STEM teaching competency framework for pre-service teacher: a study in Vietnam

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ABSTRACT

Science, technology, engineering, and mathematics (STEM) education has been emphasized in Vietnam's new general education curriculum; however, the teaching competencies of pre-service teachers in this area remain underexplored. This study addresses that gap by proposing and validating a STEM teaching competency framework tailored for pre-service teachers. A mixed-methods approach was employed, including literature review, expert interviews, and surveys. The sample consisted of 400 participants—pre-service teachers, in-service teachers, and lecturers—selected through stratified random sampling. Data were collected using questionnaires and analyzed with SPSS 24. Reliability was confirmed using Cronbach's alpha (0.724) and construct validity was assessed through exploratory factor analysis (EFA). Results indicate that pre-service teachers face challenges in interdisciplinary integration, classroom organization, and technology application. The proposed framework includes five key domains: understanding STEM education, designing integrated lessons, organizing learning environments, implementing instruction, and evaluating and improving teaching practices. This study offers a reliable and practical tool to assess and enhance STEM teaching competencies. Its novelty lies in contextualizing competencies for pre-service teachers in Vietnam. The framework has practical implications for teacher training programs and policy development, and further application across teacher education institutions is recommended.

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1. INTRODUCTION

In the context of globalization and the rapid development of science, technology, engineering, and mathematics (STEM), STEM education has become a priority in many education systems around the world. Developed countries, such as the United States, Germany, the United Kingdom, and South Korea have integrated STEM into their curricula to equip students with the necessary skills to meet the demands of the fourth industrial revolution [1], [2]. STEM education not only provides specialized knowledge but also develops critical thinking, creativity, problem-solving, and teamwork skills–essential skills in the 21st century [3]. Many studies affirm that STEM education promotes innovation and sustainable economic development [4]. Countries that heavily invest in STEM have a high-skilled labor force, increased competitiveness, and economic innovation [5]. In Asia, South Korea and Singapore are promoting STEM education to train a high-quality workforce that meets the global labor market [6], [7]. STEM education in

Vietnam has been encouraged by the Ministry of Education and Training (MoET) to be implemented in the new general education curriculum according to Official Dispatch No. 3089/BGDĐT-GDTrH in 2020. The incorporation of STEM into general education is an important step in educational reform, helping to develop students' competencies instead of merely focusing on imparting theoretical knowledge [8]. The forms of organizing STEM education in Vietnam include teaching science subjects through STEM lessons, organizing STEM experiential activities, and conducting scientific and technical research activities for students. STEM education is not only applied at the high school level but also extends to elementary and middle school levels to build a solid foundation for students in accessing and applying STEM knowledge in practice [9].

However, one of the challenges for STEM education in Vietnam is the shortage of teachers capable of teaching STEM [10]. Although STEM education has been widely promoted, the training of teachers, the design of curricula, and learning materials still have many limitations [11], [12]. The success of STEM education depends on teachers' ability to design and organize effective integrated STEM teaching activities. The STEM teaching competence of teachers is identified as a crucial factor determining the effectiveness of STEM education implementation in secondary schools [9]. Teachers need to have the ability to integrate STEM knowledge, design lesson plans, organize practical-oriented learning activities, and assess students using innovative methods [13]. International studies indicate that teachers' STEM teaching competence includes three main components: STEM subject knowledge, pedagogical skills in integrated teaching, and the ability to use technology and modern teaching methods [14].

Many studies in Vietnam have proposed STEM teaching competency frameworks for secondary school teachers and pedagogy students, contributing to the training and professional development of teachers in the context of an expanding STEM education movement. However, most of these studies have primarily focused on in-service teachers or individual subject areas and often lack a comprehensive, empirically validated framework tailored to the needs of pre-service teacher education. These fragmented efforts reveal a critical gap in equipping future educators with the competencies required to design and implement integrated STEM instruction. To address this gap, the present study seeks to answer the following research questions:

- What are the essential components of a STEM teaching competency framework for pre-service teachers in Vietnam?
- What is the underlying structure of such a framework?

The results of this study are expected to provide a foundational basis for curriculum development and the design of professional training programs in teacher education institutions.

2. METHOD

This study employed a mixed-methods research approach, synthesizing and analyzing previous international, and domestic studies on STEM teaching competencies. The design combines qualitative synthesis with quantitative survey methods to ensure comprehensive and accurate evaluation of pre-service teachers' competencies. The participants include three key groups: pre-service teachers, in-service teachers, and training management staff. These groups were selected to represent various perspectives in STEM teacher development. A structured questionnaire was used to assess the feasibility of a proposed competency framework. The instrument consisted of 25 items aligned with five main competency groups and utilized a 5-point Likert scale (1=very unsuitable to 5=very suitable) [15]. To test reliability, the Cronbach's alpha coefficient was applied. A score between 0.7–0.8 was considered acceptable. If above 0.9, it could indicate item redundancy [16]. Based on the theoretical overview and the current state of STEM education, the research identifies aspects that need to be further investigated regarding STEM teaching competence. To collect data, the research team designed a survey questionnaire and an interview question set aligned with the set objectives. Quantitative data were processed using descriptive statistical methods to analyze trends and general characteristics, while qualitative data were content-analyzed to clarify teachers' perspectives and experiences. From the collected results, the study draws conclusions about the current state of STEM teaching capacity and proposes improvement solutions, contributing to enhancing the quality of STEM education in practice [15], [17].

3. RESULTS AND DISCUSSION

3.1. Overview STEM teaching competency framework in Vietnam and globally

STEM teaching competence is the combination of subject knowledge, pedagogical skills, and the ability to apply technology to effectively teach STEM topics [3]. STEM teachers need to be able to organize interdisciplinary learning activities, helping students solve real-world problems by applying principles of STEM [18], [19]. Many studies indicate in Vietnam that general education teachers still face difficulties in teaching according to the STEM model due to limitations in interdisciplinary knowledge and innovative teaching methods [20]–[24]. The STEM teaching competency of teachers is understood as the ability to design, organize, and effectively implement STEM activities, combining specialized knowledge with pedagogical skills. The development of the STEM teaching competency framework helps teachers have a specific direction to enhance their own competencies and effectively apply them in educational practice [20], [21], [25]. There is a growing need for teacher education in Vietnam to integrate local community knowledge, as community members perceive K-12 teachers to possess insufficient subject matter expertise and to rely on rigid, traditional pedagogical practices. Collaborative engagement among community members, teacher educators, teacher candidates, and in-service teachers is suggested as a means to enhance the quality of teaching and teacher education [26].

Research agrees that to teach STEM effectively, teachers need to develop specific competencies, including knowledge, skills, and attitudes in STEM education. Yu *et al.* [27] proposed a framework for STEM teaching competencies for teachers in the 6th-grade engineering subject, consisting of seven directions: conceptual knowledge of engineering, technical skills, knowledge of the engineering industry, pedagogical content knowledge of engineering, attitudes towards engineering, attitudes towards teaching the engineering subject, and integrating engineering with other subjects. Each of these directions includes many component competencies and criteria, contributing to the specific requirements for STEM teachers.

Song [14], [28] proposed a framework for STEM teaching competencies of teachers in South Korea, which includes three main components: cognitive competencies, teaching skills, and attitudes. Cognitive competence is demonstrated through the ability to link subjects, understand the concept of STEM integration, create based on interdisciplinary knowledge, think flexibly, master STEM knowledge, understand practical science and technology, and identify multifaceted issues. Teaching skills include diverse assessments, guiding information technology, building project-based programs, centering on students, granting autonomy, playing a supportive role, encouraging the connection of science and technology, and applying knowledge to real-life situations. A positive attitude is reflected in trust in students, collaboration among teachers, breaking down subject boundaries, self-assessment, overcoming anxiety about new knowledge, and proactively integrating STEM. The criteria for evaluating teaching competence in science, technology, engineering, arts, and mathematics (STEAM) education in South Korea were implemented [29]. The official criteria for evaluating teaching competence in STEAM education consist of 35 criteria across seven component competencies: understanding of the subject matter (5 criteria); teaching and learning methods (8 criteria); promoting learner engagement (5 criteria); understanding of learners (4 criteria); learning environment and context (5 criteria); learner assessment (4 criteria); and personal growth (4 criteria).

A study [30] emphasizes the development of the STEAM competence model for teachers, with criteria focusing on the integration of information technology, the application of project-based learning methods, and creativity in teaching. Teacher are required to have not only expertise in their subject matter but also the capacity to amalgamate technology, pedagogy, and content knowledge (TPACK) to develop multidisciplinary STEM curricula [30]. Fundamental competencies encompass engineering design thinking, mathematical reasoning, technology expertise, and the ability for critical and creative thinking. Moreover, educators' self-efficacy in pedagogical design and their confidence in teaching STEM disciplines substantially affect their engagement and instructional efficacy. The research underscores the need of professional development initiatives centered on practical, real-world projects to augment these competencies and assist students in cultivating 21st-century skills, including problem-solving and innovation [31].

It can be seen that studies around the world have proposed frameworks for teachers' STEM teaching competencies, which identify STEM teaching competencies as comprising many component competencies and criteria. The main component competencies, include the ability to understand STEM education; pedagogical competencies (skills in designing programs, methods, and forms of STEM teaching, the ability to relate and integrate knowledge from STEM subjects, and assessment in STEM teaching); a positive attitude towards STEM teaching. Each component competency includes many specific criteria. The studies also employed various methods such as literature reviews, expert surveys, and factor analysis to establish STEM teaching competency frameworks. These competency frameworks are normative, serving as the basis for developing tools to assess teachers' STEM teaching competencies.

Some studies have proposed a STEM teaching competency framework specifically for secondary school teachers. Regarding the structure of competencies, most studies divide STEM teaching competencies into component competencies, each of which includes specific criteria. However, the number and names of the component competencies differ between studies. Research on STEM teaching competencies in Vietnam has been synthesized to provide a comprehensive overview of the existing frameworks and their implications for teacher education. Studies emphasize that STEM teaching competence is pivotal for the effective implementation of STEM education in secondary schools, highlighting the need for teachers to integrate interdisciplinary knowledge, design practical-oriented lesson plans, and employ innovative assessment methods [9]. Additionally, it indicates that Vietnamese general education teachers face challenges due to limited interdisciplinary knowledge and reliance on traditional pedagogical approaches, underscoring the necessity for a structured competency framework to guide teacher training [20], [22], [26], [32]–[34]. These studies propose frameworks that typically divide STEM teaching competencies into component groups, such as subject knowledge, pedagogical skills, and technology application, though the number and naming of these components vary across studies. For instance, another research suggests a framework tailored for secondary school teachers, focusing on the ability to design and organize STEM activities that foster student engagement and real-world problem-solving. Collectively, these findings highlight the critical role of well-defined competency frameworks in addressing the gaps in teacher preparation and enhancing the quality of STEM education in Vietnam [13], [20], [21], [25].

Upon analyzing domestic and international texts regarding STEM teaching competencies, the research team discerned the theoretical and practical underpinnings necessary to develop a competency framework. The theoretical foundation encompasses STEM teacher competency models, integrated pedagogical approaches, and the prerequisites of STEM education within the framework of educational innovation. The research team examines teacher training programs, assesses the current status of STEM education, and cites established teacher competency frameworks. The research team developed a framework for STEM teaching abilities for pre-service teacher in Vietnam.

3.2. Reliable STEM teaching competency framework

This study utilized a mixed-methods approach to comprehensively assess Vietnamese teachers' STEM teaching competencies. Responses from 400 participants were processed using SPSS version 24. A minimum sample of 384 was determined using Yamane's formula, with ±5% error margin at 95% confidence level [35]. Quantitative data from survey responses were analyzed calculating descriptive statistics such as frequency, percentage, mean, and standard deviation. The reliability of the competency scale was confirmed with a Cronbach's alpha coefficient of 0.724, indicating acceptable internal consistency [15], [16]. Exploratory factor analysis (EFA) identified that criteria NL1.3, NL1.4, and NL1.5 formed a single factor (eigenvalue=1.971, 65.692% variance), suggesting consolidation to reduce redundancy [36]. Qualitative data from expert interviews were thematically coded and analyzed, complementing quantitative findings to ensure objectivity and depth.

3.3. Distribution of scores and evaluation trends of the STEM teaching competency framework

The survey results presented in Tables 1 to 5 offer empirical insights into the effectiveness and areas of improvement of the proposed STEM teaching competency framework for Vietnamese pre-service teachers. This aligns with the study's objective to validate and optimize a context-specific competency structure. Table 1 shows that NL1.1 to NL1.7 (conception of STEM education) have moderate mean scores (2.99–3.09), indicating teachers' awareness of STEM concepts but limited mastery. This is consistent with the findings by Thuy *et al.* [13], which report similar difficulties in interdisciplinary integration. Table 2 highlights NL2.1 and NL2.5 as stronger points (mean>3.0), reflecting readiness in real-world problem identification and resource selection—competencies emphasized in Song's framework [14], [28] for Korean STEM teachers.

Table 3 uniform responses for NL3.1 to NL3.5 (mean ~2.97) reflect pre-service teachers' consistent but moderate confidence in organizing STEM classes. The high standard deviations shown in Table 4 (NL4.1–NL4.5) suggest varied abilities in implementing STEM activities. These findings highlight the need to improve flexibility and instructional guidance. This is aligned with Morze and Strutynska [30], who stress the importance of adaptive pedagogy in STEM.

Table 1. Descriptive statistics of the survey results on "the capacity to conceive concepts regarding STEM education"

Item	NL1.1	NL1.2	NL1.3	NL1.4	NL1.5	NL1.6	NL1.7
Mean	2.99	3.09	3.09	3.06	2.99	3.06	3.00
N	400	400	400	400	400	400	400
Std. Deviation	1.120	1.125	1.119	1.118	1.155	1.080	1.197

Table 2. Descriptive statistics of the survey results on "the capacity to formulate concepts on STEM education"

Item	NL2.1	NL2.2	NL2.3	NL2.4	NL2.5	NL2.6	NL2.7
Mean	3.06	3.04	3.05	2.99	3.08	2.99	3.01
N	400	400	400	400	400	400	400
Std. Deviation	1.085	1.118	1.084	1.160	1.129	1.150	1.180

Table 3. Descriptive statistics of the survey results on “the capacity to organize STEM classes”

Item	NL3.1	NL3.2	NL3.3	NL3.4	NL3.5
Mean	2.97	2.96	2.96	2.96	2.98
N	400	400	400	400	400
Std. Deviation	1.202	1.163	1.093	1.164	1.126

Table 4. Descriptive statistics of the survey results on “the capacity to execute STEM educational initiatives”

Item	NL4.1	NL4.2	NL4.3	NL4.4	NL4.5
Mean	3.04	2.99	2.94	3.10	3.10
N	400	400	400	400	400
Std. Deviation	1.149	1.157	1.141	1.140	1.187

Table 5 shows relatively lower scores for NL5.1 to NL5.4 (mean 2.84–2.96), indicating that reflection, adjustment, and assessment—key to lesson improvement—are underdeveloped. This supports the call for stronger evaluation-focused training, as emphasized by Kelley and Knowles [19]. The transition from implementation, as in Table 4, to evaluation, as in Table 5, underscores the iterative nature of STEM instruction, where teaching practice should directly inform feedback and framework refinement. These observations suggest the framework’s adaptability and reinforce the necessity of targeted interventions to support reflective teaching and formative assessment.

The framework effectively outlines essential STEM teaching competencies but highlights gaps in implementation and evaluation skills. Targeted improvements—especially in reflective assessment and adaptive instruction—are needed. Enhancing teacher training with practical experiences and formative evaluation will increase the framework’s relevance and impact in preparing competent STEM educators for Vietnam’s educational context.

Table 5. Descriptive statistics of the survey results on “the capacity to enhance, assess, and modify instruction”

Item	NL5.1	NL5.2	NL5.3	NL5.4	NL5.5
Mean	2.96	2.95	2.84	2.94	2.87
N	400	400	400	400	400
Std. Deviation	1.152	1.139	1.162	1.170	1.166

3.4. The reliability of the components in the STEM teaching competency framework

The reliability of the STEM teaching competency framework was evaluated using Cronbach’s alpha, a common metric to measure internal consistency among the items [16], [20], [21]. The overall coefficient was 0.724, exceeding the 0.7 threshold commonly accepted in educational research [16], [17], indicating acceptable internal consistency while allowing for diversity among items. To examine consistency within each competency group, Pearson correlation analysis was performed. In the domain “generating STEM education ideas,” NL1.1 to NL1.6 showed moderate to strong correlations ($r=0.429$–0.537, $p<0.01$), supporting their alignment with the intended construct. However, NL1.7 showed a weak correlation, suggesting its formulation should be revised [15], [18], [36].

Similarly, items in the domain of “designing STEM activities” also demonstrated strong internal consistency, aligning with Song’s framework [13], [14], [20], [21]. Meanwhile, lower correlations for NL5.1 and NL5.3 (in the assessment domain) point to the need for revision to ensure consistency. These findings emphasize that refining underperforming indicators is crucial for strengthening the framework’s reliability [19], [30].

3.5. Optimizing the STEM teaching competency framework

This study employed EFA to evaluate the structural coherence of the proposed STEM teaching competency framework for pre-service teachers in Vietnam. EFA is widely used in educational research to detect patterns among variables and consolidate related items into unified factors [36]. Using SPSS software and a correlation matrix, the researchers calculated initial eigenvalues, % of variance, and communalities to assess the explanatory power and representativeness of each item. Table 6 indicates that NL1.3, NL1.4, and NL1.5 loaded strongly on a single factor (eigenvalue=1.971, 65.692% variance), with communalities>0.64, suggesting a shared underlying construct. Consistent with Falloon *et al.* [18], such overlap implies content redundancy. Consequently, NL1.4 and NL1.5 were merged to streamline the framework. Consolidation to avoid duplicate content.

Table 6. EFA results for merging NL1.3, NL1.4, and NL1.5 into revised criterion NL1.3

Item	Initial	Extraction	Total	Initial eigenvalues		Extraction sums of squared loadings		Extraction sums of squared loadings
				% of variance	Cumulative %	Total	% of variance	Cumulative %
NL1.3	1.000	0.669	1.971	65.692	65.692	1.971	65.692	65.692
NL1.4	1.000	0.646	0.529	17.636	83.328			
NL1.5	1.000	0.656	0.500	16.672	100.000			

A similar pattern was observed in Table 7 with NL3.1 and NL3.2 (eigenvalue=1.503), related to classroom arrangement and resource selection, both showing high internal representation (communalities=0.751). The new criterion integrates spatial and material organization, aligning with the model proposed by Song [28]. Integrating these two criteria into one composite criterion helps reduce the load and increase coherence in the competency framework.

Table 8 shows NL3.3 and NL3.4 also loaded onto a single factor (eigenvalue=1.485), representing structured, safe material arrangement and interaction. Following Morze and Strutynska [30], the merged criterion emphasizes effective classroom management. The grouping is intended to better reflect the capacity to organize effective classroom environments in STEM contexts.

Table 9 reveals that NL5.3 and NL5.4, both related to reflection and evaluation, formed a strong factor (eigenvalue=1.470, 73.486% variance), indicating the need for integrated evaluative practices. These revisions reduce redundancy, improve clarity, and support the holistic development of teaching skills, as emphasized by Kelley and Knowles [19]. Combining these two criteria helps clarify the link between reflection and instructional improvement, and streamlines the assessment framework.

The revised framework, as shown in Table 10, now includes 25 criteria under 5 competency domains. Survey findings confirmed its relevance, particularly in areas of planning, organizing, and implementing STEM lessons. However, certain competencies, such as integrating transdisciplinary knowledge and digital tools, received lower correlation values, consistent with challenges cited in previous research [13], [20], [21], [26], [27]. This reflects a broader need to strengthen teacher training in these areas through targeted interventions and curriculum updates.

Table 7. EFA results for merging NL3.1 and NL3.2 into revised criterion NL3.1

Item	Initial	Extraction	Total	Initial eigenvalues		Extraction sums of squared loadings		Extraction sums of squared loadings
				% of variance	Cumulative %	Total	% of variance	Cumulative %
NL3.1	1.000	0.751	1.503	75.148	75.148	1.503	75.148	75.148
NL3.2	1.000	0.751	0.497	24.852	100.000			

Table 8. EFA results for merging NL3.3 and NL3.4 into revised criterion NL3.2

Item	Initial	Extraction	Total	Initial eigenvalues		Extraction sums of squared loadings		Extraction sums of squared loadings
				% of variance	Cumulative %	Total	% of variance	Cumulative %
NL3.3	1.000	0.743	1.485	74.275	74.275	1.485	74.275	75.275
NL3.4	1.000	0.743	0.515	25.725	100.000			

Table 9. EFA results for merging NL5.3 and NL5.4 into revised criterion NL5.3

Item	Initial	Extraction	Total	Initial eigenvalues		Extraction sums of squared loadings		Extraction sums of squared loadings
				% of variance	Cumulative %	Total	% of variance	Cumulative %
NL5.3	1.000	0.735	1.470	73.486	73.486	1.470	73.486	75.486
NL5.4	1.000	0.735	0.530	26.514	100.000			

3.6. Comparative evaluation of the proposed competency framework

EFA provided strong empirical evidence to refine the competency framework. The consolidation of overlapping items not only enhanced structural clarity but also increased the model's generalizability. This aligns with global trends in competency-based teacher education and supports Vietnam's strategic goals in educational innovation. The proposed STEM teaching competency framework was evaluated in relation to existing models in Vietnam and internationally to assess its coherence and relevance. Structurally, the framework comprises five competency domains and 25 indicators, which align with foundational elements highlighted in several studies [14], [27], [30], including interdisciplinary integration, pedagogical design, and reflective practice. Compared to frameworks developed in Vietnam [13], [20]–[22], [33], the current model demonstrates higher internal consistency and empirical validation. While Vietnamese models often focus on specific subjects or general descriptors, this study provides a systematic structure with clearly defined, observable indicators tailored to pre-service teacher training.

Notably, the framework addresses key gaps identified in previous research, such as the lack of integration between STEM content and pedagogy, limited use of educational technology, and underdeveloped assessment competencies. Its contextual design considers local educational reforms and pre-service training conditions in Vietnam. Therefore, the framework not only aligns with global standards but also contributes an innovative, culturally grounded model for enhancing the quality of STEM teacher education in emerging contexts.

Table 10. Revised STEM teaching competency framework for pre-service teachers in Vietnam

No	Competency	Competency indicators
[NL1]	The capacity to conceive concepts regarding STEM education	[NL1.1] Identify the role of STEM education in practical life issues. [NL1.2] Describe the objectives of STEM education in general education. [NL1.3] Analyze the relationship between the S.T.E.M components in the integrated STEM education. [NL1.4] Applying new trends and achievements in the STEM field. [NL1.5] Proposing methods to address practical issues in STEM education.
[NL2]	The capacity to formulate concepts on STEM education	[NL2.1] Identify practical issues for the STEM teaching topic. [NL2.2] Developing teaching objectives that align with practical issues for the STEM teaching theme. [NL2.3] Selecting teaching content that integrates STEM components. [NL2.4] Develop evaluation criteria that align with the objectives of the STEM teaching theme. [NL2.5] Selecting materials and teaching aids appropriate to the content and objectives of STEM education. [NL2.6] Choose teaching methods, processes, and assessment evaluation that align with the objectives and content of the STEM teaching topic. [NL2.7] Develop a lesson plan for the STEM teaching theme with appropriate teaching activities and assessment evaluations.
[NL3]	The capacity to organize STEM classes	[NL3.1] Organize the classroom environment to enhance instructional and evaluative activities in alignment with the STEM lesson plan. [NL3.3] Systematically arrange equipment and educational materials in a safe and suitable manner for STEM teaching and assessment activities. [NL3.3] Building positive interactive activities in the classroom environment. [NL3.4] Maintain and adjust a positive, safe, and suitable classroom environment after teaching and assessment activities.
[NL4]	The capacity to execute STEM educational initiatives	[NL4.1] Analyze the objectives, learning requirements, and content structure of the STEM teaching topic. [NL4.2] Flexibly use teaching methods, processes, and techniques, and encourage students to actively participate in teaching activities and assessments. [NL4.3] Effectively utilizing educational resources and technology to support teaching and assessment activities in the STEM education theme. [NL4.4] Guide students to explore, practice, and experience to solve problems in the STEM teaching topic. [NL4.5] Guiding students to get acquainted with scientific research.
[NL5]	The capacity to execute STEM educational initiatives	[NL5.1] Summary, systematization, conclusion of key knowledge and issues addressed in the STEM teaching topic. [NL5.2] Evaluate, comment, and provide feedback on the learning process and outcomes of students according to the criteria of the STEM teaching theme. [NL5.3] Evaluate the advantages, limitations, and draw lessons from the teaching and assessment activities according to the lesson plan. [NL5.4] Adjust and address the limitations in the design of content and lesson plans for the STEM teaching theme.

4. CONCLUSION

This study aimed to develop and validate a STEM teaching competency framework tailored for pre-service teachers in Vietnam. Through a mixed-methods approach incorporating expert consultation, surveys, and EFA, the research confirmed the internal consistency and construct validity of the proposed framework. The results highlighted five core competency domains and 25 indicators, addressing critical dimensions such as lesson design, classroom management, instructional implementation, and evaluation. However, certain areas, particularly the integration of interdisciplinary knowledge and technology, revealed lower reliability and remain challenging for pre-service teachers. These findings reflect the need for targeted enhancements in teacher training programs.

Therefore, it is concluded that while the framework provides a practical and reliable foundation for evaluating and developing STEM teaching competencies, further refinement is necessary. Future research should continue to improve its reliability, test its applicability across different educational levels, and explore its adaptability in under-resourced contexts. Comparative studies with countries possessing advanced STEM systems can offer deeper insights. Ultimately, the framework holds promise as a guiding tool for advancing STEM teacher preparation in line with the demands of 21st-century education.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
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Fo : **Fo**rmal analysis
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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.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

DATA AVAILABILITY

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

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