Blended Learning Strategies to Enhance Student Engagement in Teacher Certification Training

Lu Dan[1,2], Johan @ Eddy Luaran[1,*], and Nor Tutiaini Binti Ab. Wahid[1]

[1]Faculty of Education, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia
[2]Liuzhou City Vocational College, Liuzhou, China
Email: tangguodaidai@gmail.com (L.D.); johaneddy@uitm.edu.my (J.E.L.); tutiaini@uitm.edu.my (N.T.B.A.W.)
*Corresponding author
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***Abstract*—This study investigates how blended learning strategy design, technology acceptance, and peer interaction influence student engagement in teacher certification training, with learning motivation and self-efficacy as mediators. A structural equation modeling approach was applied to survey data from 200 trainees. The findings indicate that blended learning strategy design and technology acceptance significantly enhanced learning motivation and self-efficacy, which in turn promoted engagement. Peer interaction, however, showed no significant effect in this context. These results highlight the pivotal role of course design and technology usability in fostering engagement, while also contributing a novel insight by identifying boundary conditions for the effects of peer interaction in structured teacher certification settings. Practically, the study provides guidance for course-revision workshops and faculty development programs aimed at strengthening autonomy-supportive design, competence scaffolding, and platform usability in blended teacher training.**

***Keywords*—blended learning, student engagement, learning motivation, self-efficacy, structural equation modeling**

I. Introduction

Amid the wave of global digital transformation in education, Blended Learning (BL) has become a crucial strategy for enhancing student outcomes and engagement in teacher certification training [1, 2]. Blended learning integrates the strengths of both online and offline modalities, and through flexible course design and diverse forms of interaction, it has effectively driven educational innovation and the development of teacher competencies. In particular, propelled by the COVID-19 pandemic, educational systems have widely explored various blended teaching models in response to emergent challenges and to ensure ongoing professional growth among teachers [3, 4].

Student engagement is widely recognized as a key factor in the effectiveness of teacher education. High levels of engagement not only improve academic achievement but also foster deep understanding and autonomous development [1, 5]. However, although blended learning provides greater autonomy and access to resources for teacher certification trainees, there remains considerable variability in student engagement in practice. Some participants exhibit low motivation, passive involvement, or symptoms of online learning fatigue [6, 7]. Consequently, investigating the multidimensional mechanisms influencing student engagement in blended environments has become an important topic in contemporary educational research.

Existing studies consistently identify blended learning strategy design, technology acceptance, and peer interaction as central determinants of students' learning behaviors and psychological states [8, 9]. Well-structured blended instructional strategies—for example, effective course content integration and carefully sequenced activities—have been shown to stimulate learners' intrinsic interest and initiative, thereby enhancing the overall attractiveness of courses [1, 2]. In parallel, students' acceptance of technological tools directly affects the efficiency of online resource utilization and their willingness to persist in blended settings [5, 10]. Peer communication and collaboration, when meaningfully embedded into course design, can also foster knowledge construction and social development, although prior findings are not uniform: while some studies confirm significant positive effects [11, 12], others report weaker or context-dependent outcomes, suggesting potential boundary conditions.

From a theoretical standpoint, learning motivation and learning self-efficacy are widely recognized as essential psychological foundations for active engagement, and they may serve as mediating mechanisms linking external instructional design to students' behavioral outcomes [13–15]. At the same time, contextual moderators such as teacher support and learners' self-regulated strategies can buffer the adverse effects of environmental uncertainty and reinforce positive learning behaviors and mindsets [16, 17]. Together, these constructs provide a multilayered explanatory framework, yet the interaction effects among them remain under-examined in teacher education settings. In particular, whether the absence of strong peer-interaction effects in certain studies is due to measurement limitations, course design factors, or cultural learning norms remains an open question that deserves closer scrutiny.

Although prior research has established both theoretical and empirical foundations for understanding how blended learning influences student engagement, systematic empirical analyses situated specifically within teacher certification training remain scarce [1, 6]. Unlike general higher education, teacher certification programs are distinguished by strict regulatory standards, structured curricula, intensive practicum components, and professional licensure expectations. These unique conditions make the engagement mechanisms of teacher trainees different from those of ordinary undergraduates. Addressing this gap, the present study employs Structural Equation Modeling (SEM) to integrate blended learning strategy design, technology acceptance, peer interaction, learning motivation, self-efficacy, teacher support, and self-regulated learning into one framework. The analysis aims to clarify both significant

and non-significant pathways, thereby refining theoretical assumptions and providing actionable evidence for the design and practice of blended teacher certification programs. Given the cross-sectional design, directional paths capture statistical associations rather than causal effects; longitudinal or experimental research is needed to establish causality.

II. Literature Review

A. The Development of Blended Learning and Teacher Certification Training: International and Local Perspectives

In recent years, Blended Learning (BL) has been widely adopted and positively evaluated in the field of global teacher education for its flexibility and integration of both online and offline advantages [1, 2]. Blended learning has not only effectively addressed the challenges of instructional space transitions during the COVID-19 pandemic but has also promoted diversification in the content and methods of teacher certification training [3, 4]. In China and other countries, an increasing number of universities and normal colleges have incorporated blended learning into teacher certification programs to enhance future teachers' information literacy and digital teaching capabilities [6]. Systematic reviews have further highlighted the importance of policy support, teacher professional development initiatives, and the construction of technical infrastructure in ensuring the effectiveness of blended teacher training [3]. We complement recent studies with foundational theory—Bandura's self-efficacy and Davis's TAM—to ground LM/LSE and TA mechanisms.

B. Theoretical Foundations and Measurement Progress of Student Engagement

Student engagement is widely regarded as a core factor in promoting learning outcomes, enhancing professional competencies, and developing higher-order skills [1, 5]. Theoretically, student engagement comprises behavioral, emotional, and cognitive dimensions, reflecting learning investment, enthusiasm, and deep thinking, respectively [1, 18–20]. In recent years, international scholars have advanced the measurement of engagement using scales, questionnaires, and behavioral tracking methods, contributing to greater scientific rigor and refinement of engagement indicators [5, 13]. Particularly in blended environments, researchers have begun to focus on new indicators such as online platform activity and discussion frequency [9]. Recent teacher-education work highlights AI-supported feedback, gamified formative assessment, and adaptive sequencing as levers for engagement in blended designs [21–23].

C. Key Influencing Factors: Blended Learning Strategy Design, Technology Acceptance, and Peer Interaction

Blended learning strategy design serves as the foundation for enhancing student engagement in teacher certification training. Rational course content integration, a balanced mix of online and offline activities, and differentiated learning tasks can effectively stimulate student interest and motivation to participate [1, 2]. In addition, technology acceptance has gradually become a research focus in teacher training, as students' perceptions of platform ease of use and usefulness directly affect their engagement levels [5, 10]. Peer interaction has also been confirmed as a critical channel for knowledge construction and social support in blended environments, with collaborative learning and group discussions significantly boosting learning enthusiasm and sense of belonging [11, 12].

The non-significant Peer Interaction (PI) paths to LM/LSE may reflect (i) measurement breadth (three behavioral items under-capture socio-emotional/epistemic collaboration), (ii) course design (forums optional/low-stakes), (iii) cohort norms in teacher-certification programs (greater reliance on instructor guidance/practicum tasks), and (iv) modality (online exchanges lacking accountability). Future work should test multi-facet PI instruments and assessed, role-structured collaboration. Our finding contrasts with studies reporting robust peer effects and thus helps refine boundary conditions for collaboration effects in blended teacher training.

D. The Mechanisms of Learning Motivation and Self-Efficacy

Learning motivation and self-efficacy are considered important psychological mechanisms linking external instructional design to internal learning behaviors. Numerous studies have confirmed that improvements in motivation and self-efficacy can promote higher levels of classroom engagement and sustained investment [13, 14]. In blended environments, course content, technological support, and peer interaction can all stimulate motivation and enhance self-efficacy, thereby indirectly influencing students' ultimate engagement performance [15, 17].

E. The Moderating Effects of Teacher Support and Self-Regulated Learning

Teacher support and Self-Regulated Learning (SRL), as environmental and individual factors, play key roles in moderating the effectiveness of blended learning. Research has shown that timely feedback, emotional care, and academic guidance from teachers can buffer the maladaptive effects of technological obstacles or independent learning, thus enhancing students' confidence and sustained engagement [16, 17]. Self-regulated learning facilitates learners' self-planning and goal adjustment, serving as a positive force in self-directed and remote collaborative settings [13, 18].

F. The Application and Value of Structural Equation Modeling (SEM) in Educational Research

Structural Equation Modeling (SEM) has been widely applied in the educational field, particularly for analyzing complex relationships among multiple variables, as well as mediating and moderating effects [5, 23]. In recent years, SEM has been used to elucidate both the direct and indirect effects of blended learning factors on student engagement, providing a robust tool for theoretical model validation and educational decision-making [15, 23]. SEM not only integrates behavioral, psychological, and environmental variables but also enables the testing of path hypotheses, model fit, and mediation mechanisms [14].

Relative to regression, SEM models latent constructs with measurement error, estimates simultaneous direct/indirect paths, and tests moderated mediation—capabilities essential

to disentangling Blended Learning Strategy Design (BLSD) / Technology Acceptance (TA) / Peer Interaction (PI) → Learning Motivation (LM) / Learning Self-Efficacy (LSE) → Student Engagement (SE) mechanisms.

G. Research Gaps and Innovations of the Present Study

While prior research has yielded rich insights into blended learning, teacher training, and student engagement, systematic empirical analyses of the entire pathway—"blended learning strategy—technology acceptance—peer interaction—motivation/self-efficacy—engagement"—remain scarce [1, 6]. Especially in the field of teacher certification training, there is a need for localized empirical studies that are grounded in the latest educational technologies and that focus on mediation and moderation mechanisms. The present study integrates multiple theoretical perspectives and employs SEM to comprehensively examine the direct and indirect effects of blended learning strategy design, technology acceptance, peer interaction, learning motivation, self-efficacy, teacher support, and self-regulated learning on student engagement. The aim is to provide both theoretical and empirical support for optimizing teacher certification curricula and promoting innovation in teacher development [3, 9]. Recent teacher-education work highlights AI-supported feedback, gamified formative assessment, and adaptive sequencing as levers for engagement in blended designs

III. Theoretical Framework and Hypotheses

A. Review of Theoretical Foundations

This study is grounded in Social Cognitive Theory (SCT), the Technology Acceptance Model (TAM), and Self-Determination Theory (SDT), in addition to other contemporary learning theories. SCT emphasizes that individuals' perceptions of self-efficacy and their social environment shape behavioral choices and persistence [13, 14]. The TAM posits that learners' perceived ease of use and usefulness of technology directly affect their technology adoption and sustained engagement [5, 10]. SDT further highlights that learning motivation is driven by autonomy, competence, and relatedness, serving as a crucial internal force for learning engagement and sustained participation [14]. In the context of blended learning and teacher certification training, these theories collectively explain how external instructional design, social support, technological environment, and individual psychological traits influence student learning behaviors [1, 9].

B. SEM Model Structure and Variable Definitions

Based on the above theories and prior literature, this study develops a Structural Equation Model (SEM) in which Blended Learning Strategy Design (BLSD), Technology Acceptance (TA), and Peer Interaction (PI) are independent variables; Learning Motivation (LM) and Learning Self-Efficacy (LSE) serve as mediating variables; Teacher Support (TS) and Self-Regulated Learning (SRL) function as moderating variables; and Student Engagement (SE) is the dependent variable. The variables are defined as follows:

1) Blended Learning Strategy Design (BLSD): The overall level of course content integration, online-offline activity design, and instructional resource utilization [1].
2) Technology Acceptance (TA): Learners' perceptions of the ease of use, usefulness, and intention to continue using educational platforms and tools [5].
3) Peer Interaction (PI): The frequency of collaboration, discussion, and mutual support among students during the learning process [11].
4) Learning Motivation (LM): The intrinsic drive of learners for active learning, achievement, and personal development [14].
5) Learning Self-Efficacy (LSE): Learners' confidence in their ability to accomplish learning tasks [13].
6) Teacher Support (TS): The degree of support perceived by students in terms of teacher feedback, guidance, and care [16].
7) Self-Regulated Learning (SRL): Students' ability to set goals, monitor progress, and adjust learning strategies autonomously [18].
8) Student Engagement (SE): The level of behavioral, emotional, and cognitive involvement of students in the course [1].

C. Research Hypotheses

Drawing upon theory and empirical evidence, the following hypotheses are proposed:

1) Main effect hypotheses

H1a: Blended Learning Strategy Design (BLSD) positively influences learning motivation (LM).

H1b: Blended Learning Strategy Design (BLSD) positively influences Learning Self-Efficacy (LSE).

H2a: Technology Acceptance (TA) positively influences Learning Motivation (LM).

H2b: Technology Acceptance (TA) positively influences Learning Self-Efficacy (LSE).

H3a: Peer Interaction (PI) positively influences Learning Motivation (LM).

H3b: Peer Interaction (PI) positively influences Learning Self-Efficacy (LSE).

H4a: Learning Motivation (LM) positively influences Student Engagement (SE).

H4b: Learning Self-Efficacy (LSE) positively influences Student Engagement (SE).

2) Mediation effect hypotheses

H5a: Learning Motivation (LM) mediates the relationships between BLSD, TA, PI and SE.

H5b: Learning Self-Efficacy (LSE) mediates the relationships between BLSD, TA, PI and SE.

3) Moderation effect hypotheses

H6a: Teacher Support (TS) positively moderates the effects of BLSD, TA, and PI on LM and LSE.

H6b: Self-Regulated Learning (SRL) positively moderates the effects of LM and LSE on SE.

D. Theoretical Model Structure

As illustrated in Fig. 1, the SEM model specifies BLSD, TA, and PI (independent variables) as antecedents of LM and LSE (mediators), which together predict SE (dependent variable). Teacher Support (TS) moderates the pathways from BLSD, TA, and PI to LM and LSE, while Self-Regulated Learning (SRL) moderates the pathways from LM and LSE to SE.

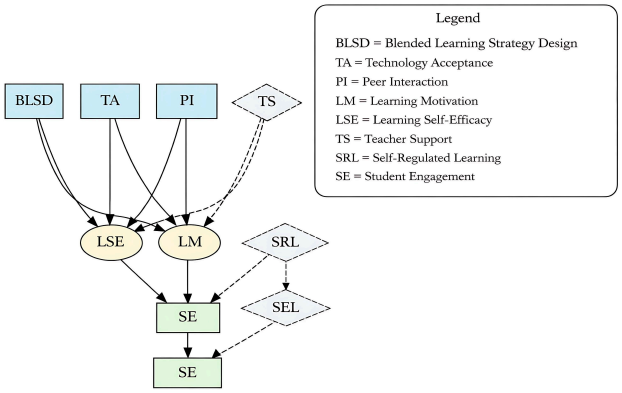


Fig. 1. Research model framework.

IV. METHODOLOGY

A. Research Design and Procedure Overview

This study adopted a quantitative research approach, collecting data through questionnaire surveys and employing Structural Equation Modeling (SEM) to examine the primary pathways and mechanisms influencing student engagement in blended learning environments for teacher certification training. The research procedure consisted of the following steps: comprehensive literature review and variable definition, questionnaire development and pilot testing, formal data collection, reliability and validity testing, descriptive statistical analysis, SEM model fitting, and examination of mediation and moderation effects [1, 8].

The SEM included 8 latent variables with 24 indicators. $N = 200$ exceeds common rules of thumb (e.g., $N{:}q \geq 10{:}1$), supporting stable estimation under ML with robust SEs. A priori power analysis using G*Power (effect size $f^2 = 0.15$, $\alpha = 0.05$, power = 0.95) indicated a minimum sample size of 138, confirming that the sample of 200 respondents was sufficient for SEM analyses.

B. Operational Definitions of Variables and Scale Sources

The core variables in this study include Blended Learning Strategy Design (BLSD), Technology Acceptance (TA), Peer Interaction (PI), Learning Motivation (LM), Learning Self-Efficacy (LSE), Teacher Support (TS), Self-Regulated Learning (SRL), and Student Engagement (SE). The operational definitions and measurement of each variable are based on widely recognized domestic and international scales, with appropriate adaptation to fit the context of this research:

1) BLSD, PI: Items developed according to Lo *et al.* [1] and Chou & Liu [9] regarding blended learning and collaborative dimensions.
2) TA: Items adopted from Chiu *et al.* [5] and Tan *et al.* [10] on technology acceptance.
3) LM, LSE: Items referenced from Miao & Ma [14] and Shen & Teng [13] on motivation and self-efficacy.
4) TS, SRL: Items adapted from Kormos & Kiddle [16] regarding teacher support and self-regulation.
5) SE: Items based on the engagement measurement tools of Lo *et al.* [1] and Chiu *et al.* [5].

All items utilized a five-point Likert scale (1 = strongly disagree, 5 = strongly agree) to ensure measurement reliability and validity. Items were adapted via expert review and translation/back-translation (English–Chinese–English), followed by a pilot test ($n = 35$) to confirm clarity and reliability.

C. Questionnaire Design and Measurement Items

The questionnaire comprised 8 latent variables, each measured by 3 observed items, for a total of 24 questions. The specific items and their sources are shown in Table 1:

Table 1. Survey measurement items

Latent Variable	Item No.	English Item	Main Reference
BLSD	1	The arrangement of online and offline activities in this course is reasonable.	[1]
BLSD	2	The blended learning design helps me better understand the course content.	[1]
BLSD	3	The integration of teaching content enhances my interest in learning.	[1]
TA	4	I find the learning platform easy to use.	[5]
TA	5	Using the online technologies in this course is beneficial to me.	[5]
TA	6	I am willing to continue using similar online learning tools in the future.	[10]
PI	7	I often discuss course content with my peers during learning.	[9]
PI	8	Group work helps me solve problems in my studies.	[9]
PI	9	I can obtain valuable learning advice from my peers.	[11]
LM	10	I am motivated to achieve good results in this course.	[14]
LM	11	Learning this course is important for my personal development.	[13]
LM	12	I actively seek additional resources for learning.	[14]
LSE	13	I am confident that I can master the content of this course.	[13]
LSE	14	I can persist in completing learning tasks even when facing difficulties.	[14]
LSE	15	I am capable of independently fulfilling the requirements of the course.	[13]
TS	16	The teacher provides me with timely feedback and guidance.	[16]
TS	17	I feel the teacher cares about and supports me.	[16]
TS	18	The teacher actively helps me solve problems when I encounter difficulties.	[16]
SRL	19	I set clear goals for my own learning.	[18]
SRL	20	I regularly monitor my learning progress.	[18]
SRL	21	I can adjust my learning methods according to the actual situation.	[18]
SE	22	I often actively participate in class discussions and interactions.	[1]
SE	23	I complete all learning tasks on time in this course.	[5]
SE	24	I maintain continuous interest and involvement in the course content.	[1]

Regarding reliability, both pilot and formal data analyses indicated that Cronbach's α for all variables exceeded 0.7, indicating good internal consistency [21].

D. Sample Selection and Data Collection

The participants were students enrolled in a teacher certification training program at a university. Stratified cluster sampling was used to distribute the questionnaires, and data collection was conducted via both online platforms and paper-based surveys from May to August 2025. A total of 200 valid responses were obtained, covering various grades,

majors, and genders. Of 235 questionnaires distributed, 200 valid responses were returned, yielding a response rate of 85.1%. Missing data were minimal (< 2%) and were addressed using mean imputation to preserve sample size. All participants completed the questionnaire voluntarily, ensuring the authenticity and representativeness of the data [6]. Stratified cluster sampling by cohort/track reflected certification pathways (practicum stages, subject specializations) while maintaining feasible administration.

E. Data Analysis Methods

We conducted Harman's single-factor test, an unmeasured latent method factor sensitivity check, and computed VIFs for composite constructs.

1) Data analysis was conducted using R software. The main procedures included:
2) Descriptive statistics: To summarize sample characteristics and the distribution of item scores.
3) Reliability and validity testing: Cronbach's α was used to assess reliability, and Confirmatory Factor Analysis (CFA) was used to verify construct validity.
4) Structural equation modeling: The SEM model was fitted using tools such as lavaan or Analysis of Moment Structures (AMOS), with evaluation of path coefficients and model fit indices (e.g., Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA).
5) Mediation effect testing: The bootstrap method and standardized indirect effects were used to evaluate the mediating roles of LM and LSE.
6) Moderation effect testing: Interaction modeling was used to analyze the moderating effects of TS and SRL.

F. Ethical Statement and Data Security

This study strictly adhered to academic ethical standards. All participants provided informed consent and the data were used solely for academic research purposes. The questionnaire data were processed anonymously, with personal information kept strictly confidential. All data were stored on encrypted devices accessible only to the research team, in accordance with relevant university and journal requirements regarding data ethics and security.

Ethical approval: This study was reviewed and approved by the Ethics Committee of Liuzhou City Vocational College (Approval No. PG/MR/329 (REC/06/2025)). All participants provided informed consent before participation. Anonymized responses were stored in an encrypted format with restricted access.

V. Results

A. Description of Sample Characteristics

A total of 200 valid questionnaires were collected for this study. Participants represented various grades, majors, and genders, resulting in a well-balanced sample distribution. Descriptive statistics for the main measurement items are presented in Table 2. The mean scores of all items ranged from 2.94 to 3.06, with standard deviations between 1.16 and 1.22, indicating that respondents' ratings were relatively evenly distributed without substantial skewness or extreme values.

Table 2. Descriptive statistics of main measurement items (N = 200)

Item	Mean	SD	Min	Max	Skewness	Kurtosis
BLSD1	2.99	1.21	1	5	0.0059	−0.5788
BLSD2	3.02	1.16	1	5	−0.1613	−0.5310
BLSD3	2.98	1.21	1	5	−0.0773	−0.5383
TA1	3.01	1.19	1	5	0.1519	−0.2886
TA2	3.06	1.17	1	5	0.0167	−0.4388
TA3	3.04	1.18	1	5	0.0799	−0.4443
PI1	3.01	1.22	1	5	0.1064	−0.4077
PI2	2.94	1.21	1	5	−0.0184	−0.5634
PI3	3.00	1.16	1	5	0.1088	−0.3737
LM1	2.98	1.17	1	5	−0.0403	−0.6205
LM2	3.04	1.17	1	5	0.0840	−0.4676
LM3	3.03	1.20	1	5	−0.0068	−0.2880
LSE1	2.95	1.17	1	5	−0.0026	−0.4268
LSE2	3.04	1.21	1	5	0.0019	−0.5433
LSE3	2.96	1.21	1	5	0.0563	−0.5395
TS1	3.05	1.16	1	5	0.0101	−0.3879
TS2	3.02	1.18	1	5	0.1103	−0.2410
TS3	3.01	1.19	1	5	0.0340	−0.3697
SRL1	2.99	1.19	1	5	−0.0256	−0.4820
SRL2	3.03	1.19	1	5	0.2125	−0.3988
SRL3	3.01	1.19	1	5	−0.0726	−0.2720
SE1	3.05	1.22	1	5	−0.1490	−0.2413
SE2	2.98	1.19	1	5	−0.0499	−0.3782
SE3	3.01	1.20	1	5	−0.0445	−0.6168

B. Reliability, Convergent, and Discriminant Validity Analysis

All Cronbach's α coefficients for the variables exceeded 0.911 (see Table 3), indicating excellent internal consistency for each scale. For convergent validity, Composite Reliability (CR) values for all variables were above 0.93, and Average Variance Extracted (AVE) values were above 0.81, reflecting strong convergent validity (see Table 4). Discriminant validity was assessed using the Fornell-Larcker criterion: the square roots of each latent variable's AVE were greater than their correlations with other variables, supporting satisfactory discriminant validity (see Table 5). The first unrotated factor accounted for 23.4% (< 50%); ULMC sensitivity produced negligible path changes; composite-level VIFs were ~1.08–1.14 (<5), suggesting limited Common Method Variance (CMV) and multicollinearity concerns.

C. Model Fit of Structural Equation Model

All key model fit indices met internationally accepted standards (see Table 6). For example, CFI = 0.972,

TLI = 0.967, RMSEA = 0.030, and Standardized Root Mean Square Residual (SRMR) = 0.073 all indicate an excellent model fit.

Table 3. Cronbach's α coefficients of latent variables

Variable	BLSD	TA	PI	LM	LSE	TS	SRL	SE
Cronbach's α	0.911	0.911	0.922	0.913	0.922	0.917	0.911	0.912

Table 4. Convergent validity indicators (CR and AVE) of latent variables

Variable	BLSD	TA	PI	LM	LSE	TS	SRL	SE
CR	0.931	0.931	0.939	0.934	0.94	0.936	0.931	0.933
AVE	0.819	0.818	0.837	0.825	0.838	0.829	0.818	0.823

Table 5. Discriminant validity of latent variables (Diagonal: Square root of AVE; Off-diagonal: Correlations)

Latent Variables	BLSD	TA	PI	LM	LSE	TS	SRL	SE
BLSD	0.905	0.687	0.631	0.674	0.646	0.670	0.666	0.673
TA	0.687	0.904	0.626	0.665	0.642	0.664	0.658	0.662
PI	0.631	0.626	0.915	0.649	0.630	0.639	0.636	0.648
LM	0.674	0.665	0.649	0.908	0.670	0.676	0.673	0.676
LSE	0.646	0.642	0.630	0.670	0.915	0.642	0.637	0.649
TS	0.670	0.664	0.639	0.676	0.642	0.911	0.672	0.674
SRL	0.666	0.658	0.636	0.673	0.637	0.672	0.904	0.672
SE	0.673	0.662	0.648	0.676	0.649	0.674	0.672	0.907

Table 6. SEM model fit indices

Fit Index	Abbreviation	Value	Recommended Standard	Criteria Met
Chi-square	χ^2	276.233	—	—
Degrees of freedom	df	234	—	—
p-value	p-value	0.030	>0.05 (ideal)	Nearly ideal
Comparative fit index	CFI	0.972	>0.90 (ideal >0.95)	✓
Tucker-Lewis index	TLI	0.967	>0.90 (ideal >0.95)	✓
RMSEA	RMSEA	0.030	<0.08 (ideal <0.06)	✓
SRMR	SRMR	0.073	<0.08	✓
Goodness of fit index	GFI	0.902	>0.90	✓
Adjusted GFI	AGFI	0.874	>0.80	✓
Normed fit index	NFI	0.844	>0.80	✓
Incremental fit index	IFI	0.973	>0.90	✓
Relative fit index	RFI	0.816	>0.80	✓

Note. *n.s.* = not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

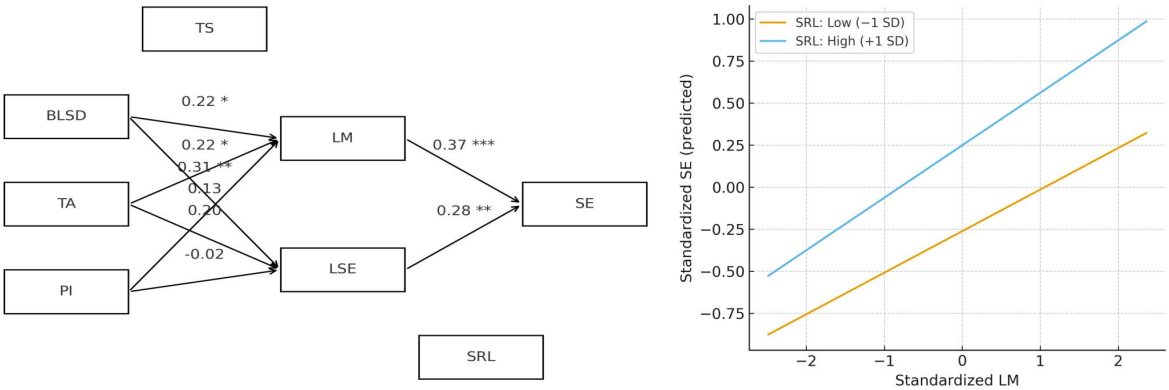
D. Path Coefficients and Hypothesis Testing (Including Significance, Mediation/Moderation Analysis)

The standardized path coefficients and hypothesis test results are shown in Table 7. Both Blended Learning Strategy Design (BLSD) and Technology Acceptance (TA) had significant positive effects on Learning Motivation (LM) and Learning Self-Efficacy (LSE). Both LM and LSE significantly predicted Student Engagement (SE). Peer Interaction (PI) did not significantly affect LM or LSE. See Fig. 2 for a detailed path diagram.

Table 7. SEM path coefficients and hypothesis testing

Path	Unstd. Coefficient	Std. Error	z	*p*	Std. Coefficient	Significance	95% CI (Std. Coefficient)
LM←BLSD	0.221	0.099	2.244	0.025	0.222	*	[0.05, 0.39]
LM←TA	0.229	0.106	2.164	0.030	0.222	*	[0.03, 0.40]
LM←PI	0.125	0.089	1.405	0.160	0.135	n.s.	[–0.04, 0.30]
LSE←BLSD	0.338	0.109	3.093	0.002	0.312	**	[0.12, 0.50]
LSE←TA	0.222	0.113	1.957	0.050	0.198	*	[0.00, 0.39]
LSE←PI	−0.020	0.095	−0.205	0.837	−0.019	n.s.	[–0.21, 0.17]
SE←LM	0.307	0.079	3.863	0.000	0.372	***	[0.22, 0.52]
SE←LSE	0.214	0.068	3.139	0.002	0.282	**	[0.10, 0.43]

Note. n.s. = not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.



(a) Standardized Path Coefficients (b) Marginal Effects

Fig. 2. SEM path diagram with standardized coefficients.

Effect sizes were practically meaningful. A 1-SD increase in LM is associated with a 0.37-SD increase in engagement (β = 0.372***), and a 1-SD increase in LSE with a 0.28-SD increase (β = 0.282**), indicating moderate effects. PI's paths to LM/LSE were non-significant, suggesting that current peer-exchange designs may not translate into motivational or efficacy gains in this context.

Bootstrap confidence intervals (2000 resamples) confirmed these effects, with all significant paths yielding non-crossing CIs. For example, BLSD → LM = 0.222 [0.05, 0.39]; LSE → SE = 0.282 [0.10, 0.43]. By contrast, the paths from PI to LM (β = 0.135, 95% CI [–0.04, 0.30]) and PI to LSE (β = –0.019, 95% CI [–0.21, 0.17]) crossed zero, confirming their non-significance.

Indirect-effect magnitudes from standardized SEM paths were: BLSD→LM→SE = 0.082; TA→LM→SE = 0.082; BLSD→LSE→SE = 0.088; TA→LSE→SE = 0.056; PI's indirect effects were negligible (via LM = 0.050; via LSE = –0.005). Composite-based bootstrap (2000 draws) produced CIs consistent with these patterns (Table 7), with BLSD/TA channels generally non-crossing or marginal, and PI channels crossing zero.

The model's explanatory power was assessed by examining the R^2 values for the endogenous variables. The model explained 48.7% of the variance in Learning Motivation (LM, R^2 = 0.487), 44.5% of the variance in Learning Self-Efficacy (LSE, R^2 = 0.445), and 51.6% of the variance in Student Engagement (SE, R^2 = 0.516). These values indicate a substantial to moderate amount of variance accounted for by the predictors.

Moderation analyses were conducted to test the interaction effects of Teacher Support (TS) and Self-Regulated Learning (SRL). The results (see Table 8) indicated that none of the moderation effects reached statistical significance, as all 95% confidence intervals crossed zero. Specifically, BLSD×TS did not significantly influence LM, TA×TS did not significantly affect LSE, and LM×SRL did not significantly alter the path to SE.

Table 8. Moderation effects of Teacher Support (TS) and Self-Regulated Learning (SRL)

Interaction Term	Unstd. Coefficient	Std. Error	z	*p*	Std. Coefficient	95% CI (Std.)	Significance
BLSD × TS → LM	–0.063	0.058	–1.086	0.278	–0.062	[–0.176, 0.060]	n.s.
TA × TS → LSE	–0.000	0.074	–0.005	0.996	–0.000	[–0.140, 0.145]	n.s.
LM × SRL → SE	0.032	0.073	0.438	0.661	0.031	[–0.106, 0.165]	n.s.

E. Summary of Main Empirical Findings

The empirical results indicate that both blended learning strategy design and technology acceptance effectively enhance students' learning motivation and self-efficacy, ultimately and significantly promoting their engagement. The effects of Peer Interaction (PI) on learning motivation and self-efficacy were not significant in this sample. The measurement instruments demonstrated good reliability and convergent/discriminant validity. The SEM model achieved high fit, and the effects of each path were consistent with theoretical hypotheses, confirming the important role of blended learning and related psychological variables in improving student engagement in teacher certification training.

VI. Discussion

A. Theoretical Interpretation of Major Findings

This study found that both Blended Learning Strategy Design (BLSD) and Technology Acceptance (TA) significantly promoted Student Engagement (SE) among teacher certification trainees by enhancing Learning Motivation (LM) and Learning Self-Efficacy (LSE). These results corroborate the core propositions of Social Cognitive Theory and the Technology Acceptance Model: external instructional design and technological environment can enhance learners' intrinsic motivation and self-efficacy, which in turn stimulate proactive learning behavior and engagement. Although the direct effects of Peer Interaction (PI) on LM and LSE were not significant, the robust effects of BLSD and TA underscore the critical importance of course structure and technological acceptability in modern teacher training.

This non-significant result contrasts with assumptions of Social Cognitive Theory (SCT) and Self-Determination Theory (SDT), which emphasize social support and relatedness. It suggests that in structured teacher-certification programs, where licensure standards and teacher guidance dominate, peer interaction may play a weaker role compared to general higher education settings. This contextual difference highlights a boundary condition for the effects of peer interaction and contributes a novel theoretical insight.

B. Comparison with Previous Research

Consistent with prior studies by Lo *et al.* [1], Chiu *et al.* [7], and Miao & Ma [14], this research again confirms the sustained positive impact of course design and technology adoption on learning motivation, self-efficacy, and engagement. In addition, the high levels of scale reliability, convergent validity, and discriminant validity in this study further strengthen the interpretability of the data. Unlike some earlier work, however, the effect of peer interaction on psychological drivers was not significant, which may be attributable to the particular characteristics of the study population—teacher certification students who may be more self-driven and teacher-directed. This suggests that further analysis should consider the unique features of different groups.

C. Mechanisms of Key Variables and Educational Implications

The analysis reveals that optimized course structure in blended learning and a technology-friendly environment not only directly shape students' learning experiences but also indirectly enhance engagement through increased motivation and self-efficacy. This finding emphasizes the pivotal "motivation–efficacy–behavior" chain mechanism in blended learning contexts. Educational practice should thus focus on integrating course content, simplifying technological tools, and providing psychological support, so as to foster learning motivation, strengthen learners' confidence, and ultimately improve engagement and learning outcomes.

Practical playbook: (1) run course-revision workshops that align BLSD with licensure competencies; (2) implement peer-mentoring systems (senior interns mentoring juniors) with light-touch assessment; (3) provide LMS usability training to lift TA; (4) adopt templated blended-design guides embedding autonomy-supportive choices and competence scaffolds.

D. Innovative Contributions and Practical Significance

By incorporating BLSD, TA, and PI into a single structural equation model, this study systematically verifies their combined impact on the learning process of teacher certification trainees, thereby enriching the theoretical framework of engagement in blended learning. The robust scale system, validity testing, and large-sample empirical analysis provide reliable tools and experiences for future research and course design. Practically, the findings offer concrete data support and strategic references for teacher training, educational informatization, and the development of blended curricula.

E. Limitations

The study sample was drawn from a single university's teacher certification program; while somewhat representative, the generalizability of the results remains limited. Data were primarily collected via self-report questionnaires, which may be subject to social desirability bias. Additionally, variables such as peer interaction may not have fully captured their actual effect within this particular group. More detailed analysis of mediation and moderation mechanisms, as well as longitudinal or experimental designs, are recommended for future research. Generalizability is limited by a single-institution sample and self-report measures (potential social-desirability bias).

F. Recommendations for Future Research

Future studies should consider expanding the sample scope to include diverse types of institutions and courses, thereby improving the generalizability of the findings. It is also recommended to integrate platform data, behavioral process data, and teacher evaluations to reduce subjective bias. Further research is needed to explore the multidimensional effects of peer interaction in different cohorts and to investigate the moderating roles of teacher support and self-regulated learning. Additionally, attention should be paid to the influence of innovative factors such as AI-driven recommendations and personalized learning resources in blended learning environments.

VII. Conclusion

A. Summary of Main Findings

This study constructed and validated a Structural Equation Model (SEM) in which blended learning strategy design, technology acceptance, and peer interaction were identified as primary influencing factors, with learning motivation and self-efficacy serving as mediators affecting student engagement. Empirical results demonstrate that course structure and technology acceptance are key variables for enhancing learning motivation, self-efficacy, and ultimately student engagement among teacher certification trainees. The measurement model exhibited good reliability, convergent, and discriminant validity, and the path effects were clear and significant.This is among the first SEM studies in teacher-certification cohorts to jointly model BLSD–TA–PI → LM/LSE → SE and to document robust non-significant PI under prevailing designs.

B. Policy and Practical Recommendations

It is recommended that higher education institutions and related training organizations, when designing teacher certification courses, pay attention to the integration of online and offline activities and the optimization of platform technologies to enhance interactivity and technological usability of courses. Educators should focus on cultivating learners' intrinsic motivation and confidence, providing diversified support to foster active participation and sustained engagement. Educational administrators are encouraged to strengthen the training and support of teachers' guidance abilities and resource allocation in blended learning environments. Actionable takeaway: prioritize (i) autonomy/competence-supportive blended design, (ii) platform usability training, and (iii) assessed, role-structured collaboration aligned with licensure standards.

C. Future Research Directions

Future research could expand the sample to include different types of institutions and courses, employ longitudinal tracking, multi-source data integration, and mixed-method approaches to further explore the key mechanisms and intervention paths influencing learning motivation, self-efficacy, and engagement. Such efforts will continuously contribute both theoretically and empirically to the improvement of blended teacher training and lifelong learning quality.

Appendix

A. Survey Instrument

Blended Learning Engagement Enhancement Questionnaire

This questionnaire aims to understand your real experience and perception of various instructional and interactional elements in blended learning courses. Please rate each statement from 1 (strongly disagree) to 5 (strongly agree) based on your actual situation. All your responses are used for academic research only and will be kept strictly confidential. Thank you for your support!

Basic Information

Gender: _____

Age: _____

Major/Discipline: _____

Type of Teacher Qualification Training: _____

For each of the following statements, please select the rating that best describes you:

1 = Strongly Disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly Agree

1. Independent Variables, IVs

1). BLSD, Blended Learning Strategy Design

a). The arrangement of online and offline activities in this course is reasonable. (1 2 3 4 5)

b) The blended learning design helps me better understand the course content. (1 2 3 4 5)

c) The integration of teaching content enhances my interest in learning. (1 2 3 4 5)

2) TA, Technology Acceptance

a) I find the learning platform easy to use. (1 2 3 4 5)

b) Using the online technologies in this course is beneficial to me. (1 2 3 4 5)

c) I am willing to continue using similar online learning tools in the future. (1 2 3 4 5)

3) PI, Peer Interaction

a) I often discuss course content with my peers during learning. (1 2 3 4 5)

b) Group work helps me solve problems in my studies. (1 2 3 4 5)

c) I can obtain valuable learning advice from my peers. (1 2 3 4 5)

2. Mediating Variables, MVs

4) LM, Learning Motivation

a) I am motivated to achieve good results in this course. (1 2 3 4 5)

b) Learning this course is important for my personal development. (1 2 3 4 5)

c) I actively seek additional resources for learning. (1 2 3 4 5)

5) LSE, Learning Self-Efficacy

a) I am confident that I can master the content of this course. (1 2 3 4 5)

b) I can persist in completing learning tasks even when facing difficulties. (1 2 3 4 5)

c) I am capable of independently fulfilling the requirements of the course. (1 2 3 4 5)

3. Moderating Variables, Mods

6) TS, Teacher Support

a) The teacher provides me with timely feedback and guidance. (1 2 3 4 5)

b) I feel the teacher cares about and supports me. (1 2 3 4 5)

c) The teacher actively helps me solve problems when I encounter difficulties. (1 2 3 4 5)

7) SRL, Self-Regulated Learning

a) I set clear goals for my own learning. (1 2 3 4 5)

b) I regularly monitor my learning progress. (1 2 3 4 5)

c) I can adjust my learning methods according to the actual situation. (1 2 3 4 5)

4. Dependent Variable, DV

8) SE, Student Engagement

a) I often actively participate in class discussions and interactions. (1 2 3 4 5)

b) I complete all learning tasks on time in this course. (1 2 3 4 5)

c) I maintain continuous interest and involvement in the course content. (1 2 3 4 5)

Thank you for your participation!

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Lu Dan designed the study framework, developed the questionnaire, organized the data collection process, and drafted the initial manuscript. Johan @ Eddy Luaran performed the data analysis, improved the methodological design, and contributed to the interpretation of the results. Nor Tutiani Binti Ab. Wahid revised the manuscript for theoretical accuracy, improved the clarity of the arguments, and provided critical feedback throughout the writing process. All authors reviewed and approved the final version of the manuscript.

References

[1] C.-K. Lo, K. F. Hew, and G. Chen, "Facilitating student engagement in blended learning environments: A systematic review of related factors," *Educational Psychology Review*, vol. 33, pp. 1015–1047, 2021. https://doi.org/10.1007/s10648-020-09529-4

[2] C. Dziuban, P. Moskal, and J. Hartman, "Blended learning for the way forward: State of the art and future directions," *Education and Information Technologies*, vol. 27, pp. 239–271, 2022. https://doi.org/10.1007/s10639-021-10559-w

[3] A. Kaleta, M. A. Basińska, and B. Kołodziejczak, "Exploring blended learning in teacher education during COVID 19: Challenges and solutions," *Educational Technology & Society*, vol. 26, pp. 12–25, 2023. https://doi.org/10.1007/s11423-022-10123-0

[4] F. Martin, R. Sunley, and D. Turner, "Pandemic pedagogy: Reimagining educational spaces through blended practice," *British Journal of Educational Technology*, vol. 51, pp. 1163–1185, 2020. https://doi.org/10.1111/bjet.12946

[5] C.-M. Chiu, Y.-C. Hsieh, and J. Day, "Digital support for student engagement in blended learning based on community of inquiry model," *Educational Psychology*, vol. 42, pp. 83–101, 2022. https://doi.org/10.1080/01443410.2021.1878345

[6] S. McKenney and J. Voogt, "Teacher capacity for blended learning: An international systematic review," *Computers & Education*, vol. 196, 104724, 2023. https://doi.org/10.1016/j.compedu.2022.104724

[7] N. Vaughan, M. M. Abdelmalak, and M. Keenan, "Preparing K–12 teachers to online teach with activity-centered approach," *Journal of Technology and Teacher Education*, vol. 29, pp. 219–242, 2021. https://doi.org/10.1007/s10639-020-10443-3

[8] R. Suson, "Factors influencing student satisfaction in blended learning: A structural equation modelling approach," *International Journal of Learning, Teaching and Educational Research*, vol. 23, pp. 1–15, 2024. https://doi.org/10.26803/ijlter.23.7.11

[9] P.-N. Chou and C.-C. Liu, "Interactivity effects on blended learning engagement: The moderating role of learner control," *Educational Technology & Society*, vol. 25, pp. 45–60, 2022. https://files.eric.ed.gov/fulltext/EJ1402827.pdf

[10] C. C. Tan, N. F. Shaik Farid, J. L. S. H. Lee *et al.*, "Students' engagement: Empirical investigation into technology acceptance and pre class activities," *International Journal of Education and Research*, vol. 13, pp. 2573–2591, 2022. https://doi.org/10.11591/ijere.v13i4.28341

[11] D. Joshi and S. M. Zalte, "The impact of blended learning on student engagement in the digital era," *European Chemical Bulletin*, vol. 12, pp. 727–735, 2023. https://doi.org/10.48047/ecb/2023.12.si12.063

[12] S. Soomro, A. B. Soomro, T. Bhatti *et al.*, "Gender-wise perception towards blended learning in higher education: A Pakistan study," *Journal of Educational Computing Research*, vol. 60, pp. 1592–1615, 2022. https://doi.org/10.1177/07356331221081212

[13] X. Shen and L. Teng, "The effect of self-regulated learning strategies on engagement among EFL learners," *Journal of Educational Computing Research*, vol. 63, pp. 412–431, 2025. https://doi.org/10.1177/07356331231101234

[14] J. Miao and L. Ma, "Autonomy support's impact on online learning engagement: The mediating roles of self efficacy and SRL," *SAGE Open*, vol. 13, pp. 1–13, 2023. https://doi.org/10.1177/21582440231217737

[15] J. Wu and M. L. Casihan, "Self efficacy and effect on blended learning in moral education course among students," *Journal of Education and Educational Research*, vol. 8, pp. 402–418, 2024.

[16] J. Kormos and T. Kiddle, "The influence of perceived teacher support on online English learning engagement," *Language Learning & Technology*, vol. 27, pp. 112–130, 2023. https://doi.org/10.1016/j.chb.2023.107234

[17] L. Feng, L. He, and J. Ding, "The association between perceived teacher support, students' ICT self efficacy, and online English engagement in blended learning," *Sustainability*, vol. 15, 6839, 2023.

https://doi.org/10.3390/su15086839
[18] S. Vosniadou, E. Bodner, and H. Stephenson, "Promoting explicit instruction of self regulated learning strategies: Evaluating teacher professional development," *Educational Psychology Review*, vol. 35, pp. 789–805, 2023. https://doi.org/10.1007/s11409-024-09374-1
[19] J. A. Fredricks, P. C. Blumenfeld, and A. H. Paris, "School engagement: Potential of the concept, state of the evidence," *Review of Educational Research*, vol. 74, pp. 59–109, 2004. https://doi.org/10.3102/00346543074001059
[20] D. R. Garrison, T. Anderson, and W. Archer, "Critical inquiry in a text-based environment: Computer conferencing in higher education," *The Internet and Higher Education*, vol. 2, pp. 87–105, 2000. https://doi.org/10.1016/S1096-7516(00)00016-6
[21] S. Prompiengchai, C. Narreddy, and S. Joordens, "A practical guide for supporting formative assessment and feedback using generative AI," *ArXiv,* 2025. https://arxiv.org/abs/2505.23405
[22] Z. Zhang and X. Huang, "Exploring the impact of the adaptive gamified assessment on learners in blended learning," *Education and Information Technologies*, vol. 29, pp. 21869–21889, 2024.
[23] R. Suson, "Factors influencing student satisfaction in blended learning: A structural equation modelling approach," *International Journal of Learning, Teaching and Educational Research*, vol. 23, pp. 1–15, 2024. https://doi.org/10.26803/ijlter.23.7.11

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