.

Teaching Skill

Teaching skill is a central dimension of teacher professionalism, encompassing the ability to design, implement, and evaluate learning processes effectively. It involves not only instructional delivery but also pedagogical reasoning, classroom orchestration, and reflective decision-making. [29] proposed a comprehensive framework identifying eight interrelated dimensions of teaching competence: pedagogical knowledge, content mastery, facilitation of learning, classroom management, assessment and feedback, professional development, student support, and instructional quality. This framework remains foundational for assessing teacher capability, particularly in pre-service contexts.

Contemporary studies have refined this construct by linking teaching skill to measurable aspects of instructional effectiveness and student achievement. [30] conceptualized teaching competence as a dynamic system where cognitive, motivational, and situational factors interact to produce effective instruction. Their findings underscore that skilled teaching requires interpretive expertise—the ability to diagnose learners' needs and adapt instruction responsively. Such competencies emerge from reflective and experiential practice.

An often underemphasized yet vital element of teaching skill is student support. Research indicates that teachers' perceived support significantly predicts students' motivation, engagement, and persistence [31]. Studies on instructional quality in mathematics and science classrooms also highlight teacher support as an essential contributor to sustaining a positive learning environment and promoting successful instructional outcomes [32], [33].

The ongoing transformation within the education sector has broadened the definition of teaching skills to encompass digital adaptability. [34] emphasized that effective teaching now requires flexibility across traditional and digital learning environments. Likewise, [35] found that successful online teaching depends on clear instructional design, interactivity, and feedback—all aligning with Tigelaar's core dimensions. [36] added that synchronous online teaching demands digital communication, classroom management, and collaborative facilitation, reinforcing the integration of pedagogical and technological competence.

In line with these developments, this study adopts the multidimensional framework of [29], refined by contemporary evidence from [30], [34], [35], [36], and recent studies highlighting student support and responsiveness [31], [32], [33]. Collectively, these works justify operationalizing teaching skill as an integrated construct that bridges theory and practice across cognitive, affective, and technological domains essential for 21st-century teacher education.

HYPOTHESIS DEVELOPMENT

Grounded in [13] Experiential Learning Theory (ELT), which highlights learning as a recurring cycle involving experience, reflection, and conceptual development, this study positions Project-Based Learning (PjBL) as a pedagogical framework that applies these principles within microteaching environments. Through PjBL, pre-service teachers engage in authentic teaching design, implementation, and evaluation, allowing them to internalize pedagogical concepts through direct experience and reflection. Empirical studies have consistently demonstrated that PjBL enhances problem-solving ability, creativity, and pedagogical reflection—dimensions that directly contribute to teaching skill development [6], [20].

Further evidence reinforces these outcomes. [37] found that PjBL strengthens pre-service teachers' self-efficacy and instructional confidence through authentic engagement in project tasks. Similarly, [38] emphasized that PjBL fosters learning motivation and bridges pedagogical theory with classroom practice, enhancing reflective teaching behavior. [39] further concluded that PjBL encourages the adoption of collaborative, problem-based, and authentic assessment strategies, which are essential dimensions of instructional quality. [40] reported that technology-enhanced PjBL enables pre-service teachers to improve instructional clarity, creativity, and classroom evaluation skills. [41] also confirmed that pedagogical competence is a central determinant of student motivation, while [42] highlighted the importance of instructional design alignment for achieving optimal learning outcomes.

When applied in microteaching, PjBL facilitates iterative cycles of lesson design, practice, and feedback consistent with the experiential learning process. Collectively, these studies affirm that PjBL promotes reflective, student-centered, and evidence-based instructional practices that strengthen pre-service teachers' teaching skills. Accordingly, the following hypothesis is proposed:

1. H1: Project-Based Learning has a positive and significant effect on teaching skill.

Digital technology has a significant influence on enhancing the effectiveness of experiential and project-based approaches to learning. When integrated purposefully, digital tools foster interaction, collaboration, and self-reflection among pre-service teachers. Evidence from recent research demonstrates that technology-supported microteaching facilitates continuous feedback and structured reflection, thereby enhancing pedagogical growth

and teaching performance [10], [28]. In addition, digital portfolios, recorded teaching sessions, and collaborative platforms enable prospective teachers to systematically evaluate their instructional practices and identify strategies for improvement [36].

Recent literature also underscores that technology integration must go beyond mere digital adoption to achieve meaningful learning. [43] emphasized that integrated, technology-supported learning environments help students connect concepts across contexts, develop critical thinking, and strengthen conceptual understanding through authentic experiences. Similarly, [44] highlighted that educators' proficiency in using digital technologies is a key determinant of instructional quality, while [27] found that technology-based professional development enhances teachers' confidence and capability to apply digital platforms and tools effectively.

Pedagogical readiness and digital literacy have also been identified as critical mediators of instructional effectiveness. [45] argued that teachers' preparedness for digital innovation determines the extent to which technology can improve instructional quality. Likewise, [46], [47] emphasized that digital and interactive media significantly increase learner engagement and foster sustained participation in learning activities. Empirical evidence from [48] and [49] further demonstrates that multimodal, technology-mediated feedback substantially enhances teaching competence in pre-service teacher training. Aligning with these findings, [50] confirmed that effective feedback—especially when supported by digital tools—plays a vital role in improving learning outcomes and strengthening instructional quality.

Taken together, these studies affirm that purposeful and pedagogically aligned technology use not only supports reflection and feedback but also empowers teachers to design, deliver, and evaluate instruction more effectively. Accordingly, the following hypothesis is formulated:

2. H2: Digital technology has a positive and significant effect on teaching skill.

Beyond its direct influence, digital technology may also serve as a moderating variable that amplifies the pedagogical benefits of PjBL. By facilitating dynamic project management, authentic assessment, and data-informed reflection, digital tools enhance the alignment between PjBL design and learning outcomes. Empirical evidence indicates that teachers' readiness to use digital platforms and involvement in collaborative professional networks strengthen the connection between innovative pedagogical models and teaching competence [27]. Accordingly, digital technology integration is expected to intensify the impact of PjBL on teaching skill by improving feedback quality, engagement, and reflective learning.

3. H3: Digital technology moderates the relationship between Project-Based Learning and teaching skill, such that the effect of PjBL on teaching skill is stronger when the level of digital technology integration is high.

Drawing from the previously outlined theoretical foundation, integrated review of prior studies, and supporting empirical findings, the conceptual model developed for this study is illustrated in Figure 1, which shows the proposed linkages between the research variables.

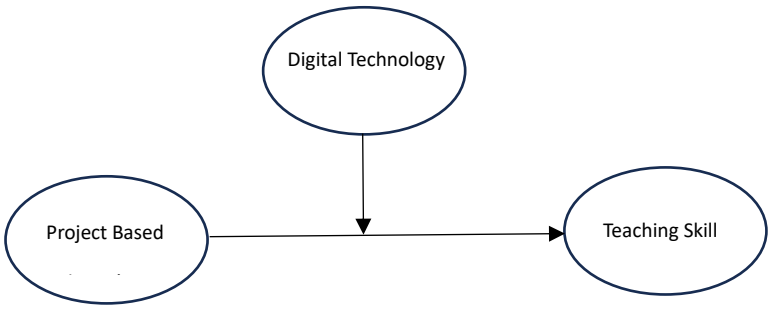

Figure 1. Conceptual model of the research

METHOD

Research Design

This research utilized a quantitative survey approach and was examined using Partial Least Squares–Structural Equation Modeling (PLS-SEM) to analyze the interactions between Project-Based Learning (PjBL), digital technology, and teaching skills in microteaching settings for pre-service teachers. Although the data originated from the implementation of an established instructional model, the objective of this study was not model development, but rather to evaluate its empirical effectiveness. Therefore, an implementation-oriented evaluation design was adopted, prioritizing the empirical testing of theoretical linkages among the key constructs. This methodological choice aligns with the study's aims, the nature of the dataset, and the analytical framework employed.

Participants

The participants comprised 120 pre-service teachers enrolled in microteaching courses across three universities in Indonesia (Wisnuwardhana University, PGRI Kanjuruhan University of Malang, Islam University of Malang). A purposive sampling strategy was applied to guarantee that all participants had experience with Project-Based Learning (PjBL)-based microteaching activities supported by digital tools. Of the total participants, 82 were

female (68.3%) and 38 were male (31.7%), with a mean age of 22.1 years. The number of participants satisfied the recommended minimum sample size for analysis using Partial Least Squares–Structural Equation Modeling (PLS-SEM), which suggests a ratio of at least ten respondents per structural path connected to a latent variable [51]. This ensured sufficient statistical power and reliable parameter estimation for hypothesis testing.

Instruments

Data were obtained through a standardized survey instrument constructed based on established conceptual models and prior empirical evidence. The instrument included three latent variables: Project-Based Learning (PjBL), Digital Technology, and Teaching Skill. Each variable was represented through a set of indicators adapted from reputable sources—PjBL from [6], [23], [24]; Digital Technology from [25] and [28]; and Teaching Skill from [29], [30], [35].

Each indicator was assessed using two statements, resulting in a total of 38 items (12 for PjBL, 10 for Digital Technology, and 16 for Teaching Skill). All statements employed a five-point Likert response format from 1 = Strongly Disagree to 5 = Strongly Agree. Content validity was ensured through evaluation by two experts in teacher education to verify theoretical relevance and conceptual precision. A pilot test involving 30 pre-service teachers demonstrated high reliability levels, with Cronbach's alpha values above 0.80 for all constructs. The operational definitions of the variables and their associated indicators are summarized in Table 1.

Table 1. Operational definition of study variables

Variable	Indicator	Item	Source
Project Based Learning	Student Autonomy	Independent task planning; Decision-making in project completion	[6], [23], [24]
	Constructivist Orientation	Active knowledge construction; Inquiry and discovery emphasized	
	Alignment with Learning Outcomes	Project aligned with intended competencies; Tasks linked to learning objectives	
	Collaborative Learning	Peer collaboration during project; Group discussion for improvement	
	Contextual and Experiential Learning	Projects reflect real teaching contexts; Learning through authentic experience	
	Formative Assessment Integration	Continuous feedback during project; Ongoing assessment for improvement	
Digital Technology	Accessibility	Easy access to digital tools; Usability without technical barriers	[25], [28]
	Interactivity	Interactive communication via platforms; Online collaboration opportunities	
	Visual and Technical Design	Clear and engaging interface; Smooth and stable performance	
	Instructional Relevance	Technology supports course objectives; Tools enhance learning effectiveness	
	Integration in Teaching	Technology embedded in microteaching; Use of tools for evaluation	
Teaching Skill	Pedagogical Competence	Lesson design based on pedagogy; Adaptation to student needs	[29], [30], [35]
	Content Knowledge	Mastery of subject matter; Clear explanation of key concepts	
	Facilitation of Learning	Promotion of active participation; Use of engaging learning activities	
	Classroom Management	Control of class attention; Handling of disruptions effectively	
	Instructional Quality	Achievement of learning objectives; Overall teaching effectiveness	
	Professional Development	Reflection for improvement; Seeking feedback for growth	
	Student Support	Academic and emotional guidance; Responsiveness to student needs	

	Assessment and Feedback	Appropriate assessment methods; Constructive student feedback	

Data Collection Procedure

Data collection was conducted toward the conclusion of the microteaching semester through an online survey administered using Google Forms. Before taking part in the study, participants received information regarding the research objectives, confidentiality of responses, and their right to withdraw at any time. Digital consent was secured prior to accessing the instrument. The survey required approximately 15 minutes to complete. Participants were guaranteed anonymity, and no personal identifying details were recorded. Ethical clearance for this procedure was granted by the university's research ethics board, confirming adherence to recognized ethical principles in educational research.

Digital Technology Implementation

Digital tools were integrated systematically throughout the microteaching project cycle to support collaborative planning, teaching simulation, assessment, and reflection. Google Classroom and Moodle were used as learning management platforms for distributing project instructions, teaching materials, and submission of lesson plans. Google Forms and Quizizz facilitated formative assessment during peer teaching sessions, allowing both instructors and peers to provide structured feedback. In addition, each microteaching performance was recorded using video to enable self-reflection and iterative teaching improvement, which aligns with the experiential learning cycle. Through this integration, digital technology functioned not only as an instructional medium but also as a pedagogical enhancer that supported the execution of Project-Based Learning in microteaching.

Data Analysis

Data analysis was performed to evaluate the proposed hypotheses (H1–H3) and to examine whether digital technology moderates the association between Project-Based Learning (PjBL) and teaching skill. The analysis was carried out using Partial Least Squares–Structural Equation Modeling (PLS-SEM) in SmartPLS version 4.0, following the two-stage analytical procedure suggested by [51].

(1) Measurement Model Assessment

The reliability and validity of the constructs were verified before proceeding with hypothesis testing. Internal consistency was examined using Cronbach's alpha and Composite Reliability (CR), with both metrics required to be above 0.70. Convergent validity was established when the Average Variance Extracted (AVE) exceeded 0.50 for each construct. Discriminant validity was evaluated using the Fornell–Larcker criterion and the Heterotrait–Monotrait (HTMT) ratio, where HTMT values below 0.85 confirmed satisfactory construct distinctiveness.

(2) Structural Model Assessment

Once the measurement model was validated, the structural paths were analyzed using bootstrapping with 5,000 subsamples to estimate path coefficients (β), t-statistics, and p-values. Model explanatory strength was assessed through R^2 values for endogenous constructs and f^2 to estimate effect sizes. Predictive relevance (Q^2) was assessed using the Stone–Geisser criterion via blindfolding procedures. Model appropriateness was confirmed using Standardized Root Mean Square Residual (SRMR $\leq$ 0.08) and Normed Fit Index (NFI $\geq$ 0.90), indicating acceptable model fit.

This analytical procedure enabled rigorous estimation of both the direct and moderating effects in alignment with the study's conceptual framework.

RESULT AND DISCUSSION

RESULT

Respondent Charactristics

The demographic description of participants provides an overview of the profile of prospective teachers involved in microteaching courses, as summarized in Table 2.

Table 2. Demographic profile of respondents

Category	Number of Respondents	%
Gender		
Man	38	31.7
Woman	82	68.3
Age		
< 20 years	10	8.3
21-22 years	84	70.0
> 23 years	26	21.7
University Affiliation		

Wisnuwardhana University, Indonesia	38	31.7
University of Islam Malang, Indonesia	40	33.3
University of PGRI Kanjuruhan Malang, Indonesia	42	35.0
Use of Digital Technology in Learning		
High	46	38.3
Moderate	56	46.7
Low	18	15.0

Drawing from the demographic results, most participants in this study were women (68.3%), a pattern frequently reported in teacher education programs globally where female enrollment tends to be higher than male participation. This gender composition is consistent with the observations of [52], who explained that teaching is often perceived as a profession that aligns with nurturing attributes traditionally associated with women, leading to their stronger representation in the field.

With respect to age, the majority of participants (70%) were in the 21–22 year age range, which corresponds to the typical stage of final-year undergraduate students in teacher education. This stage is considered both cognitively and professionally significant, as pre-service teachers begin to connect theoretical understanding with practical classroom application. According to [53], this period is essential for forming professional judgment, as teacher candidates start engaging in reflective practice and instructional decision-making through experiential learning activities such as microteaching.

Regarding institutional affiliation, respondents were drawn from three Universities in Indonesia—Wisnuwardhana University, PGRI Kanjuruhan University of Malang, and Islam University of Malang—with relatively balanced proportions, ensuring diverse institutional representation within the dataset.

Finally, regarding the application of digital tools in the learning process, most respondents indicated a medium degree of technology use (46.7%), followed by high (38.3%) and low (15%) levels. This suggests that although students generally have access to and are familiar with digital learning platforms, their ability to integrate technology into pedagogical practice is still developing. This result aligns with insights reported by [54], who noted that future teachers often demonstrate sufficient technological literacy yet still struggle to translate technical skills into meaningful instructional strategies.

Overall, these demographic characteristics indicate that the participants involved in this research reflect the current profile of pre-service teachers in Indonesia—young, predominantly female, and moderately proficient in digital technology—thereby providing a valid basis for analyzing the relationships among Project-Based Learning, digital technology, and teaching skill within microteaching settings.

Instrument Testing

This procedure aimed to verify whether the measurement tool (questionnaire) applied in this research demonstrated acceptable validity and reliability in capturing the studied constructs. The instrument was piloted with 30 prospective teachers who were excluded from the primary sample. Item validity was examined using Pearson's product–moment correlation, while internal consistency reliability was measured using Cronbach's Alpha values. A summary of the instrument validation results is provided in Table 3.

Table 3. Results of instrument validity and reliability analysis

Variable	**Item**	**Correlation**		**Cronbach's Alph**	
		r	**Status**	**Alpha**	**Status**
Project Based Learning	X1.1.1	0.858	Valid	0.923	Reliable
	X1.1.2	0.755	Valid		
	X1.2.1	0.764	Valid		
	X1.2.2	0.803	Valid		
	X1.3.1	0.858	Valid		
	X1.3.2	0.755	Valid		
	X1.4.1	0.764	Valid		
	X1.4.2	0.803	Valid		
	X1.5.1	0.403	Valid		
	X1.5.2	0.795	Valid		
	X1.6.1	0.636	Valid		
	X1.6.2	0.679	Valid		
Digital Technology	X2.1.1	0.863	Valid	0.882	Reliable
	X2.1.2	0.711	Valid		
	X2.2.1	0.712	Valid		

	X2.2.2	0.729	Valid		
	X2.3.1	0.512	Valid		
	X2.3.2	0.790	Valid		
	X2.4.1	0.640	Valid		
	X2.4.2	0.697	Valid		
	X2.5.1	0.523	Valid		
	X2.5.2	0.862	Valid		
Teaching Skill	Y.1.1	0.836	Valid	0.956	Reliable
	Y.1.2	0.731	Valid		
	Y.2.1	0.627	Valid		
	Y.2.2	0.752	Valid		
	Y.3.1	0.694	Valid		
	Y.3.2	0.662	Valid		
	Y.4.1	0.857	Valid		
	Y.4.2	0.720	Valid		
	Y.5.1	0.713	Valid		
	Y.5.2	0.863	Valid		
	Y.6.1	0.831	Valid		
	Y.6.2	0.840	Valid		
	Y.7.1	0.655	Valid		
	Y.7.2	0.899	Valid		
	Y.8.1	0.808	Valid		
	Y.8.2	0.811	Valid		

Based on Table 3, all indicators of the study variables satisfied the required validity and reliability thresholds, as demonstrated by item–total correlation coefficients (r) exceeding 0.30 and Cronbach's Alpha coefficients greater than 0.60.

Causal Relationship Analysis between Project-Based Learning, Digital Technology, and Teaching Skills

Causal Relationship Analysis between Project-Based Learning, Digital Technology, and Teaching Skills Data analysis was conducted through Partial Least Squares–Structural Equation Modeling (PLS-SEM) implemented in SmartPLS. This method was chosen due to its appropriateness for analyzing multifaceted models and its effectiveness when working with moderate sample sizes. Assessment of the measurement model included verification of convergent validity (examining outer loadings and Average Variance Extracted/AVE) and construct reliability (evaluated using Cronbach's Alpha and Composite Reliability/CR). The structural model was subsequently examined to determine causal relationships among the latent variables using path coefficients and significance values (p-values).

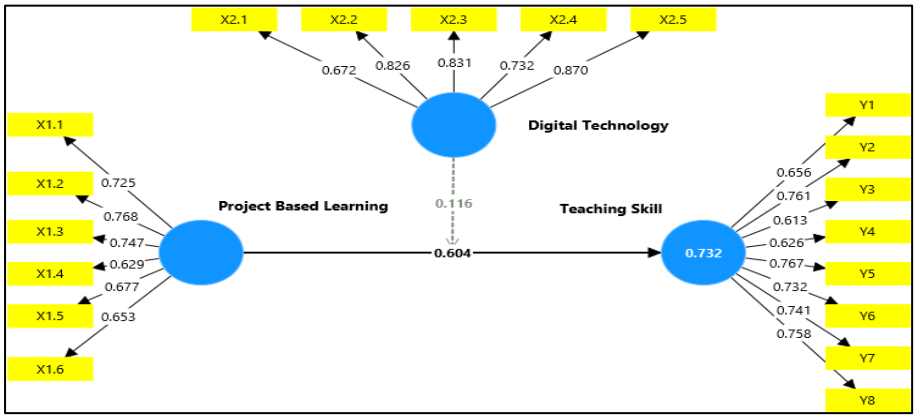

Figure 2. Research model (measurement and structural model)

Table 4. Measurement model

Dimenssion	**Project Based Learning**	**Digital Technology**	**Teaching Skill**
Student Autonomy	0.725		
Constructivist Orientation	0.768		

Alignment with Learning Outcomes	0.747		
Collaborative Learning	0.629		
Contextual and Experiential Learning	0.677		
Formative Assessment Integration	0.653		
Accessibility		0.672	
Interactivity		0.826	
Visual and Technical Design		0.831	
Instructional Relevance		0.732	
Integration in Teaching		0.870	
Pedagogical Competence			0.656
Content Knowledge			0.761
Facilitation of Learning			0.613
Classroom Management			0.626
Instructional Quality			0.767
Professional Development			0.732
Student Support			0.741
Assessment and Feedback			0.758

Based on Table 4, all indicators of the three latent variables met the criteria for convergent validity, as all factor loading values exceeded 0.60 [51]. For the Project-Based Learning (PjBL) construct, indicators including Constructivist Orientation, Student Autonomy, Alignment with Learning Outcomes, Collaborative Learning, Contextual and Experiential Learning, and Formative Assessment Integration were found to be valid. Among these, Constructivist Orientation recorded the highest loading value (0.768), indicating its dominant contribution to shaping the PjBL construct. This finding suggests that pre-service teachers tend to emphasize active knowledge construction, inquiry, and discovery as the core principles when implementing project-based learning during microteaching sessions.

For the Digital Technology construct, all indicators—Accessibility, Interactivity, Visual and Technical Design, Instructional Relevance, and Integration in Teaching—also met the convergent validity threshold. The highest factor loading was obtained for Integration in Teaching (0.870), implying that the integration of digital tools into lesson design and evaluation plays a critical role in how pre-service teachers implement technology in microteaching. This finding underscores that technology effectiveness lies primarily in its seamless integration into pedagogical practices rather than its standalone use.

Regarding the Teaching Skill construct, eight indicators were found to be valid: Pedagogical Competence, Content Knowledge, Facilitation of Learning, Classroom Management, Assessment and Feedback, Professional Development, Student Support, and Instructional Quality. Among these, Instructional Quality yielded the highest loading value (0.767), indicating that it is the most influential dimension in defining teaching competence. This suggests that pre-service teachers' teaching skill development primarily manifests in their ability to achieve learning objectives effectively and manage classroom interactions productively.

In summary, all measurement indicators across the three constructs demonstrated adequate convergent validity (loading > 0.60), confirming that each latent variable was well represented by its corresponding dimensions. These findings confirm that the model meets the necessary criteria to proceed with further examination of the causal relationships among Project-Based Learning, Digital Technology, and Teaching Skill.

Table 5. Outer loading results for project-based learning, digital technology, and teaching skills variables

	Composite reliability (rho_a)	**Average variance extracted (AVE)**
Digital Technology	0.851	0.624
Project Based Learning	0.792	0.502
Teaching Skill	0.864	0.503

Table 5 shows that all constructs have composite reliability values above 0.7. Therefore, no unidimensionality issues were found, and all constructs also have Average Variance Extracted (AVE) scores exceeding 0.50. These results confirm that the requirement for convergent validity has been satisfied.

Table 6. Results of validity and reliability of latent variables

	R-square
Teaching Skill	0.732

The structural model analysis (Inner Model) was performed by reviewing the R^2 coefficients of the latent variables and Geisser's Q^2 predictive relevance, then continuing with an examination of the strength of the structural path coefficients. The robustness of the path estimations was verified using t-statistics generated from the bootstrapping technique. The evaluation of the inner model is reflected in the R-Square values obtained from the relationships among the latent variables.

$$Q^2 = 1 - (1 - R_1^2)$$

The computation of Q-square utilizing the R-square data from the three models mentioned above can be performed in the following manner:

$Q2 = 1 - (1-0.732^2)$

$Q2 = 1 - (0.464)$

$Q2 = 0.536$

From the Q-square (Q^2) estimation, a score of 56.3% was obtained, indicating that the proposed model possesses strong predictive relevance and demonstrates substantial accuracy in explaining the variance of the endogenous variables.

Table 7. Path coefficient results and significance of relationships among variables

	Koefisien	**T statistics**	**P values**
Project Based Learning -> Teaching Skill	0.604	8.120	0.000
Digital Technology -> Teaching Skill	0.296	4.093	0.000
Digital Technology x Project Based Learning -> Teaching Skill	0.116	2.143	0.032

The results of the structural model show that Project-Based Learning (PjBL) exerts a significant positive influence on Teaching Skill ($\beta = 0.604$, $t = 8.120$, $p = 0.000$). Likewise, Digital Technology also has a significant positive impact on Teaching Skill ($\beta = 0.296$, $t = 4.093$, $p = 0.000$). An important finding is the interaction effect between Digital Technology and Project-Based Learning, which significantly strengthens Teaching Skill ($\beta = 0.116$, $t = 2.143$, $p = 0.032$). This suggests that the inclusion of Digital Technology enhances the effectiveness of PjBL and supports the improvement of Teaching Skill.

DISCUSSION

The Influence of Project-Based Learning (PjBL) on Teaching Skills

The findings of this study show that Project-Based Learning (PjBL) exerts a significant positive influence on the teaching skills of pre-service teachers. The implementation of PjBL emphasizes a constructivist orientation, which manifests through active knowledge construction—encouraging student teachers to connect new information with their prior experiences and conceptual understanding. Within microteaching settings, this process enables pre-service teachers to engage in authentic learning experiences where lecturers act as facilitators who provide contextualized problems, guide inquiry, and promote collaborative meaning-making. Moreover, the emphasis on inquiry and discovery is reflected through activities such as project investigations, field-based experiments, real-world problem solving, and case studies. These practices allow pre-service teachers to identify patterns, principles, and new concepts through direct experience, making learning more meaningful, contextual, and personally relevant. Consequently, this experiential engagement enhances teaching skills, particularly in achieving learning objectives, designing effective instructional plans, and fostering reflective and student-centered teaching practices. This finding is aligned with prior research that emphasizes the pedagogical strength of PjBL in teacher education. [6], [20] found that PjBL improves problem-solving ability, creativity, and pedagogical reflection—dimensions that directly contribute to the development of teaching competence. Similarly, [37] demonstrated that PjBL strengthens pre-service teachers' teaching self-efficacy through authentic engagement in project-based tasks. [38] noted that PjBL fosters motivation and reduces the disconnect between pedagogical theory and field practice, leading to more holistic professional learning. [39] further revealed that PjBL encourages teachers to adopt collaborative, problem-solving, and authentic assessment strategies—key components of instructional quality. In addition, [40] concluded that technology-supported PjBL helps student teachers enhance clarity in instruction, creativity in lesson delivery, and effectiveness in classroom evaluation. [41], [42] confirmed that teachers' pedagogical competence plays a central role in stimulating students' learning motivation, while [42] highlighted the significance of coherent instructional design for optimizing learning outcomes.

Overall, these findings collectively reinforce that PjBL serves as a transformative pedagogical framework that integrates theory and practice through authentic and reflective learning experiences. When applied within microteaching, PjBL enhances the instructional performance of teacher candidates as well as their level of

professional preparedness, while simultaneously supporting the development of essential competencies for effective teaching in 21st-century classrooms.

The Influence of Digital Technology on Teaching Skills

The analysis results confirm that digital technology significantly influences teaching skills among pre-service teachers. This relationship can be explained by the high degree of technology integration in teaching, particularly reflected in the indicator Integration in Teaching—implemented through technology embedded in microteaching and the use of digital tools for evaluation and reflection. During microteaching, pre-service teachers utilized various digital platforms and applications to support lesson delivery, observation, assessment, and self-reflection. The integration of digital tools in lesson planning, implementation, and evaluation enhanced their instructional competence, helping them achieve the learning objectives formulated in the lesson design. Consequently, digital technology contributed to creating richer, more engaging, and reflection-oriented learning processes that optimized both teaching performance and student learning outcomes.

This finding is consistent with the argument of [43], who highlighted that integrated learning helps learners understand connections across topics, fosters critical thinking, and deepens conceptual understanding through authentic contexts. Thus, integration in teaching is not merely about combining content but about creating holistic, student-centered learning experiences. Technology-supported microteaching facilitates continuous feedback and structured reflection, which in turn enhances pedagogical growth and teaching performance [10], [28]. Similarly, the use of digital portfolios, video-based feedback, and collaborative platforms enables prospective teachers to evaluate their instructional practices critically while also identifying concrete strategies for improvement [36].

Current empirical evidence emphasizes the significant importance of digital competence as a key factor influencing teaching quality. [44] highlighted that teachers' digital literacy is an essential factor in ensuring instructional effectiveness, while [27] found that technology-based training programs significantly enhance teachers' confidence in integrating digital media into classroom practice. Likewise, [45] asserted that pedagogical readiness for digital innovation determines how effectively technology can improve instructional quality. [46] further argued that digital technology integration is a prerequisite for equipping teachers with 21st-century teaching capabilities.

Moreover, interactive media has been proven to effectively increase student engagement in learning [47], while multimodal, technology-mediated feedback contributes to improved teaching competence among pre-service teachers [48], [49]. In line with this, [50] emphasized that feedback effectiveness is a key determinant of student achievement and supports the enhancement of instructional quality among future teachers.

Taken together, the results demonstrate that the purposeful incorporation of digital tools in microteaching not only strengthens the instructional design process but also enhances pre-service teachers' reflective, evaluative, and adaptive teaching capacities. This confirms that digital technology is not a supplementary component, but a transformative pedagogical tool that amplifies the effectiveness of teacher preparation practices within contemporary educational contexts.

Digital Technology Moderating the Influence of Project-Based Learning (PjBL) on Teaching Skills

The analysis results demonstrate that digital technology significantly strengthens the effect of Project-Based Learning (PjBL) on teaching competence among pre-service teachers. This moderating effect can be explained by the alignment between PjBL's constructivist orientation and the integration of digital tools within microteaching practice. PjBL emphasizes active knowledge construction, where pre-service teachers connect new knowledge to prior experiences and conceptual frameworks. In this process, instructors act as facilitators who design authentic contexts, pose open-ended problems, and guide collaborative inquiry. Moreover, inquiry and discovery-based learning—implemented through project investigations, real-world problem solving, and case analyses—allows pre-service teachers to derive patterns, principles, and pedagogical insights through direct experience.

The findings of this study confirm that the integration of digital technology reinforces the implementation of Project-Based Learning in microteaching. The use of Google Classroom and Moodle facilitated structured project coordination, enabling pre-service teachers to collaboratively plan lesson designs and submit teaching documents in an organized manner. Furthermore, formative assessment through Google Forms and Quizizz provided immediate and systematic feedback during microteaching sessions, allowing both peers and lecturers to evaluate teaching performance more transparently. The use of recorded microteaching videos also enabled reflective teaching practices, as student teachers were able to revisit their teaching sessions, identify areas for improvement, and refine their instructional strategies in subsequent project cycles. These findings demonstrate that technology supports the experiential learning process by extending opportunities for continuous feedback, reflection, and iterative teaching improvement within the PjBL framework.

When reinforced by digital technology, particularly through integrating technology into microteaching and utilizing digital tools for evaluation and reflection, it enhances the overall effectiveness of PjBL in developing teaching competence. Through the integration of digital applications for lesson delivery, observation, evaluation and self-reflection, teacher candidates not only participate in deeper reflection but also demonstrate improved

instructional quality—as reflected in their ability to meet learning objectives, facilitate active learning, and design meaningful educational experiences. This synergy between PjBL and digital technology ultimately supports more reflective, student-centered, and adaptive teaching practices.

These findings align with [55], who identified a synergistic effect between PjBL and digital technology in enhancing pre-service teachers' pedagogical competence. Similarly, [56] emphasized that technology-enhanced projects foster metacognitive engagement through iterative practice, self-reflection, and continuous improvement of teaching strategies. [57] further highlighted that digital integration strengthens student support dimensions by addressing socio-emotional and academic needs, both of which are essential for effective learning.

Thus, digital technology not only reinforces the pedagogical mechanisms of PjBL but also broadens its impact by fostering more holistic, reflective, and contextually relevant teaching skills that meet the professional expectations of modern education. This finding underscores that the intersection of PjBL and digital integration represents a powerful pedagogical synergy—bridging experiential, reflective, and technological dimensions of teacher learning.

RESEARCH IMPLICATIONS

Theoretical Implications

The primary focus of this study was to analyze the role of Project-Based Learning (PjBL) in enhancing teaching skills, with digital technology serving as a moderating variable, within a framework explained by [13] Experiential Learning Theory (ELT). ELT proposes that learning progresses through a four-phase cyclical process: concrete experience, reflective observation, abstract conceptualization, and active experimentation. This cyclical process enables learners—including both prospective and practicing teachers—to build deep understanding alongside practical competence through repeated cycles of experience, reflection, and implementation. When applied within teacher education, this framework provides a solid theoretical explanation for how pedagogical competence and teaching skills evolve through authentic practice and guided reflection.

Within this framework, PjBL serves as the operationalization of experiential learning. The model emphasizes a constructivist orientation, where teachers facilitate students' active, collaborative, reflective, and contextual learning experiences that encourage knowledge construction rather than passive reception. This constructivist process becomes more powerful when strengthened by the integration of digital technology—specifically, through the dimension of Integration in Teaching. This includes teachers' capacity to skillfully use technology-based resources (hardware, software, and media applications) to support lesson planning, implementation, and evaluation.

The synergy between constructivist orientation and technology integration enhances teachers' capacity to design and implement engaging, reflective, and authentic learning environments. This integration ultimately leads to improved instructional quality, characterized through lesson clarity, efficient classroom management, student engagement, and constructive feedback. Theoretically, this finding refines Kolb's ELT by demonstrating that digital mediation acts as a reinforcing mechanism that strengthens the experiential learning cycle—linking concrete teaching experiences with reflective digital feedback and iterative improvement.

Thus, this research offers a theoretical advancement by extending the ELT framework into a digitally supported pedagogical model. It demonstrates that the integration of Project-Based Learning and digital technology not only facilitates experiential learning but also fosters adaptive, reflective, and technologically grounded teaching competence—key characteristics of effective educators in 21st-century learning environments.

Practical Implications

The findings of this study emphasize the important function of Project-Based Learning (PjBL) in strengthening pre-service teachers' teaching skills. Therefore, microteaching programs and field teaching practices in teacher education institutions should consistently integrate PjBL into their instructional design. Such integration allows pre-service teachers not only to understand pedagogical theories conceptually but also to gain authentic, hands-on experiences in lesson planning, classroom implementation, and reflective evaluation. Embedding PjBL in microteaching ensures that future teachers develop essential professional competencies through real teaching challenges that mirror actual classroom dynamics.

Moreover, the study provides clear evidence that digital technology competence significantly strengthens the effectiveness of PjBL. This underscores the necessity for teacher education programs to provide systematic and intensive training in the pedagogical use of technology—covering hardware, software, digital applications, and media tools. Strengthening digital literacy and technology integration skills will enable pre-service teachers to create more interactive, data-informed, and student-centered learning environments.

Integrating PjBL with digital technology offers a dual advantage: it promotes instructional innovation and cultivates reflective and adaptive teaching practices. By combining experiential learning principles with digital tools, teacher education institutions can better prepare pre-service teachers to meet the demands of 21st-century

education, where effective teaching requires not only pedagogical expertise but also proficiency in operating within and leveraging digital learning environments.

CONCLUSION

This study provides new empirical evidence on how digital technology strengthens the linkage between Project-Based Learning (PjBL) and teaching skills within microteaching contexts. Using PLS-SEM analysis, it confirms that PjBL significantly enhances pre-service teachers' instructional competence, reflective practice, and professional readiness. In addition, digital technology not only exerts a direct influence on teaching performance but also amplifies the pedagogical effects of PjBL through continuous feedback and reflective engagement—core processes in Experiential Learning Theory (ELT).

Taken together, these findings broaden the application of ELT by showing that digital mediation enriches experiential learning mechanisms in teacher education. The study contributes theoretically by integrating project-based and technology-supported pedagogies into one empirical framework, and practically by demonstrating how this integration can be implemented effectively in microteaching.

In light of these results, universities are encouraged to strengthen both digital infrastructure and pedagogical innovation to support authentic, collaborative, and technology-driven learning environments. Such alignment not only improves instructional quality but also ensures that teacher education programs remain responsive to the demands of modern classrooms.

Beyond its pedagogical implications, the study offers insight for educational policymakers seeking evidence-based strategies to promote digital competence and experiential learning in teacher preparation. Subsequent studies may build on these results by investigating their long-term effects, exploring other moderating variables such as digital self-efficacy, or validating the model across different institutional and cultural settings.

These findings highlight that the meaningful integration of digital technology can reinforce the experiential and collaborative dimensions of project-based microteaching, making it a relevant pedagogical approach for 21st-century teacher preparation.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal adopts the Contributor Roles Taxonomy (CRediT) to acknowledge individual author contributions, minimize authorship disputes, and support effective collaboration.

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C: **C**onceptualization	I : **I**nvestigation	Vi : **Vi**sualization
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So : **So**ftware	D : **D**ata Curation	P : **P**roject administration
Va : **Va**lidation	O : Writing - **O**riginal Draft	Fu : **Fu**nding acquisition
Fo : **Fo**rmal analysis	E: Writing - Review & **E**diting	

CONFLICT OF INTEREST STATEMENT

No potential conflicts of interest were reported.

INFORMED CONSENT

This research was conducted with informed consent from all participants.

ETHICAL APPROVAL

The research was conducted in compliance with the ethical procedures and scientific requirements.

DATA AVAILABILITY

All data supporting the conclusions of this research are contained within the article and its supplementary materials. Further details may be obtained from the corresponding author [KMAA], upon reasonable request.

REFERENCES

[1] D. W. Allen and K. Ryan, Microteaching. Addison-Wesley, 1969.
[2] L. Iliasova, I. Nekrasova, J. Mena, and O. Estrada-Molina, "Microteaching on pre-service teachers' education: literature review," Front Educ (Lausanne), vol. 10, p. 1562975, 2025, doi: 10.3389/feduc.2025.1562975.
[3] A. Mukuka and J. K. Alex, "Review of research on microteaching in mathematics teacher education: Promises and challenges," Eurasia Journal of Mathematics, Science and Technology Education, vol. 20, no. 1, p. em2381, 2024, doi: 10.29333/ejmste/13941.
[4] R. M. Simamora, A. R. Probosini, and S. Sarjiwo, "Learning to be a Teacher: Prospective Teachers' Experiences and Perceptions in Micro Teaching Course," Studies in Learning and Teaching, vol. 5, no. 3, pp. 688–719, 2024, doi: 10.46627/silet.v5i3.509.
[5] H. Q. Hama and Ű. V. Osam, "Revisiting Microteaching in Search of Up-to-Date Solutions to Old Problems," SAGE Journals, vol. 11, no. 4, 2021, doi: 10.1177/21582440211061534.
[6] P. Guo, N. Saab, L. S. Post, and W. Admiraal, "A review of project-based learning in higher education: Student outcomes and measures," Int J Educ Res, vol. 102, p. 101586, 2020, doi: 10.1016/j.ijer.2020.101586.
[7] J. W. Thomas, "A Review of Research on Project-Based Learning," San Rafael, California, 2000.
[8] A. Fikria, S. Setiawan, and A. Munir, "A Systematic Review of Technology-Enhanced Project-Based Language Learning: Theoretical Frameworks, Project Types, and Implications for Future Research and Practice," F1000Res, vol. 14, p. 775, 2025, doi: 10.12688/f1000research.165491.1.
[9] B. P. Uyen, D. H. Tong, and L. K. Ngan, "Online project-based learning for teacher education during the COVID-19 pandemic: A systematic review," 2023, Bastas. doi: 10.30935/cedtech/13238.
[10] H. Sezaki, Y. Lei, Y. Xu, S. Hachisuka, S. Warisawa, and K. Kurita, "Online Technology-Based Microteaching in Teacher Education: A Systematic Literature Review," Procedia Comput Sci, vol. 225, pp. 2487–2496, 2023, doi: 10.1016/j.procs.2023.10.240.
[11] X. Wang, C.-F. Lee, Y. Li, and X. Zhu, "Digital Transformation of Education: Design of a 'Project-Based Teaching' Service Platform to Promote the Integration of Production and Education," Sustainability, vol. 15, no. 16, p. 12658, 2023, doi: 10.3390/su151612658.
[12] A. Lohr, M. Sailer, M. Stadler, and F. Fischer, "Digital learning in schools: Which skills do teachers need, and who should bring their own devices?," Teach Teach Educ, vol. 152, p. 104788, 2024, doi: 10.1016/j.tate.2024.104788.
[13] D. A. Kolb, Experiential learning: Experience as The Source of Learning and Development, vol. 1. Englewood Cliffs, NJ: Englewood Cliffs, NJ: Prentice-Hall, 1984.
[14] T. H. Morris, "Experiential learning – a systematic review and revision of Kolb's model," Interactive Learning Environments, vol. 28, no. 8, pp. 1064–1077, 2020, doi: 10.1080/10494820.2019.1570279.
[15] M. Wijnen-Meijer, T. Brandhuber, A. Schneider, and P. O. Berberat, "Implementing Kolb´s Experiential Learning Cycle by Linking Real Experience, Case-Based Discussion and Simulation," J Med Educ Curric Dev, vol. 9, 2022, doi: 10.1177/23821205221091511.
[16] K. Mechouat, "The Impact of Aligning Kolb's Experiential Learning Theory with a Comprehensive Teacher Education Model on Pre-service Teachers' Attitudes and Teaching Practice," Eur Sci J, vol. 20, no. 8, pp. 135–164, 2024, doi: 10.19044/esj.2024.v20n28p135.
[17] S. Domene-Martos, M. Rodríguez-Gallego, D. Caldevilla-Domínguez, and A. Barrientos-Báez, "The Use of Digital Portfolio in Higher Education before and during the COVID-19 Pandemic," International Journal of Environmental Research and Public Health 2021, Vol. 18, Page 10904, vol. 18, no. 20, p. 10904, 2021, doi: 10.3390/ijerph182010904.
[18] S. Radović, H. G. K. Hummel, and M. Vermeulen, "The Challenge of Designing 'More' Experiential Learning in Higher Education Programs in the Field of Teacher Education: A Systematic Review Study," International Journal of Lifelong Education, vol. 40, no. 5–6, pp. 545–560, 2021, doi: 10.1080/02601370.2021.1994664.

[19] P. Zhang and G. Tur, "A systematic review of e-portfolio use during the pandemic: Inspiration for post-COVID-19 practices," Open Praxis, vol. 16, no. 3, pp. 429–444, 2024, [Online]. Available: https://openpraxis.org/articles/10.55982/openpraxis.16.3.656
[20] W. Fimansyah, D. A. Rulyani, C. F. B. Maibang, Y. S. Fatimah, and A. S. Hasibuan, "Development of Microteaching Module Based on PjBL Model (Project Based Learning) on Materials Basic Teaching Skills," in Proceedings of the 5th International Conference of Educational Science, ICONSEIR 2023, Medan: EAI, 2024. doi: 10.4108/eai.30-11-2023.2346957.
[21] S. K. W. Chu, R. B. Reynolds, N. J. Tavares, M. Notari, and C. W. Y. Lee, 21st Century Skills Development Through Inquiry-Based Learning. Springer Singapore, 2017. doi: 10.1007/978-981-10-2481-8.
[22] A. Markula and M. Aksela, "The key characteristics of project-based learning: how teachers implement projects in K-12 science education," Disciplinary and Interdisciplinary Science Education Research, vol. 4, no. 2, pp. 1–17, 2022, doi: 10.1186/s43031-021-00042-x.
[23] S. Bell, "Project-Based Learning for the 21st Century: Skills for the Future," The Clearing House, vol. 83, no. 2, pp. 39–43, 2010, doi: 10.1080/00098650903505415.
[24] P. C. Blumenfeld, E. Soloway, R. W. Marx, J. S. Krajcik, M. Guzdial, and A. Palincsar, "Motivating Project-Based Learning: Sustaining the Doing, Supporting the Learning," Educ Psychol, vol. 26, no. 3–4, pp. 369–398, 1991, doi: 10.1080/00461520.1991.9653139.
[25] E. Alqurashi, "Predicting student satisfaction and perceived learning within online learning environments," Distance Education, vol. 40, no. 1, pp. 133–148, 2018, doi: 10.1080/01587919.2018.1553562.
[26] R. Saltos-Rivas, P. Novoa-Hernández, and R. S. Rodríguez, "Understanding university teachers' digital competencies: a systematic mapping study," Educ Inf Technol (Dordr), vol. 28, no. 12, pp. 16771–16822, 2023, doi: 10.1007/s10639-023-11669-w.
[27] S. K. Amemasor, S. O. Oppong, B. Ghansah, B. B. Benuwa, and D. D. Essel, "A systematic review on the impact of teacher professional development on digital instructional integration and teaching practices," Front Educ (Lausanne), vol. 10, p. 1541031, 2025, doi: 10.3389/feduc.2025.1541031.
[28] F. Pettersson, "On the issues of digital competence in educational contexts – a review of literature," Educ Inf Technol (Dordr), vol. 23, pp. 1005–1021, 2018, doi: 10.1007/s10639-017-9649-3.
[29] D. E. H. Tigelaar, D. H. J. M. Dolmans, I. H. A. P. Wolfhagen, and C. P. M. van der Vleuten, "The development and validation of a framework for teaching competencies in higher education," High Educ (Dordr), vol. 48, no. 2, pp. 253–268, 2004, [Online]. Available: https://doi.org/10.1023/B:HIGH.0000034318.74275.e4
[30] S. Blömeke, A. Jentsch, N. Ross, G. Kaiser, and J. König, "Opening up the black box: Teacher competence, instructional quality, and students' learning progress," Learn Instr, vol. 79, p. 101600, 2022, doi: 10.1016/j.learninstruc.2022.101600.
[31] K. Prananto, S. Cahyadi, F. Y. Lubis, and Z. R. Hinduan, "Perceived teacher support and student engagement among higher education students – a systematic literature review," BMC Psychol, vol. 13, no. 1, p. 112, 2025, doi: 10.1186/s40359-025-02412-w.
[32] X. Liu, K. Y. Hansen, J. De Neve, and M. Valcke, "Teacher versus student perspectives on instructional quality in mathematics education across countries," Instr Sci, vol. 52, pp. 477–513, 2024, doi: 10.1007/s11251-023-09652-6.
[33] N. Teig and T. Nilsen, "Profiles of instructional quality in primary and secondary education: Patterns, predictors, and relations to student achievement and motivation in science," Studies in Educational Evaluation, vol. 74, p. 101170, 2022, doi: 10.1016/j.stueduc.2022.101170.
[34] A. Jentsch and B. Senden, "Hybrid frameworks to capture teaching quality in secondary classrooms: the case of the TEDS-Instruct observation system," School Effectiveness and School Improvement, vol. 36, no. 3, pp. 433–447, 2025, doi: 10.1080/09243453.2025.2527727.
[35] A. Almufarreh, K. M. Noaman, and M. N. Saeed, "Academic Teaching Quality Framework and Performance Evaluation Using Machine Learning," Applied Sciences 2023, Vol. 13, Page 3121, vol. 13, no. 5, p. 3121, 2023, doi: 10.3390/app13053121.
[36] M. Grammens, M. Voet, R. Vanderlinde, L. Declercq, and B. De Wever, "A systematic review of teacher roles and competences for teaching synchronously online through videoconferencing technology," Educ Res Rev, vol. 37, p. 100461, 2022, doi: 10.1016/j.edurev.2022.100461.
[37] A. M. Mahasneh and A. F. Alwan, "The Effect of Project-Based Learning on Student Teacher Self-Efficacy and Achievement.," International Journal of Instruction, vol. 11, no. 3, pp. 511–524, 2018, doi: 10.12973/iji.2018.11335a.
[38] D. Kokotsaki, V. Menzies, and A. Wiggins, "Project-based learning: A review of the literature," Improving Schools, vol. 19, no. 3, pp. 267–277, 2016, doi: 10.1177/1365480216659733.

[39] N. Rehman, X. Huang, A. Mahmood, M. A. M. AlGerafi, and S. Javed, "Project-based learning as a catalyst for 21st-Century skills and student engagement in the math classroom," Heliyon, vol. 10, no. 23, Dec. 2024, doi: 10.1016/j.heliyon.2024.e39988.
[40] S. Lee and S. Kim, "Preservice teachers' learning by design through space construction in the metaverse," British Journal of Educational Technology, vol. 56, no. 1, pp. 208–230, 2025, doi: 10.1111/bjet.13493.
[41] I. A. Adamu and H. A. Mohammed, "Teachers' Pedagogical Competence as a Determinant of Students' Motivation Towards Business Education in Federal College of Education (Technical) Gombe in North-East Nigeria," Kashere Journal of Education, vol. 2, no. 2, pp. 42–49, 2021, doi: 10.4314/kje.v2i2.6.
[42] N. Lubis, A. Lubis, and R. I. Ashadi, "Integrating Teaching Models to Enhance Efl Students' Interpersonal Communication Skill and Creativity," International Journal of Education and Literacy Studies, vol. 6, no. 4, pp. 129–137, 2018, doi: 10.7575/aiac.ijels.v.6n.4p.129.
[43] S. M. Drake and J. Reid, "Integrated curriculum: Increasing relevance while maintaining accountability (WHAT WORKS? Research into Practice, Research Monograph #28)," Ontario, Canada, 2010. [Online]. Available: https://www.researchgate.net/publication/352888512
[44] M. de los Á. Domínguez-González, A. Luque de la Rosa, C. Hervás-Gómez, and P. Román-Graván, "Teacher digital competence: Keys for an educational future through a systematic review," Contemp Educ Technol, vol. 17, no. 2, p. ep577, 2025, doi: 10.30935/cedtech/16168.
[45] N. Yulin and S. D. Danso, "Assessing Pedagogical Readiness for Digital Innovation: A Mixed-Methods Study," 2025, doi: 10.48550/arXiv.2502.15781.
[46] A. L. Rodrigues, "Digital technologies integration in teacher education: The active teacher training model," Journal of E-Learning and Knowledge Society, vol. 16, no. 3, pp. 24–33, 2020, [Online]. Available: https://www.researchgate.net/publication/344493831_Digital_technologies_integration_in_teacher_education_the_active_teacher_training_model
[47] X. Yang, J. Yao, T. Jiang, and R. Li, "Application of Microteaching Combined with Problem-Based Learning (PBL) Teaching Model in Teaching Clinical Nursing Interns in Otorhinolaryngology Department," Journal of Contemporary Educational Research, vol. 7, no. 11, pp. 147–153, 2023, doi: 10.26689/jcer.v7i11.5589.
[48] M. P. Fathima and Vimala, "Metacognitive Intervention Strategies in Enhancing Teaching Competency Among Prospective Teachers," International Journal of Advanced Science and Technology, vol. 29, no. 3s, pp. 202–212, 2020, [Online]. Available: https://www.researchgate.net/publication/349239124
[49] R. Van der Lans, "A Probabilistic Model for Feedback on Teachers' Instructional Effectiveness: Its Potential and the Challenge of Combining Multiple Perspectives," in Student Feedback on Teaching in Schools: Using Student Perceptions for the Development of Teaching and Teachers, Springer International Publishing, 2021, ch. 5, pp. 73–90. [Online]. Available: https://doi.org/10.1007/978-3-030-75150-0_5
[50] F. N. Yusuf, U. Widiati, and T. Sulistyo, "Multimodal Feedback Provision in Improving Pre-Service Teachers' Competence," Indonesian Journal of Applied Linguistics, vol. 7, no. 2, pp. 239–246, 2017, [Online]. Available: https://ejournal.upi.edu/index.php/IJAL/article/view/8126/5238
[51] J. F. Hair, G. T. M. Hult, C. M. Ringle, M. Sarstedt, N. P. Danks, and S. Ray, Partial Least Squares Structural Equation Modeling (PLS-SEM) Using R. in Classroom Companion: Business. Cham: Springer International Publishing, 2021. doi: 10.1007/978-3-030-80519-7.
[52] I. Rots, A. Aelterman, G. Devos, and P. Vlerick, "Teacher education and the choice to enter the teaching profession: A prospective study," Teach Teach Educ, vol. 26, no. 8, pp. 1619–1629, Nov. 2010, doi: 10.1016/j.tate.2010.06.013.
[53] L. Darling-Hammond, L. Flook, C. Cook-Harvey, B. Barron, and D. Osher, "Implications for educational practice of the science of learning and development," Appl Dev Sci, vol. 24, no. 2, pp. 97–140, Apr. 2019, doi: 10.1080/10888691.2018.1537791.
[54] J. Tondeur, R. Scherer, E. Baran, F. Siddiq, T. Valtonen, and E. Sointu, "Teacher educators as gatekeepers: Preparing the next generation of teachers for technology integration in education," British Journal of Educational Technology, vol. 50, no. 3, pp. 1189–1209, May 2019, doi: 10.1111/bjet.12748.
[55] A. Rahmawati, N. Suryani, M. Akhyar, and Sukarmin, "Technology-Integrated Project-Based Learning for Pre-Service Teacher Education: A Systematic Literature Review," Open Engineering, vol. 10, no. 1, pp. 620–629, 2020, doi: 10.1515/eng-2020-0069.
[56] S. Çetinkaya, "Field Experience and Digital Technology-Based Literacy Instruction," vol. 9, no. 2, pp. 77–92, 2024, doi: 10.24331/ijere.1404019.
[57] M. Kabatiah, A. Batubara, T. Ramadhan, F. Rachman, and P. A. Tanjung, "Digital Design of Teaching Materials in Microteaching Courses by Implementing Borg and Gall Method," in Proceedings of the 5th International Conference on Innovation in Education, Science, and Culture, ICIESC 2023, 24 October 2023, Medan, Indonesia, European Alliance for Innovation, 2024. doi: 10.4108/eai.24-10-2023.2342188.