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A structural model of factors influencing the practicum effectiveness of mathematics pre-service teachers in Vietnam

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ABSTRACT

Teacher education in Vietnam has undergone significant transformation following the implementation of the 2018 General Education Reform. Within this reform context, the teaching practicum plays a crucial role in enabling pre-service teachers to connect pedagogical knowledge acquired at universities with authentic classroom practice. This study developed and validated a structural model examining the factors influencing the practicum effectiveness (PE) of mathematics pre-service teachers in Vietnam. Using a quantitative research design, data were collected from 290 final-year pre-service teachers through a 25-item survey instrument representing six latent constructs: student characteristics (SC), training curriculum and practicum management (TCM), mentor teachers at partner schools (MT), university-based teacher educators (UTE), practicum conditions and innovations (PCI), and PE. The sample size satisfied the requirements for structural equation modeling (SEM) based on recommended minimum ratios of observations to estimated parameters. Confirmatory factor analysis (CFA) and SEM were conducted using SPSS 26 and AMOS 24 to examine the reliability and validity of the measurement model and the structural relationships among the constructs. The findings indicate that mentor teachers and SC exert significant direct effects on PE, whereas institutional and structural factors do not demonstrate significant direct effects in the structural model. These results highlight the critical role of relational and human factors in shaping practicum outcomes within authentic teaching contexts, particularly in the Vietnam's ongoing educational reform.

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1. INTRODUCTION

In the context of Vietnam's comprehensive reform of general education under the 2018 General Education Curriculum [1], mathematics teacher education is expected to equip pre-service teachers with a solid foundation in mathematical and pedagogical knowledge. Equally important, it should foster the development of professional competencies, including the ability to analyze pedagogical situations, regulate instructional practices, and adapt to diverse classroom contexts. The teaching practicum therefore becomes a pivotal stage in shaping the professional identity of mathematics pre-service teachers, where they apply theoretical knowledge to authentic classroom settings, practice core teaching competencies, and develop professional attitudes.

The effectiveness of teaching practicum is reflected in the outcomes that pre-service teachers experience during their practicum in secondary schools. Jenssen and Haara [2] indicate that a high-quality practicum is characterized as inclusive, professionally preparatory, and supportive development of teachers' professional identity. Moreover, the quality of mentoring, opportunities for reflection, and the integration of theory and practice are identified as key components of the practicum experience. Prieto-Prieto *et al.* [3] argue that practicum outcomes are manifested in the development of core clusters of professional competencies. These include teaching, management, and collaborative competencies, assessed by comparing students' expected competencies prior to the practicum with their self-evaluated competencies after its completion.

Lee and Davis [4] in their study of a blended practicum integrating face-to-face and online modes, report statistically significant improvements in three key domains of teaching competence: instructional strategies, classroom management, and the promotion of student interaction. These findings indicate a notable development in pre-service teachers' perceptions of self-efficacy during the practicum. Additionally, Kazaz and Alagözlü [5] conceptualize practicum effectiveness (PE) as the degree to which the practicum program meets students' expectations. They further emphasize that this effectiveness is evidenced by positive post-practicum feedback, especially concerning the quality of supervision, feedback, and the program's contribution to professional readiness. Collectively, these studies underscore the pivotal role of teaching practicum in strengthening pedagogical skills, fostering professional attitudes, and enhancing pre-service teachers' readiness to engage in authentic teaching practice.

PE has been shown to be influenced by multiple groups of factors. Previous research [6]–[8] highlight the roles of student characteristics (SC) and professional autonomy, supervision and preparation by university-based teacher educators (UTE), support from mentor teachers at partner schools (MT), and the overall quality of the practicum environment. Recently, Pan *et al.* [9] adopting the job demands–resources framework, found that professional resources and demands within the practicum significantly affect pre-service teachers' perceptions of professional growth and their intention to remain in the teaching profession.

Adding to this body of work, Smithers *et al*. [10] conducted a recent review synthesizing the competencies, knowledge, and attributes required of supervising teachers. Their findings emphasize the dual role of supervising teachers as both mentors and evaluators in helping pre-service teachers translate university-based theoretical knowledge into classroom practice. This reinforces the argument for the critical importance of pedagogical support from both university-based educators and mentor teachers in schools.

In mathematics education, the practicum carries particular significance as it is where pre-service teachers directly develop their pedagogical content knowledge (PCK)–a central component of mathematics teaching competence. Several studies [11]–[13] demonstrate that the practicum provides opportunities for pre-service teachers to display, refine, and expand their PCK through real classroom teaching, error analysis, mathematical task design, and interaction with students. This underscores the centrality of the practicum within mathematics teacher education. In Vietnam, empirical research examining the structural determinants of PE remains limited, particularly in the field of mathematics teacher education. Although Hang [14] employed exploratory factor analysis (EFA) to identify six latent dimensions–namely SC, training curriculum and practicum management (TCM), PE, MT, UTE, and practicum conditions and innovations (PCI), explaining 64.287% of the variance, the measurement structure has not yet been validated using confirmatory factor analysis (CFA). More importantly, the potential causal and structural relationships among these factors have not been examined through structural equation modeling (SEM).

Existing studies, both in Vietnam and internationally, tend to investigate determinants of practicum quality separately or within descriptive and correlational frameworks. Consequently, how institutional conditions, mentoring support, and individual characteristics jointly operate within an integrated structural model to explain PE remains underexplored. This gap highlights the need for a comprehensive validation of both the measurement and structural components of a theoretically grounded SEM framework in the context of mathematics teacher education in Vietnam.

To address this gap, the present study seeks to answer the central question of which factors and structural relationships explain the PE of mathematics pre-service teachers. The study pursues three objectives: to validate the measurement model of six factors using CFA and to develop and test a SEM model examining the effects of independent factors on PE. It also aims to analyze the magnitude and statistical significance of each structural path, thereby providing practical implications for the organization and management of the teaching practicum.

2. LITERATURE REVIEW

The teaching practicum is a central component of teacher education programs, serving as a bridge between theoretical knowledge and actual classroom practice. Based on a comprehensive review of practicum research, Pratiwi [8] conceptualizes the practicum as a deliberately organized and supervised

period during which pre-service teachers have opportunities to apply pedagogical knowledge, professional skills, and teaching experience in authentic classroom contexts. More broadly, Green *et al.* [15] describe collaborative partnerships between universities and schools as boundary or third spaces in which teacher educators, school teachers, and pre-service teachers jointly construct professional knowledge, thus narrowing the gap between theory and practice.

A review by Österling and Christiansen [16] indicates that the practicum profoundly shapes pre-service teachers' development, beliefs, and professional identity; moreover, practicum experiences implemented "as usual" tend to be less effective than those intentionally designed with targeted pedagogical interventions. Kul *et al.* [17] underscore the importance of the practicum environment in mathematics education, particularly the roles of supervision, feedback mechanisms, and collaboration among university faculty, mentor teachers, and pre-service teachers. These factors contribute significantly to the development of mathematics teaching competencies and to bridging the gap between theory and classroom practice.

Research consistently indicates that pre-service teachers' personal characteristics constitute an important dimension of practicum learning. In mathematics education, school-based practicum experiences have been shown to shape pre-service teachers' mathematical affect, including beliefs, confidence, and attitudes toward teaching [11]. Such affective orientations are associated with levels of engagement in instructional tasks and responsiveness to professional feedback. Similarly, practicum experiences contribute to the development of reflective capacity, professional awareness, and clearer understanding of the teacher's role–dimensions closely related to emerging professional identity [7]. Reflection, in particular, has been conceptualized as a central mechanism in teacher education, enabling pre-service teachers to interpret classroom experiences and integrate them into their developing professional understanding [18].

Beyond reflective dispositions, beliefs about the nature of mathematics and mathematical learning also influence instructional decision-making. Pre-service teachers who view mathematics as an exploratory and meaning-making discipline may approach lesson design and classroom interaction differently from those who conceptualize it as a fixed system of rules [19]. Furthermore, the extent to which pre-service teachers recognize the importance of mathematical and statistical reasoning in teaching tasks may shape how they prepare, analyze, and deliver mathematical content in authentic classroom settings [20]. Although Pan *et al.* [9] focus on job demands and resources within the practicum context, their findings suggest that individual differences influence how pre-service teachers perceive and respond to professional challenges. Taken together, these theoretical and empirical perspectives suggest that personal dispositions, beliefs, and reflective capacities may influence how effectively pre-service teachers engage with practicum experiences. Accordingly, the following hypothesis is proposed: SC have a positive effect on PE (H1).

Beyond individual characteristics, the structure of the training program and the way the practicum is organized and managed are also important conditions shaping professional learning. Studies on university–school partnerships suggest that when cooperation is designed as a collaborative and relatively non-hierarchical process, pre-service teachers are better able to connect academic knowledge with classroom practice [15]. Such coordination between university coursework and school-based experience helps reduce the gap between theory and practice. In mathematics education, authentic teaching opportunities during the practicum allow pre-service teachers to experience real classroom demands and refine their pedagogical approaches [12]. Supportive organizational mechanisms–such as observation, structured supervision, and feedback–are consistently reported as meaningful elements that facilitate professional growth [17]. At a broader level, the overall quality of teacher preparation, including the readiness and coherence of practicum arrangements, has been associated with the instructional competence of beginning teachers [21]. Similarly, research indicates that the extent to which pre-service teachers are able to apply knowledge and develop professional confidence during the practicum is closely linked to how the practicum is structured and supported institutionally [22], [23]. Taken together, these findings suggest that the design and management of the training curriculum and practicum may influence how effectively pre-service teachers benefit from their practicum experiences. Accordingly, the following hypothesis is proposed: TCM positively influence PE (H2).

A further factor frequently associated with practicum quality is the role of MT. Mentor teachers are directly involved in guiding pre-service teachers through daily instructional activities and classroom responsibilities. Research indicates that school-based support mechanisms–such as professional guidance, structured discussion, and feedback–are regarded by both pre-service teachers and mentors as important components of meaningful practicum experiences [17]. These forms of support provide access to authentic teaching practices and clarify professional expectations within school contexts.

Core elements of mentoring, including lesson modeling, instructional guidance, and structured feedback, have been identified as central to helping pre-service teachers develop practical teaching skills and translate theoretical preparation into classroom practice [24]. In mathematics education, authentic teaching opportunities during the practicum enable pre-service teachers to demonstrate and further develop key aspects of PCK. These include explaining mathematical concepts effectively, anticipating potential student misconceptions, and selecting appropriate instructional strategies [13]. The quality of interaction between

pre-service teachers and mentor teachers–particularly in terms of pedagogical expertise and supportive engagement–has also been linked to variations in professional confidence and learning opportunities during the practicum [23], [25], [26]. Taken together, these findings suggest that mentor support may shape how effectively pre-service teachers learn from practicum experiences. Accordingly, the following hypothesis is proposed: MT positively influence PE (H3).

Another factor frequently discussed in the literature is the role of UTE, who function as supervisors, instructors, and intermediaries between university coursework and school-based practice. Studies suggest that when university supervisors maintain active engagement during the practicum, pre-service teachers are more likely to connect what they learned at university with classroom instruction [27]. In clinically oriented teacher education models, university faculty members are described as boundary-spanning educators who provide disciplinary support, pedagogical guidance, supervision, and feedback throughout the practicum process [28].

In mathematics education, the involvement of university faculty during field experiences has been associated with opportunities for pre-service teachers to relate advanced mathematical understanding to classroom teaching practices [29]. The competencies and professional dispositions of supervising educators–including subject expertise, pedagogical knowledge, and support capacity–have also been linked to variations in practicum quality [10]. In addition, university supervisors have been described as important facilitators of theory–practice transfer during student teaching [22]. Taken together, these findings indicate that the role and engagement of UTE may influence how effectively pre-service teachers integrate theoretical preparation into practicum experiences. Accordingly, the following hypothesis is proposed: UTE positively influence PE (H4).

Finally, the conditions under which the practicum is implemented and the degree of innovation within the practicum environment have been discussed as contextual factors shaping professional learning. Studies indicate that when universities and partner schools maintain structured collaboration with clear support mechanisms and feedback processes, pre-service teachers experience more consistent opportunities for development [15]. A supportive school climate has also been associated with the development of professional competencies during the practicum [23]. In this regard, a deliberately organized practicum–with supervision, guidance, and structured feedback–has been described as an important condition for facilitating knowledge application and instructional improvement [8].

From a professional–psychological perspective, research drawing on the job demands–resources framework suggests that the availability of institutional and relational resources within the practicum environment may influence how pre-service teachers experience professional demands and growth [9]. Specifically, in mathematics education, classroom conditions, lesson organization, pedagogical support, and access to instructional resources have been linked to opportunities for developing components of mathematical PCK [13]. Structured reflective activities, such as guided reflection and post-lesson analysis, have also been associated with instructional development during the practicum [30]. Taken together, these findings suggest that the broader practicum environment–including organizational conditions and innovative support practices–may shape the quality of professional learning experiences. Accordingly, the following hypothesis is proposed: PCI positively influence PE (H5).

Figure 1 presents the proposed conceptual model based on five hypotheses. The independent factors are represented by rectangles, whereas the dependent variable, PE, is illustrated by an ellipse. The arrows indicate the hypothesized relationships from the five factors to PE.

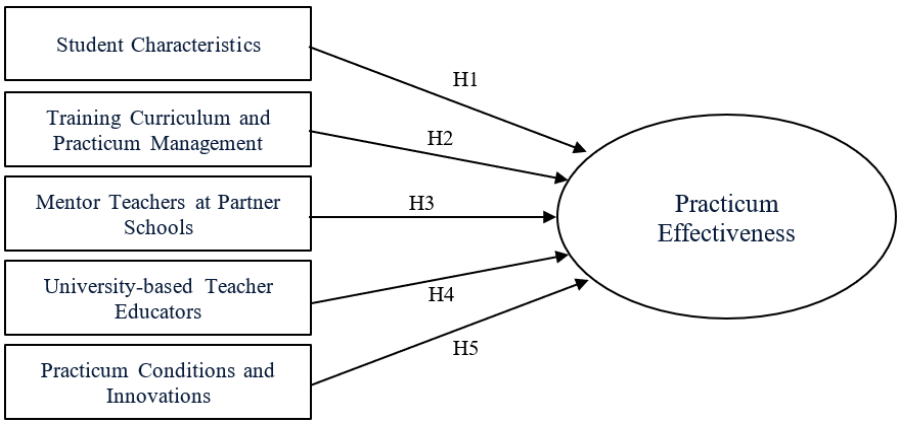

Figure 1. Structural model of factors influencing PE

3. METHOD

3.1. Research design

This study employed a quantitative research design using CFA and SEM to examine the relationships among factors influencing the PE of mathematics pre-service teachers. The research procedure consisted of two stages. The first stage validated the measurement model to confirm the convergent and discriminant validity of the latent constructs, while the second stage tested the structural model to estimate the magnitude and direction of the effects of independent factors on the dependent variable (PE).

3.2. Sample and data collection

The participants were final-year mathematics pre-service teachers who had recently completed their teaching practicum at teacher education institutions in Vietnam. These participants were selected because they had direct and recent experience with school-based practicum activities. Data were collected through an online survey administered via Google Forms between November 1st and November 25th, 2025. A total of 350 responses were obtained. After data screening and removal of incomplete or invalid responses, 290 valid cases were retained for analysis.

The final sample size satisfies recommended requirements for SEM. According to Hair *et al.* [31], a minimum of 200 observations or a ratio of at least 5 observations per estimated parameter is considered adequate. With 25 observed variables, the ratio of 290:25 (11.6:1) exceeds this recommendation, indicating sufficient statistical power and model stability.

Participation was voluntary, and respondents were informed of the research objectives and data confidentiality prior to completing the questionnaire. A convenience sampling strategy was adopted due to accessibility constraints. Table 1 presents the demographic characteristics of the participants. In terms of gender, female students accounted for 63.8% of the sample, considerably higher than the 36.2% of male students. This reflects a common trend in teacher education programs in Vietnam, where female participation is typically higher. Regarding training institutions, students came from eight different universities nationwide, contributing to diversity in educational contexts. However, Vinh University represented the largest proportion (35.2%), significantly higher than other institutions. This distribution partly reflects the researcher's greater accessibility to students from this university.

Table 1. Demographic information of the participants

Characteristic	Category	Frequency
Gender	Male	105
	Female	185
Training Institution	Vinh University	102
	Hue University of Education	30
	Hanoi National University of Education	20
	Thai Nguyen University of Education	46
	Dong Nai University	26
	Hong Duc University	33
	Saigon University	24
	Ho Chi Minh City University of Education	9
Total		290

3.3. Measurement scale and variable coding

The measurement scale was adapted and refined based on the EFA results reported by Hang [14]. The original EFA results reported satisfactory factor loadings and internal consistency. While maintaining the original factor structure and the underlying conceptual framework of the measurement items, the research team revised two observed variables (Q4 and Q5) by adding adverbs to enhance semantic precision. In addition, the content of Q1 was modified to ensure alignment with the objectives of the present study and the theoretical framework established in the literature review. The finalized scale consists of 25 observed variables grouped into six latent factors, in accordance with their original order in the EFA framework.

SC–5 items (Q1–Q5), capturing motivation, competencies, confidence, and the ability to apply knowledge during the practicum. TCM–5 items (Q6–Q10), measuring the degree of preparation, coordination, and organization of the practicum between universities and partner schools. PE–4 items (Q11–Q14), reflecting satisfaction, assessments from mentor teachers and schools, competence development, and career motivation. MT–4 items (Q15–Q18), reflecting pedagogical support, experience-sharing, and opportunities for professional practice provided by mentor teachers. UTE–4 items (Q19–Q22), measuring the role of university instructors in orienting, supervising, and providing professional feedback to pre-service teachers. PCI–3 items (Q23–Q25), capturing the school culture, infrastructure, and the level of pedagogical innovation in the practicum environment.

All observed variables were measured on a 5-point Likert scale (1=strongly disagree; 5=strongly agree). Table 2 presents the full list of questionnaire items used in this study. The items are organized according to their corresponding latent constructs.

As presented in Table 2, the 25 questionnaire items were used to operationalize six latent constructs by translating the theoretical dimensions of the practicum framework outlined in the literature review into measurable indicators. Each group of items represents a specific component of the practicum system, including SC, TCM, PE, MT, UTE, and PCI. The grouping of items under these constructs is grounded in the conceptual framework of professional learning in the teaching practicum discussed in the literature review. Each latent construct is represented by multiple observed indicators to adequately capture its conceptual meaning and ensure sufficient measurement coverage. These indicators form the basis of the measurement model, which was subsequently evaluated for construct validity and reliability using CFA. After validating the measurement model, the confirmed latent constructs were incorporated into the SEM to test the hypothesized relationships among the factors influencing PE.

Table 2. Questionnaire items used in the study

Code	Item
Factor 1: SC	
Q1	I hold positive beliefs about the nature of mathematics and learning mathematics.
Q2	I demonstrate positive motivation and professional attitudes during the teaching practicum.
Q3	I am confident in designing and delivering mathematics lessons.
Q4	I am capable of reflecting on my teaching to improve my professional practice.
Q5	I actively communicate and collaborate in the practicum environment to learn and develop professionally.
Factor 2: TCM	
Q6	Partner schools collaborate closely with the university during the teaching practicum.
Q7	The objectives and learning outcomes of the practicum are clear and aligned with professional requirements.
Q8	The mechanisms for coordinating, assigning, and monitoring the practicum are transparent and effective.
Q9	The duration and schedule of the practicum are reasonable and ensure continuity.
Q10	Practicum content is aligned with the 2018 general education curriculum and actual teaching practice.
Factor 3: PE	
Q11	I receive positive evaluations from mentor teachers and the partner school regarding my practicum performance.
Q12	The practicum helps me develop and enhance my professional competencies.
Q13	I am satisfied with the outcomes and overall experience of the practicum.
Q14	The practicum strengthens my commitment to the profession and fosters motivation for development.
Factor 4: MT	
Q15	Mentor teachers provide direct support during teaching and homeroom activities.
Q16	Mentor teachers share practical teaching experiences and methods.
Q17	Mentor teachers provide constructive feedback that supports my professional growth.
Q18	Mentor teachers create opportunities for me to experiment and innovate in teaching.
Factor 5: UTE	
Q19	University instructors regularly monitor and support me during the practicum.
Q20	University instructors provide thorough guidance and preparation before the practicum.
Q21	University instructors demonstrate responsibility and inspire professional commitment.
Q22	University instructors provide timely and constructive feedback on my practicum performance.
Factor 6: PCI	
Q23	The school culture and pedagogical climate at the practicum site are positive.
Q24	Facilities and instructional resources at the practicum school meet teaching requirements.
Q25	Classroom conditions and lesson organization at the practicum school provide opportunities for me to develop teaching skills.

3.4. Data analysis

Data were processed using SPSS 26 and AMOS 24. The analysis was conducted sequentially as: i) descriptive statistics were performed to identify sample characteristics and data distribution; ii) internal consistency reliability for each construct was assessed using Cronbach's alpha and corrected item–total correlations. Cronbach's alpha values of 0.70 or higher were considered acceptable; iii) CFA was conducted to evaluate the goodness-of-fit of the measurement model and to examine construct validity. Convergent validity was assessed through average variance extracted (AVE≥0.50), and composite reliability (CR≥0.70). Discriminant validity was examined by comparing inter-construct correlations and AVE values; iv) model fit was evaluated using multiple fit indices, including Chi-square divided by degrees of freedom (χ^2/df), goodness-of-fit index (GFI), comparative fit index (CFI), Tucker–Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR) following recommended cutoff criteria; and v) SEM was employed to test the five hypotheses (H1–H5) and to examine the structural effects of the five independent factors on the dependent variable (PE).

Maximum likelihood estimation was employed in CFA and SEM analyses. The structural model was specified to examine direct relationships only. No mediation hypotheses were theoretically proposed among the predictor variables. Therefore, indirect effects were not estimated using bootstrap procedures.

3.5. Model evaluation criteria and hypothesis testing

The goodness-of-fit of the CFA–SEM models was assessed using the criteria recommended by Hair *et al.* [32], and Kline [33], including: CMIN/df<3.0, GFI≥0.90, CFI≥0.90, RMSEA≤0.08, and SRMR≤0.08. When these indices fall within acceptable thresholds, the model is considered to exhibit good fit. Reporting multiple fit indices helps ensure comprehensive and robust evaluation of model adequacy. Hypotheses were supported when standardized regression coefficients (β) were positive and statistically significant at $p<0.05$. In the structural model, significant path coefficients were interpreted as empirical indicators of the relative contribution of each factor to PE. The magnitude and significance of standardized regression weights were used to evaluate the strength of influence of each latent construct.

4. RESULTS AND DISCUSSION

4.1. Results

4.1.1. Descriptive statistics and assessment of scale reliability

A total of 290 valid responses were included in the analysis. Table 3 presents the descriptive statistics and internal consistency reliability results for the measurement scales. These statistics provide an overview of the data distribution and the reliability of the constructs used in the measurement model.

Table 3. Descriptive statistics and internal consistency reliability of the measurement scales

Latent factor	Item	Mean	Standard deviation	Corrected item–total correlation	Cronbach's alpha	No. of items
SC	Q1	3.87	0.84	0.727	0.859	5
	Q2	3.95	0.66	0.695		
	Q3	3.91	0.83	0.706		
	Q4	3.98	0.97	0.666		
	Q5	3.84	0.75	0.629		
TCM	Q6	3.99	0.52	0.679	0.856	5
	Q7	3.99	0.73	0.763		
	Q8	4.12	0.92	0.683		
	Q9	4.07	0.99	0.689		
	Q10	3.92	0.79	0.648		
PE	Q11	4.02	0.58	0.657	0.724	4
	Q12	3.9	0.92	0.550		
	Q13	3.92	0.68	0.514		
	Q14	3.84	0.59	0.410		
MT	Q15	3.94	0.82	0.648	0.806	4
	Q16	3.98	0.49	0.636		
	Q17	4.02	0.5	0.677		
	Q18	3.98	0.73	0.634		
UTE	Q19	4.12	1.13	0.623	0.756	4
	Q20	3.78	0.83	0.586		
	Q21	3.87	0.73	0.583		
	Q22	3.96	0.61	0.570		
PCI	Q23	4.08	1.21	0.528	0.694	3
	Q24	3.84	0.92	0.594		
	Q25	3.83	0.82	0.453		

The results presented in Table 3 indicate that all measurement scales meet the required criteria in terms of descriptive statistics and reliability, thereby providing an appropriate basis for subsequent analyses. Specifically, the mean values of the observed variables range from 3.78 to 4.12, reflecting relatively positive evaluations by the survey respondents regarding aspects related to the teaching practicum. The standard deviations fall within an acceptable range (from 0.49 to 1.21), indicating that the dispersion of the data is not excessive and that the responses are relatively stable.

With respect to scale reliability, the corrected item–total correlations of most observed variables are greater than 0.50; only a small number of items have values close to the minimum threshold of 0.40, yet these still satisfy the criteria for use in both exploratory and confirmatory research. The Cronbach's alpha coefficients of the factors range from 0.694 to 0.859. Among them, the scales SC and TCM demonstrate high reliability ($\alpha>0.85$), while the remaining scales have Cronbach's alpha values greater than or approximately equal to 0.70, indicating an acceptable level of internal consistency according to standards commonly applied in educational and social science research.

Overall, the results of the descriptive statistics and reliability analysis show that the constructed scales possess adequate measurement quality. The observed variables reflect the research constructs reasonably well. Therefore, the dataset satisfies the necessary conditions to be further subjected to CFA in order to examine the factor structure and the goodness of fit of the measurement model.

4.1.2. Confirmatory factor analysis

CFA was conducted to validate the measurement structure consisting of six latent factors. CR and AVE were used to assess the reliability and convergent validity of the scales. As shown in Table 4, CR values ranged from 0.69 to 0.86. Five latent factors achieved CR values of 0.74 or higher, exceeding the recommended threshold of 0.70 suggested by Hair *et al.* [32] indicating satisfactory internal consistency of the measurement model. The factor PCI reported a CR of 0.69, which is marginally below the threshold but still considered acceptable given the limited number of observed indicators.

Regarding AVE, most latent factors obtained values of 0.50 or above, suggesting that the observed variables explain a substantial proportion of variance in their corresponding latent constructs and thus supporting convergent validity. Only the factor PCI reported an AVE of 0.48, slightly below the recommended cut-off of 0.50. Nevertheless, given that all standardized factor loadings exceeded 0.50 and CR was close to the recommended level, the construct was retained. Overall, the results indicate that the six latent factors demonstrate acceptable reliability and convergent validity for subsequent structural analysis.

Table 5 summarizes the goodness-of-fit indices for the CFA measurement model. The CMIN/df value of 1.305 is far below the cut-off of 3, indicating an excellent overall fit. The GFI value of 0.915 exceeds the recommended threshold of 0.90, suggesting that the model adequately reproduces the observed data structure. The CFI (0.968) and TLI (0.963) both surpass the more rigorous criterion of 0.95, demonstrating outstanding incremental fit. The RMSEA value of 0.033 falls well within the ideal range (<0.08), reflecting minimal approximation error. Taken together, these indices provide strong evidence that the CFA model exhibits an excellent level of goodness of fit.

Table 4. CR and AVE

Latent factor	No. of items	CR	AVE
SC	5	0.86	0.56
TCM	5	0.85	0.53
PE	4	0.80	0.51
MT	4	0.74	0.50
UTE	4	0.76	0.52
PCI	3	0.69	0.48

Table 5. Goodness-of-fit indices of the CFA model

No.	Fit index	Value	Threshold	Assessment
1	CMIN/df	1.305	<3	Excellent
2	GFI	0.915	≥0.90	Acceptable
3	CFI	0.968	≥0.90	Excellent
4	TLI	0.963	≥0.90	Excellent
5	RMSEA	0.033	≤0.08	Excellent
6	SRMR	0.046	≤0.08	Excellent

Results of the Fornell–Larcker matrix in Table 6 show that the square roots of AVE for all latent factors (ranging from 0.692 to 0.748) are greater than their corresponding inter-factor correlations. This indicates that each latent factor captures a distinct conceptual construct and does not overlap with the others. Therefore, the measurement model satisfies the discriminant validity requirement based on the Fornell–Larcker criterion [34].

The results collectively indicate that the CFA model demonstrates an excellent level of model fit. The model also shows strong reliability together with satisfactory convergent and discriminant validity according to international standards. Therefore, the measurement model fully meets the requirements to proceed to the subsequent SEM analysis.

Table 6. Fornell–Larcker matrix for discriminant validity assessment

Latent factor	$\sqrt{AVE}$	TCM	SC	MT	UTE	PE	PCI
TCM	0.728	0.728	0.148	0.142	0.034	0.007	0.172
SC	0.748	0.148	0.748	0.048	0.088	0.114	0.133
MT	0.707	0.142	0.048	0.707	0.019	0.111	0.151
UTE	0.721	0.034	0.088	0.019	0.721	–0.073	0.144
PE	0.714	0.007	0.114	0.111	–0.073	0.714	0.027
PCI	0.692	0.172	0.133	0.151	0.144	0.027	0.692

4.1.3. Structural equation modeling

After the measurement model was validated through CFA, the study proceeded to apply SEM to test the hypotheses regarding the relationships between the five predictor latent factors and the dependent latent factor (PE). The structural model demonstrated an acceptable level of fit to the data. The RMSEA was 0.066 and the SRMR was 0.073, both within recommended thresholds. The incremental fit indices were slightly below the conventional 0.90 cutoff (CFI=0.868; TLI=0.878). Nevertheless, SEM model evaluation typically relies on multiple fit indices rather than a single criterion. Considering that the absolute fit indices (RMSEA and SRMR) fall within acceptable ranges, the overall model can still be regarded as demonstrating an acceptable level of fit for hypothesis testing.

Table 7 presents the standardized regression coefficients and the corresponding statistical significance for each hypothesized path. The key indicator for determining statistical significance is the critical ratio (C.R.), calculated as the ratio of the parameter estimate to its standard error. According to conventional criteria, a path is statistically significant when $|C.R.| \geq 1.96$ at $p<.05$, indicating that the coefficient differs from zero in a meaningful way and thus supports the hypothesized structural relationship in the model.

The results show that only two latent factors exert a direct and statistically significant influence on PE, namely MT and SC. The remaining three factors are not statistically significant, suggesting that their effects may be indirect or that the corresponding measurement scales may require refinement in future studies to improve their explanatory power. Table 8 summarizes the hypothesis-testing results of the SEM analysis.

Table 7. Standardized regression coefficients in the SEM model

Hypothesized relationship	Code	Standardized estimate (β)	C.R.	p-value	Conclusion
MT → PE	H3	0.644	2.204	0.028	Significant (+)
SC → PE	H1	0.653	2.237	0.025	Significant (+)
UTE → PE	H4	-0.474	-1.496	0.135	Not significant
PCI → PE	H5	-0.122	-0.332	0.740	Not significant
TCM → PE	H2	-0.160	-0.665	0.506	Not significant

Table 8. Summary of SEM hypothesis testing results

Hypothesis code	Hypothesized statement	Test result	Conclusion
H3	MT positively influence PE.	β=0.644; C.R.=2.204; p=0.028	Supported
H1	SC positively influence PE.	β=0.653; C.R.=2.237; p=0.025	Supported
H4	UTE positively influence PE.	β=-0.474; C.R.=-1.496; p=0.135	Not supported
H5	PCI positively influence PE.	β=-0.122; C.R.=-0.332; p=0.740	Not supported
H2	TCM positively influence PE.	β=-0.160; C.R.=-0.665; p=0.506	Not supported

The SEM results indicate that MT and SC are the only two latent factors exerting a direct and statistically significant influence on PE. This finding is consistent with a substantial body of international research highlighting the central role of mentor teachers in supporting, observing, providing feedback, and creating learning opportunities for pre-service teachers during practicum placements [6], [15]. At the same time, student-related attributes–such as professional motivation, self-efficacy, and pedagogical competence–also emerge as important predictors, reflecting the active and self-regulated role of pre-service teachers in the practicum process.

In contrast, the other three latent factors–TCM, UTE, and PCI–do not show statistically significant direct effects on PE in the SEM model. However, this result does not imply that these factors are unimportant. In teacher education literature, the practicum curriculum, university supervision, and the broader practicum environment are consistently regarded as foundational conditions shaping pre-service teachers' preparedness and competence development. These factors may function as enabling or contextual conditions rather than direct predictors within the current model specification. However, examining potential mediation mechanisms was beyond the theoretical scope of the present study. Therefore, further studies employing expanded structural models, including potential mediating or moderating mechanisms, are needed to clarify the pathways through which TCM, UTE, and PCI contribute to PE. Such extended models may capture more nuanced relationships and better reflect the complex, multi-layered nature of practicum experiences.

4.2. Discussion

4.2.1. Validity of the measurement model (CFA): structural soundness and reliability of the six latent factors

The CFA results demonstrate that the measurement model achieved an excellent level of fit (CMIN/df=1.305; GFI=0.915; CFI=0.968; TLI=0.963; RMSEA=0.033; SRMR=0.046), fully satisfying the criteria recommended by Hair *et al.* [32], and Kline [33]. All standardized factor loadings exceeded 0.50. CR values ranged from 0.69 to 0.86. Five constructs achieved CR values above the recommended threshold of 0.70, whereas PCI showed a slightly lower CR of 0.69, which is marginally below the suggested cutoff. AVE values ranged from 0.48 to 0.56. Most constructs exceeded the recommended threshold of 0.50; however, PCI yielded an AVE of 0.48, slightly below the criterion. Despite this, its CR approached 0.70, suggesting that the convergent validity of this construct is acceptable though somewhat weaker compared to the others. The Fornell–Larcker criterion was satisfied, as the square roots of AVE for each construct were greater than the corresponding inter-construct correlations, indicating adequate discriminant validity among the six latent constructs.

These findings are aligned with the theoretical synthesis presented in the literature review. The practicum experience consists of relatively distinct components, including SC [11], [19], mentoring support from school-based teachers [17], [24], and supervision by university-based educators [27], [28]. It also involves the quality of the practicum environment [23] and the structure of the practicum curriculum [12], [15].

The fact that no observed variable was removed indicates that the instrument was appropriately refined and accurately captures the conceptual domains supported by the literature on workplace learning [26] and practicum-based professional learning [16]. Thus, the measurement model demonstrates high stability and provides a robust foundation for SEM analysis. Unlike many previous studies that examined these practicum components separately, the present study operationalizes them simultaneously within a unified measurement framework. This integrated specification enables a more systematic examination of how relational, individual, and institutional dimensions coexist within the practicum system.

4.2.2. Discussion of the structural model (SEM): interpretation of significant and non-significant effects

The SEM results reveal that two latent factors exerted direct and statistically significant effects on PE: MT (β=0.644; p=0.028) and SC (β=0.653; p=0.025). The remaining factors–TCM, UTE, and PCI–did not show significant direct effects. The magnitude of these standardized coefficients indicates moderate-to-large effects, suggesting that these two factors represent the most influential direct predictors in the structural model.

It should also be noted that several predictors (TCM, UTE, and PCI) yielded negative but statistically insignificant coefficients. These coefficients should not be interpreted as evidence of negative causal relationships with PE. In SEM, insignificant coefficients indicate that the data do not provide sufficient statistical support for a reliable effect in the specified structural model. The negative signs may reflect sampling variability or statistical overlap among predictors rather than substantive inverse relationships. Therefore, these paths should be interpreted as statistically inconclusive within the current direct-effects specification.

The prominence of MT suggests that PE in mathematics teacher education may depend more strongly on relational dynamics within school contexts than on structural arrangements alone. This finding supports perspectives in workplace learning theory which emphasize situated interaction and guided participation as central mechanisms of professional development [23], [26]. In the context of mathematics education, where PCK is enacted through real classroom exchanges, mentoring interactions may function as the primary site of professional knowledge transformation rather than merely as supplementary support [13]. Conceptually, this shifts attention from program design to enacted mentoring practice.

Similarly, the significant role of SC indicates that PE is not solely determined by institutional inputs but is shaped by pre-service teachers' dispositions, beliefs, and reflective capacities. Rather than viewing practicum as a uniformly structured experience, the results suggest that individual agency mediates how professional opportunities are utilized. This aligns with perspectives emphasizing teacher identity formation and reflective engagement as central to professional learning [7], [11], [19], [20]. From a conceptual standpoint, PE appears to emerge from the interaction between contextual support and individual readiness.

The absence of significant direct effects for TCM, UTE, and PCI does not negate their importance but may indicate that these institutional and structural dimensions operate as enabling conditions rather than immediate predictors. In the context of Vietnam's 2018 General Education Curriculum–which emphasizes competency-based teaching, learner-centered pedagogy, and professional autonomy–structural alignment alone may be insufficient if not accompanied by strong mentoring interaction and active professional engagement by pre-service teachers. Institutional coherence may create necessary conditions, yet relational and personal factors appear to determine whether these conditions translate into meaningful professional learning outcomes.

Compared with earlier studies that emphasized structural features of practicum quality–such as curriculum organization, institutional supervision, and competency development–these findings suggest a more differentiated pattern of influence. Structural arrangements appear to provide the institutional framework for practicum learning, whereas relational mentoring processes and the agency of pre-service teachers function as the immediate mechanisms through which professional learning outcomes are realized. This distinction helps explain why institutional variables may not emerge as direct predictors in the structural model despite their recognized importance in the teacher education literature.

It is important to emphasize that the present model was designed to test direct structural relationships. Potential mediating or moderating mechanisms were not formally examined. Therefore, the absence of significant direct effects should be interpreted strictly within the direct-effect structural specification adopted in this study. Future research may explore whether institutional structures indirectly influence PE through SC or mentoring quality, particularly within reform-driven teacher education systems.

Overall, the findings suggest that PE in mathematics teacher education is shaped primarily by relational and agentic dimensions. Institutional reforms and structural arrangements may provide a framework, but professional learning appears to be realized through interaction and individual engagement within authentic classroom contexts. The absence of significant direct effects for certain predictors should not be interpreted as evidence of indirect mechanisms. Since the model was not theoretically specified as a mediation framework, indirect effects were not examined in this study.

4.2.3. Theoretical contribution

This study contributes to the theoretical understanding of PE in teacher education by proposing an integrated explanatory model. The model is empirically validated and simultaneously examines the individual characteristics of pre-service teachers, relational mentoring processes in schools, and the institutional conditions of teacher education programs. By testing a structural model comprising six latent factors, the study clarifies the relative roles of these dimensions in shaping PE in mathematics teacher education.

First, the findings refine theoretical perspectives on workplace learning and practicum-based professional learning by indicating that relational mentoring processes and pre-service teacher agency are closely associated with professional learning during the practicum. The significant effects of MT and SC suggest that PE is related to situated interaction and reflective engagement within authentic classroom contexts, which are emphasized in workplace learning theory and studies on teacher identity formation [7], [11], [19], [20], [23], [26]. Second, the study extends mentoring-based perspectives in teacher education by distinguishing between factors that directly relate to pre-service teachers' practicum experiences and broader institutional structures of teacher education programs. While mentoring support and individual dispositions show direct effects in the structural model, institutional components such as the training curriculum, university-based supervision, and institutional coordination do not exhibit direct effects. Third, the study integrates insights from workplace learning, mentoring in practicum settings, and institutional perspectives on teacher preparation into a unified analytical framework. By examining these dimensions within a structural model, the study contributes to a clearer conceptualization of PE as an outcome associated with the interaction between contextual support and pre-service teacher agency.

4.2.4. Practical implications

The findings carry implications for teacher education practice and policy. First, strengthening the professional capacity of MT should be prioritized. Structured mentor training, clear mentoring guidelines, and mechanisms for sustained pedagogical dialogue may enhance PE. Second, teacher education programs should invest in developing pre-service teachers' reflective capacity, professional identity, and instructional confidence prior to and during the practicum. This may involve integrating structured reflection tasks, peer discussion, and supervised lesson analysis. Third, within the framework of the 2018 General Education Reform, policymakers should recognize that curriculum alignment and institutional coordination are necessary but not sufficient conditions. Reform implementation should be accompanied by attention to relational mentoring quality and the cultivation of student agency to ensure that structural changes translate into professional learning gains.

5. CONCLUSION

This study developed and tested a structural model explaining PE among mathematics pre-service teachers in Vietnam. The results show that PE is mainly associated with mentor support and SC. In contrast, institutional and structural factors do not demonstrate direct effects within the tested model. These findings contribute to the ongoing academic discussion on practicum quality in reform-oriented teacher education contexts. They suggest that PE may depend less on structural design and more on relational interaction and individual engagement. In particular, the results emphasize the importance of enacted mentoring practices and the active role of pre-service teachers in transforming institutional frameworks into meaningful professional learning.

Future research may extend the present model by examining potential mediating and moderating relationships among institutional, relational, and individual dimensions. Longitudinal research designs may provide deeper insight into how these factors evolve over time during teacher preparation. Comparative studies across different teacher education systems may also help clarify how structural reforms interact with professional learning processes in diverse contexts.

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

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY

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

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