MINISTRY OF EDUCATION AND TRAINING
HO CHI MINH CITY UNIVERSITY OF TECHNOLOGY AND ENGINEERING

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DEVELOPING COMPETENCY IN ORGANIZING STEM EDUCATIONAL ACTIVITIES FOR PRE-SERVICE TEACHERS AT UNIVERSITIES IN HO CHI MINH CITY

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SUMMARY OF DOCTORAL DISSERTATION

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LIST OF PUBLISHED SCIENTIFIC ARTICLES

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Phan Nguyen Truc Phuong, Bui Van Hong, Dinh Van De (2024) *Applying the CDIO model in STEM lesson design.*. Vietnam Journal of Education, 24(11), 51–56.

Phan Nguyễn Trúc Phương, Bùi Văn Hồng, Đào Văn Phượng, Đinh Văn Đệ, Ngô Thị Tú Trinh, Nguyễn Quốc Tiệp (2024) *Enhancing the capacity of middle school teachers to guide scientific research on STEM education: situation and solutions.* Vietnam Journal of Education, 24(Số đặc biệt 8), 267-273.

Phan Nguyen Truc Phuong, Bui Van Hong, Dinh Van De. (2025). *Improving the Quality of Technology Teacher Training in the Context of Edu 5.0: Analyzing AI Application Trends and Proposing Curriculum Improvements.* Journal of Technical Education Science, 20 (Special Issue 01), 44–53. https://doi.org/10.54644/jte.2025.1667.

Phan Nguyen Truc Phuong, Bui Van Hong, Nguyen Thi Kim Oanh, Dinh Van De. (2026). *Developing a Training Program to Enhance AI-Integrated STEM Teaching Competence for Pre-Service Teachers*. Journal of Technical Education Science. 21 (02) 23-33 https://doi.org/10.54644/jte.2026.2041.

Phan Nguyen Truc Phuong, Bui Van Hong, Nguyen Viet Trung, Dinh Van De, Tran Phuong Vi, & Le Hoang Phuoc Hien (2025). Utilization of Artificial Intelligence in STEM education: A study in Vietnam. 2025 10th International STEM Education Conference (iSTEM-Ed), 1–6. https://doi.org/10.1109/iSTEM-Ed65612.2025.11129400

INTRODUCTION

1 RESEARCH RATIONALE

In the context of rapid advancements in science and technology, education is required to equip students with the knowledge and skills necessary to meet the demands of global integration. STEM education, which encompasses Science, Technology, Engineering, and Mathematics, is considered a vital direction in developing high-quality human resources (Sanders, 2009). Theoretically, STEM education is not merely a combination of isolated subjects but an interdisciplinary approach aimed at developing problem-solving capabilities and applying knowledge to practice (Breiner et al., 2012; Vu Thi Thuy & Le Thi Thu Hien, 2023).

In Vietnam, Resolution No. 57-NQ/TW, Resolution No. 71-NQ/TW, and the 2018 General Education Program have identified STEM education as a core task in educational reform, oriented toward developing learners' qualities and competencies (Central Committee of the Communist Party of Vietnam, 2025; Ministry of Education and Training, 2018, 2020, 2023b). However, current studies predominantly focus on K-12 teachers or surveying the perceptions of pre-service teachers, whereas empirical research on developing the competency to organize STEM educational activities for pre-service teachers remains limited (Ngo Hong Diep et al., 2023; Huynh Van Son, 2024).

Based on the aforementioned rationale, the study titled "Developing Competency in Organizing STEM Educational Activities for Pre-service Teachers at Universities in Ho Chi Minh City" has been selected as the research topic for this dissertation.

2 RESEARCH OBJECTIVES

To study the competency framework for organizing STEM educational activities, and based on this, to propose strategies for developing this competency for pre-service teachers at universities in Ho Chi Minh City.

3 RESEARCH OBJECTS

The competency of pre-service teachers in organizing STEM educational activities.

Approaches to developing the competency to organize STEM educational activities for pre-service teachers at universities in Ho Chi Minh City.

4 RESEARCH QUESTIONS

The study is guided by two primary research questions:

(1) What are the constituent components of the competency framework for organizing STEM educational activities for pre-service teachers?

(2) What approaches can effectively develop pre-service teachers' competency in organizing STEM educational activities based on the proposed framework?

5 RESEARCH SCOPE

- Theoretical scope: The study focuses exclusively on developing the competency to organize STEM educational activities for pre-service teachers currently enrolled at universities in Ho Chi Minh City.
- Geographical and empirical scope: The survey and experimental phases are conducted at universities that offer teacher education programs in STEM disciplines within Ho Chi Minh City .

6 RESEARCH METHODOLOGY

6.1 Data Collection Methods

6.1.1 Theoretical Research Method: (Literature review and theoretical analysis).

6.1.2 Survey Method

6.1.3 Interview Method

6.1.4 Experimental Method

6.2 Data Processing and Analysis Methods

6.2.1 Qualitative Data Analysis

6.2.2 Quantitative Data Analysis

7 THEORETICAL AND PRACTICAL SIGNIFICANCE OF THE DISSERTATION

7.1. Theoretical Contributions

The dissertation constructs a comprehensive competency framework for organizing STEM educational activities tailored to pre-service teachers in STEM disciplines. This framework is established by synthesizing theories of STEM education, integrated teaching, and competency-based instruction. Accordingly, the competency to organize STEM educational activities is defined as an integration of the knowledge, skills, and attitudes necessary to design, implement, and evaluate interdisciplinary STEM-oriented learning activities. The framework is structured into specific component competencies, accompanied by distinct evaluation criteria and indicators, thereby establishing a theoretical foundation for defining learning outcomes and developing STEM-related training content within teacher education curricula.

Based on the developed framework, the dissertation proposes a theoretical model to develop this competency for pre-service teachers. This development model is implemented through three main approaches:

- **(i)** Enhancing the STEM teaching capacity of university faculty;
- **(ii)** Reforming learning outcomes and training curricula; and
- **(iii)** Integrating STEM education into the specialized courses of pre-service teachers.

This approach contributes to perfecting the theoretical foundation for teacher education program development aligned with STEM education.

7.2. Practical Contributions

The dissertation validates the proposed competency framework through practical surveys involving university faculty, administrators, and pre-service teachers using mixed methods. Data analysis results indicate that the proposed framework aligns well with the requirements of teacher education in the current context of STEM education. Furthermore, the study evaluates the extent to which pre-service teachers meet the criteria within the framework, thereby highlighting the strengths and weaknesses in their competency development process.

The dissertation also conducts pedagogical experiments to evaluate the efficacy of the proposed intervention model. The experimental process is deployed by incorporating integrated STEM training content into the teacher education curriculum, including the course "STEM Instructional Design" and supplementary STEM content added to relevant modules. The experimental results demonstrate a significant improvement in pre-service teachers' competency to organize STEM educational activities after participating in the program, as evidenced by pre- and post-test assessment indicators. This confirms the effectiveness of the proposed intervention model in training pre-service teachers toward STEM-oriented education.

8. DISSERTATION STRUCTURE

The dissertation consists of the following structure:

- INTRODUCTION
- Chapter 1: Theoretical Foundations on Developing the Competency to Organize STEM Educational Activities for Pre-service Teachers
- Chapter 2: Research Methodology
- Chapter 3: Research Results and Discussion
- CONCLUSIONS – RECOMMENDATIONS
- REFERENCES
- APPENDIX

CHAPTER 1: THEORETICAL FOUNDATIONS ON DEVELOPING THE COMPETENCY TO ORGANIZE STEM EDUCATIONAL ACTIVITIES FOR PRE-SERVICE TEACHERS

1.1 RESEARCH OVERVIEW

1.1.1 Studies on STEM Educational Activities

Globally, STEM education is increasingly prioritized to prepare human resources for strategic sectors and drive economic growth. Numerous studies document the long-term benefits of this approach, including the development of scientific literacy, expansion of career opportunities, enhancement of academic competitiveness, and improvement of learning outcomes in related fields (English, 2016; Zahav & Hazzan, 2017). In the face of global challenges such as climate change or food security, cultivating a STEM-capable workforce has become a vital imperative for national competitiveness. Despite its widespread implementation, STEM approaches vary across different national contexts (Marginson et al., 2013).

Although significant milestones have been reached in implementing STEM education, educational quality remains an ongoing challenge that needs to be addressed to effectively support workforce development and sustain national competitiveness.

1.1.2 Studies on Pre-service Teachers' Competency to Organize STEM Educational Activities

Developing the competency to organize STEM educational activities for pre-service teachers has become an urgent demand in teacher training. Research shows a significant gap between theoretical awareness and the practical STEM pedagogical abilities of pre-service teachers. Despite holding positive attitudes toward STEM education, many pre-service teachers lack confidence in designing and organizing hands-on activities due to limitations in technical skills, technology familiarity, and field experience. The primary cause stems from teacher education programs that remain heavily theoretical, lacking opportunities for practical design and engineering experiences. However, empirical studies confirm that participating in experiential training programs, interdisciplinary learning, robotics, digital technology, and artificial intelligence applications can substantially elevate pre-service teachers' STEM teaching competency. Thus, training curricula need to be restructured toward integration, practice, and hands-on professional experiences.

1.1.3 Studies on Developing Pre-service Teachers' Competency to Organize STEM Educational Activities

Research indicates that developing STEM pedagogical competency positively impacts the formation of students' core qualities and capabilities. Concurrently, it requires teachers to transition from knowledge transmission to organizing experiential learning environments and facilitating knowledge construction (Bybee, 2013; Laurillard, 2012; Nguyen Thanh Hai, 2019). Although pre-service teachers possess positive perceptions of STEM education, they still face major constraints, such as a lack of interdisciplinary knowledge, integrated organizational skills, and practical experience (Lee et al., 2019; Shernoff et al., 2017). Consequently, scholars emphasize the necessity of developing specialized competency frameworks for pre-service teachers, encompassing STEM lesson design, teaching organization, assessment, and curriculum development (Berisha & Vula, 2021; Wu & Albion, 2019). Curricula must be restructured around integrated, experiential, and digitally active methods to optimize the effectiveness of organizing STEM educational activities.

1.1.4 Summary of Literature Review

Prior research has clarified the concepts, objectives, and contents of STEM education, as well as identified crucial competency groups for pre-service teachers, such as instructional design, activity organization, student assessment, and integrated curriculum development. The research trajectory in STEM education reveals a paradigm shift from asserting the strategic role of STEM in human resource development to building concrete models and programs to cultivate STEM competencies in pre-service teachers. In Vietnam, STEM education is progressively evolving from spontaneous, bottom-up activities to policy-driven mandates under the 2018 General Education Program. Inheriting these prior findings, this dissertation approaches STEM education from an interdisciplinary and integrated perspective, utilizing constructivism, experiential learning theory, integrated teaching, and STEM pedagogical frameworks to construct a comprehensive competency framework for pre-service teachers. However, most existing studies focus primarily on in-service teachers, leaving a significant gap in systematic frameworks tailored specifically for pre-service teachers during initial training. This is the exact research gap this dissertation aims to address.

1.2 KEY CONCEPTS USED IN THE RESEARCH

1.2.1 STEM Education

Synthesizing the explored definitions, STEM education within the scope of this dissertation is defined as follows:

> *"STEM education is an instructional approach based on an integrated, interdisciplinary method that guides students to apply Science, Technology, Engineering, and Mathematics knowledge to solve real-world problems in specific contexts, thereby developing student qualities, competencies, and career orientations."*

1.2.2 Competency to Organize STEM Educational Activities of Pre-service Teachers

Within the scope of this study:

> *"The competency to organize STEM educational activities is the synthesis of professional pedagogical qualities and skills that teachers must possess to effectively design, execute, and evaluate STEM educational activities in schools. This encompasses STEM lessons, STEM experiential activities, and scientific and technological research guidance."*

1.2.3 Developing the Competency to Organize STEM Educational Activities for Pre-service Teachers

Combining the definition in Section 1.2.2, developing this competency in pre-service teachers is understood as a targeted, structured educational process embedded within the teacher training curriculum. It aims to form, consolidate, and elevate a combination of qualities and skills that enable pre-service teachers to systematically design, instruct, manage, and evaluate the effectiveness of STEM activities in schools.

1.3 THEORETICAL BASIS OF COMPETENCY-BASED EDUCATION

1.3.1 Instructional Theories and Models

1.3.1.1 Constructivism Theory

1.3.1.2 Experiential Learning Theory

1.3.1.3 Integrated Teaching

1.3.1.4 Reflective Practice

Summary

Developing the competency to organize STEM activities for pre-service teachers is grounded in the synergistic relationships among foundational theories. Constructivist theory emphasizes the active agency of pre-service teachers in knowledge construction ; experiential learning and integrated teaching orient the organization of activities toward real-world and interdisciplinary contexts ; meanwhile, reflective practice enables pre-service teachers to self-evaluate and regulate their professional performance. The integration of these theories forms a continuous competency development cycle, serving as the baseline for constructing both the competency framework and the intervention model for pre-service teachers.

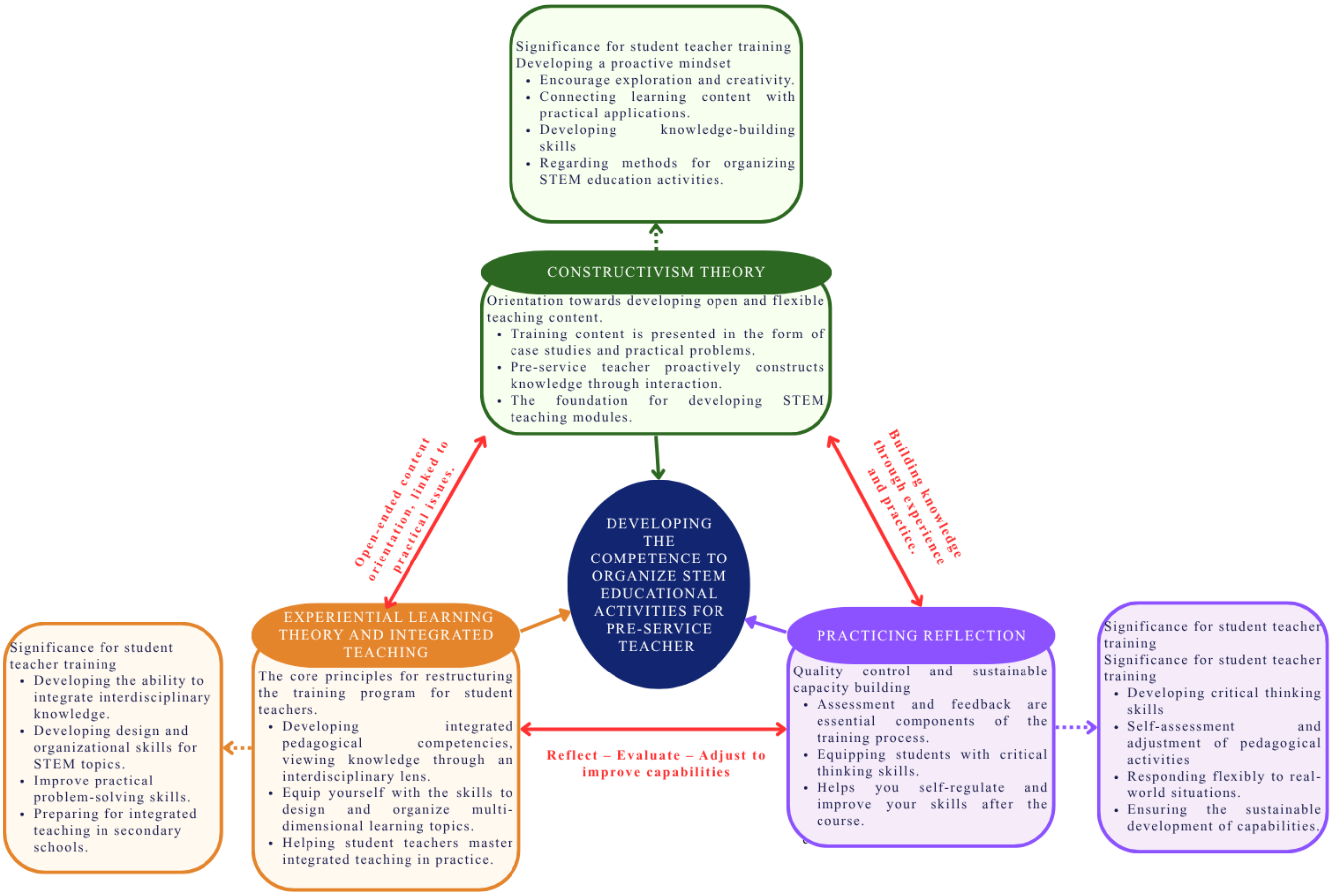

Figure 1.1: Theoretical Synergy Framework for Developing STEM Competency

1.3.2 Foundations of STEM Education and Organizing STEM Educational Activities

1.3.2.1 The CDIO Cycle in STEM Education

The CDIO (Conceive–Design–Implement–Operate) framework shares key parallels with STEM lesson design, as both emphasize real-world problem solving, interdisciplinary knowledge integration, creative development, and collaborative work (Crawley et al., 2014). CDIO links theory with practice, fostering creative thinking, problem-solving capabilities, and teamwork. These goals completely align with STEM education. Both approaches prioritize interdisciplinary capability and the application of knowledge to reality. For educators, the components of CDIO seamlessly align with the requirements of STEM teaching competencies. Thus, applying CDIO to STEM education represents a highly effective framework.

1.3.2.2 The STEM Cycle

Natural sciences, technology, and engineering are closely linked, utilizing mathematics as an essential tool. This relationship is operationalized through the STEM cycle.

1.3.2.3 Methods for Organizing STEM Activities

The tight integration of STEM disciplines represented in the STEM cycle serves as the baseline for implementing school-level STEM education via interdisciplinary integration - the main model mandated in the 2018 General Education Program.

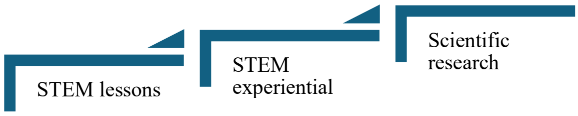

Figure 1.2: Core implementation forms of STEM education in schools (Ministry of Education and Training, 2020)

1.3.2.4. STEM Lesson Design

Drawing from standard STEM lesson design steps, integrated with the CDIO and STEM cycles, the STEM lesson design process is structured into five distinct phases:

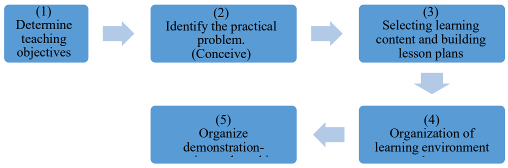

Figure 1.3: Five-step CDIO-based STEM lesson design process

1.3.3 Foundations of Teacher Education Curricula

1.3.3.1 Characteristics of the Higher Education Instructional Process

The university-level instructional process must create rich pedagogical environments that allow pre-service teachers to experience roles as both learners and teachers, thereby constructing the capacity to organize, design, and assess educational activities in their future careers.

1.3.3.2 Cognitive Characteristics of Pre-service Teachers

Upper-year pre-service teachers engage more deeply with specialized, professional modules, positioning them with a more favorable cognitive foundation to adopt STEM education compared to first-year students.

1.3.3.3 Teacher Education Curriculum

Currently, pre-service teacher training in Vietnamese universities is organized primarily under two models: the parallel model and the sequential model.

1.4 DEVELOPING COMPETENCY IN ORGANIZING STEM EDUCATIONAL ACTIVITIES FOR PRE-SERVICE TEACHERS

1.4.1 Competency to Organize STEM Educational Activities of Pre-service Teachers

1.4.1.1 Characteristics

1.4.1.2 Component Structure of the Competency to Organize STEM Educational Activities

Research on STEM education points out the critical need to clarify the component structure of pre-service teachers' STEM teaching competency. Although scholars approach this from various angles, there is a consensus that STEM pedagogical competency is a multi-dimensional construct. It integrates disciplinary content knowledge, pedagogical knowledge, technological knowledge, lesson design skills, assessment capabilities, and positive professional attitudes toward STEM.

1.4.1.3 Assessment Criteria for the Competency to Organize STEM Educational Activities

The assessment criteria system is designed to align closely with core component competencies. Each criterion in the assessment rubric is categorized into five developmental levels, from basic to advanced. This structured rubric ensures objective, fair measurement and provides a practical framework for assessing pre-service teachers' performance in realistic settings.

1.4.2 Pathways to Develop the Competency to Organize STEM Educational Activities for Pre-service Teachers

Developing the competency to organize STEM activities does not rely solely on the pre-service teacher's individual effort. Rather, it is the result of systematic interaction among input variables, validated and adjusted through continuous assessment and feedback mechanisms, securing educational sustainability and quality. Figure 1.4 illustrates the comprehensive intervention model.

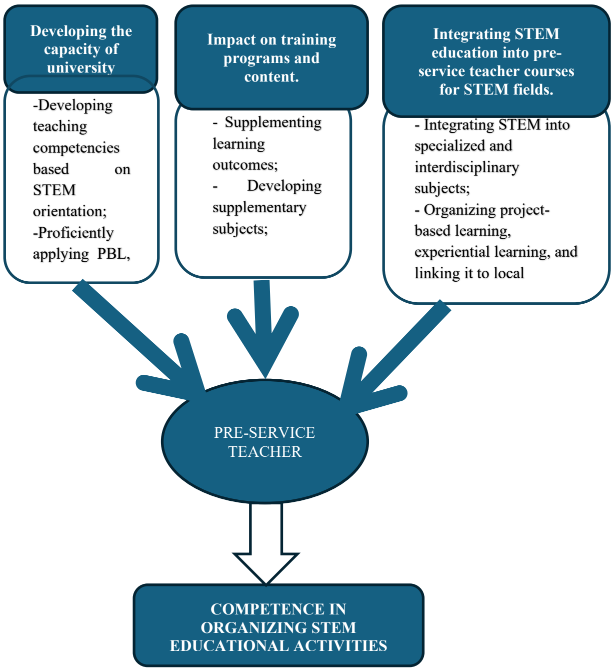

Figure 1.4: Intervention model for developing the competency to organize STEM educational activities

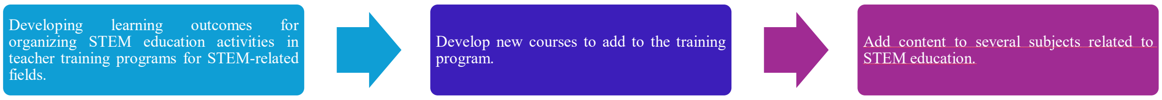

Figure 1.5: Methodological steps in developing STEM activity organization competency

1.4.3 Evaluation of the Competency to Organize STEM Educational Activities of Pre-service Teachers

The research design identifies a set of independent variables, including the training curriculum, institutional facilities, practical training activities, and STEM perceptions.

The dependent variable is the development level of the pre-service teachers' competency to organize STEM activities, measured across design, organization, implementation, and evaluation components.

CHAPTER 1 CONCLUSION

Chapter 1 establishes the theoretical foundation for developing pre-service teachers' competency in organizing STEM educational activities. Synthesizing international and domestic literature, the chapter defines STEM education as an integrated, interdisciplinary approach designed to foster students' core competencies. The conceptual definitions of STEM education, organizational competency, and teacher training pathways are systematically defined as an integration of interdisciplinary knowledge, pedagogical skills, and professional attitudes. The chapter connects constructivism, experiential learning, integrated teaching, and reflective practice as the theoretical baseline for the proposed competency framework and intervention model.

CHAPTER 2: RESEARCH METHODOLOGY

2.1 RESEARCH DESIGN

2.1.1 Research Objectives

To design and conduct a systematic empirical study using surveys and interviews to validate the structure of the proposed competency framework, and to execute a pedagogical experiment to verify the efficacy and feasibility of the proposed intervention model.

2.1.2 Research Content

The research of this dissertation is focused on:

1. Building and validating the competency framework for organizing STEM educational activities;
2. Implementing a pedagogical experiment to verify the effectiveness and feasibility of the proposed intervention model.

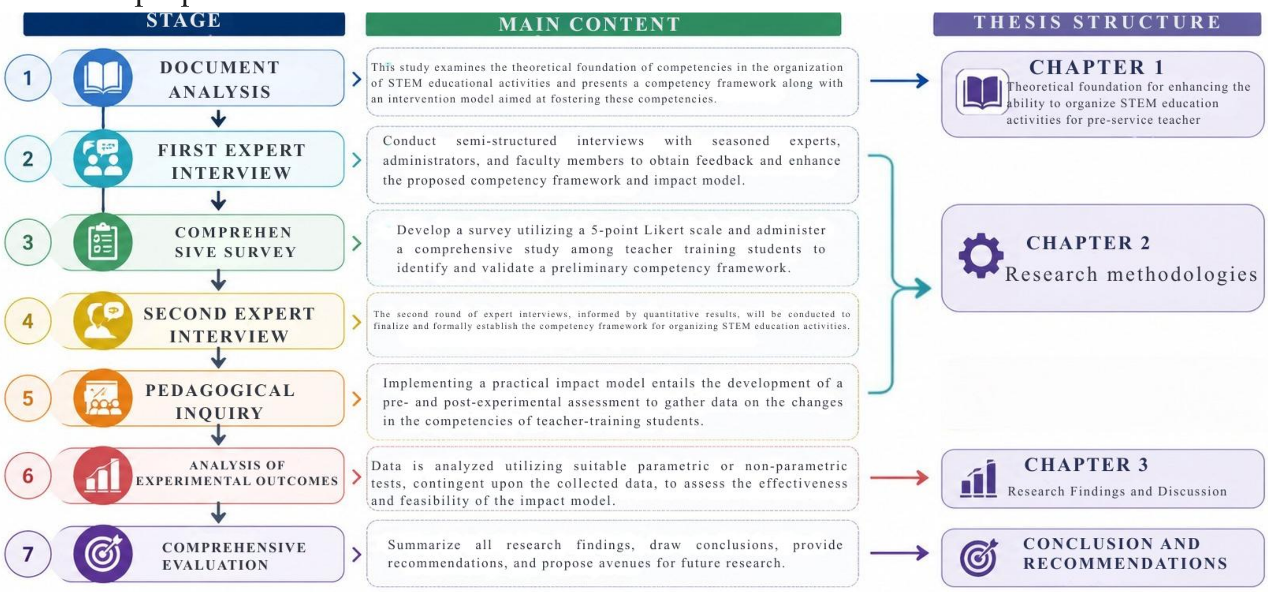

Figure 2.1: Flowchart of the research design

Figure 2.1 shows the logical and coherent stages, corresponding to the content chapters in the thesis, aimed at addressing the goal of developing STEM educational activity organization skills for pre-service teachers: (1) Literature research; (2) First expert interview; (3) Large-scale survey; (4) Second expert interview to finalize and officially establish the STEM development competency framework; (5) Pedagogical experiment; (6) Analysis of experimental results; (7) Overall evaluation of all research results, thereby making suggestions and directions for further research.

2.1.2.1 Interview Content

2.1.2.2 Survey Content

2.1.2.3 Experimental Content

2.1.3 Participants and Scope of the Survey, Interview, and Experiment

The research sample was selected using purposive sampling combined with convenience sampling to ensure alignment with the research objectives and the logistical conditions of the experiment, while accurately reflecting the target population: pre-service teachers across STEM disciplines who have participated in courses related to instructional design or STEM education. The research participants comprise three main groups:

- Survey Group: Includes 2nd- to 4th-year pre-service STEM teachers, educational researchers, and university faculty members directly involved in teaching courses related to STEM education or instructional organization and design.
- Interview Group: Comprises researchers in the field of STEM education, university faculty members directly teaching courses related to STEM education or instructional design, and educational administrators.
- Experimental Group: Consists of classes of 2nd- to 4th-year pre-service STEM teachers at selected universities in Ho Chi Minh City, assigned to the experimental group based on classroom organizational feasibility and baseline competency equivalence.

2.1.4 Research Timeline and Locations

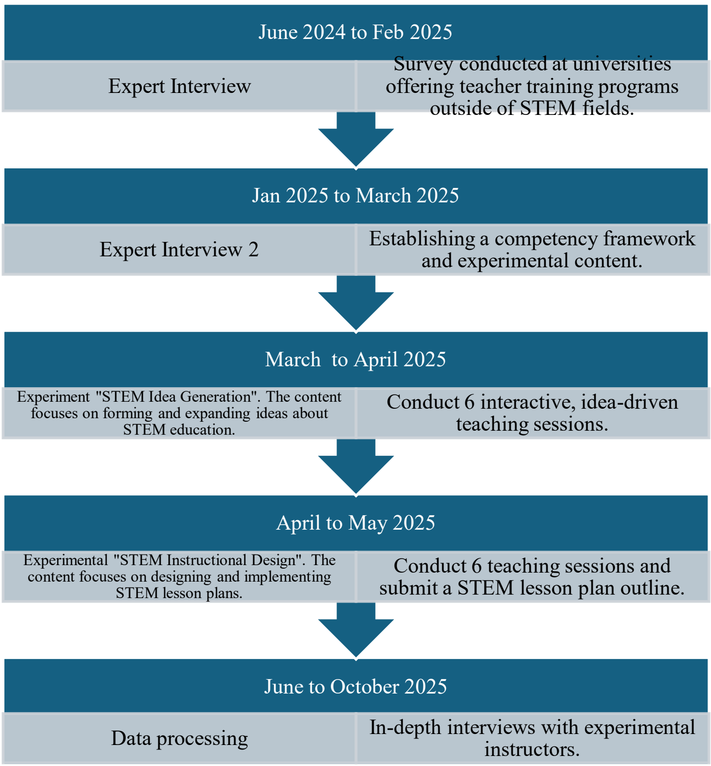

Figure 2.2: Research timeline and distribution

2.1.5 Sampling Methods for Surveys, Interviews, and Experiments

Following Cohen (2013) on experimental designs, the pedagogical experiment was executed with N = 180 pre-service teachers, subdivided into smaller groups of 20 to 25 students to maximize instructional efficacy and statistical reliability. All participating instructors underwent standardized training before the experiment. Pre-test and post-test assessments across majors were applied to improve data reliability and generalization.

2.1.6 Research Methods

This study utilizes a mixed-methods design, combining qualitative and quantitative approaches to ensure comprehensiveness, reliability, and analytical depth.

2.1.6.1 Data Collection Methods

a) Interview Method: Semi-structured interviews to obtain deep qualitative insights from experts and administrators.

b) Survey Method: Large-scale surveys using Likert-scale questionnaires to measure competencies and perceptions.

c) Experimental Method: Pedagogical intervention using a single-group pre-test/post-test model.

2.1.6.2 Data Analysis Methods

a) Qualitative Data Analysis: Thematic analysis to synthesize and code interview transcriptions.

b) Quantitative Data Analysis: Descriptive and inferential statistics using SPSS and AMOS, including Cronbach's Alpha, Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), paired T-tests, Wilcoxon signed-rank tests, ANOVA, and Kruskal-Wallis tests.

2.1.7 Research Instruments

To gather valid, objective, and accurate data, multiple instruments were designed, validated by experts, and pilot-tested:

2.1.7.1 Instrument Types: Survey questionnaires, semi-structured interview guides, and experimental assessment rubrics.

2.1.7.2 Instrument Construction Workflow: Item generation, Expert review, Pilot testing, Refinement.

2.1.7.3 Scale Validation: Confirmed using reliability and construct validity testing.

2.2 DATA COLLECTION

Four primary instruments were used for data collection: (1) content analysis sheets for scientific literature; (2) semi-structured expert interview guides; (3) quantitative survey questionnaires; and (4) pre- and post-test assessment rubrics.

2.2.1 Qualitative Data Collection

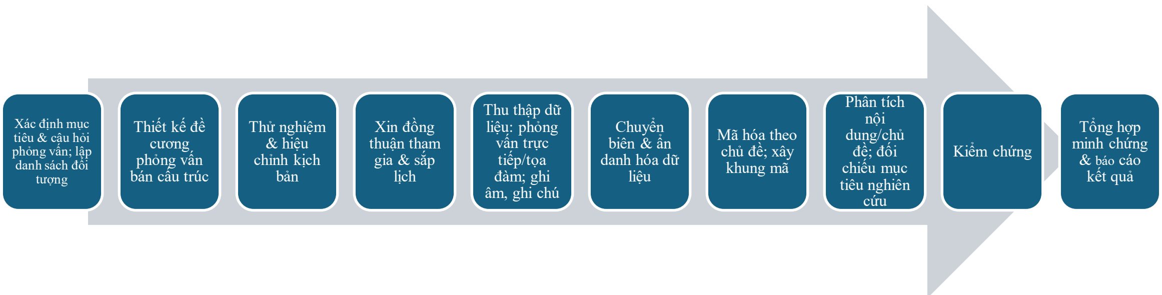

Figure 2.3: Interview and qualitative data processing workflow

2.2.2 Survey Data Collection

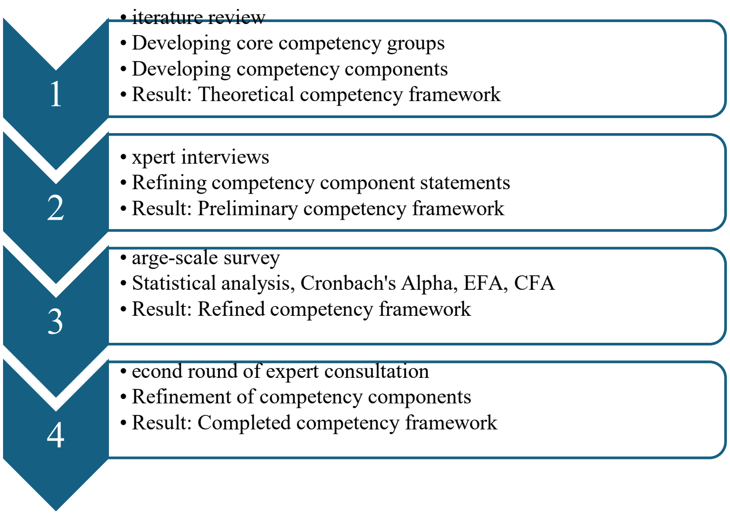

Figure 2.4: Flowchart for establishing and validating the competency framework

2.2.3 Experimental Data Collection

Figure 2.6: Competency measurement workflow

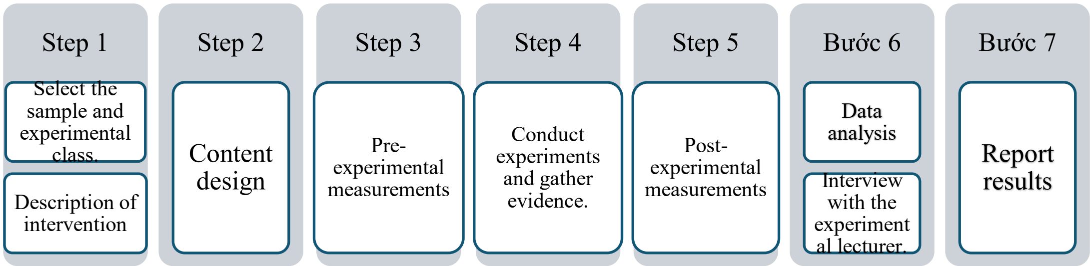

Figure 2.7: Experimental implementation process

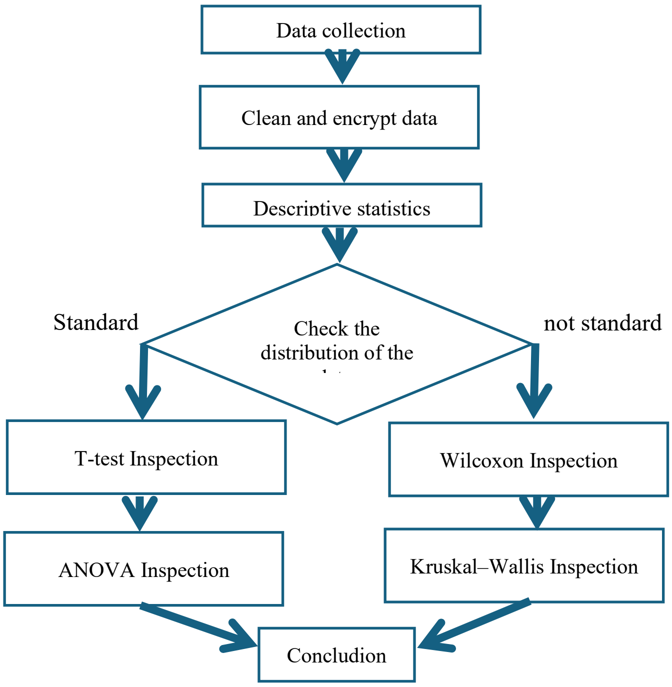

Figure 2.8: Quantitative data processing and analysis workflow

2.3 DATA ANALYSIS

2.3.1 Qualitative Data Analysis

Qualitative data from interviews was processed using thematic analysis, identifying patterns in pre-service teachers' perceptions and experiences regarding STEM.

2.3.2 Quantitative Data Analysis

Quantitative analysis was conducted at descriptive and inferential levels to evaluate the competency framework and test the hypotheses.

2.3.2.1 Competency Framework Validation

Table 2.1: Reliability Analysis (Cronbach's Alpha) of STEM Competency Dimensions

Competency Dimension	Number of Items	Cronbach's Alpha
NLCHUNG	29	0.810
NLNT	7	0.886
NLTK	7	0.878
NLTC	5	0.847
NLTH	5	0.842
NLDG	5	0.852

Table 2.4 Statistical results of the survey on the competency framework for organizing STEM educational activities.

	N	Min	Max	Mean	Std
NLCHUNG	400	2	4	3.02	.436
NLNT	400	1	5	3.08	.831
NLTK	400	1	5	3.03	.828
NLTC	400	1	5	3.02	.869
NLTH	400	1	5	3.01	.875
NLDG	400	1	5	2.90	.875

Table 2.5 KMO and Bartlett's Test of Sphericity values

Chỉ số	Giá trị
Kaiser–Meyer–Olkin (KMO)	0.861
Bartlett's Test – Chi-Square	5117.756
df	406
Sig.	.000

2.3.2.2 Descriptive Analysis of Pre-service Teachers' Baseline Competency

Table 2.13 Descriptive Statistics of Surveyed Competency Sub-indicators

Competency Sub-indicator	*N*	*Minimum*	*Maximum*	*Mean*	*Standard Deviation*
PRE_NLNT1.1	180	1	5	3.18	.734
PRE_NLNT1.2	180	1	5	3.11	.761
PRE_NLNT1.3	180	1	5	3.11	.776
PRE_NLNT1.4	180	1	5	3.21	.745
PRE_NLNT1.5	180	1	5	3.16	.790
PRE_NLNT1.6	180	1	5	3.17	.829
PRE_NLNT1.7	180	1	5	3.13	.801
PRE_NLTK2.1	180	1	5	2.90	1.031
PRE_NLTK2.2	180	1	5	3.10	1.063
PRE_NLTK2.3	180	1	5	3.05	1.026
PRE_NLTK2.4	180	1	5	2.97	1.041

PRE_NLTK2.5	180	1	5	2.90	.987
PRE_NLTK2.6	180	1	5	3.10	1.003
PRE_NLTK2.7	180	1	5	2.99	1.008
PRE_NLTC3.1	180	1	5	3.04	1.045
PRE_NLTC3.2	180	1	5	3.10	.964
PRE_NLTC3.3	180	1	5	2.97	1.000
PRE_NLTC3.4	180	1	5	2.93	1.020
PRE_NLTC3.5	180	1	5	2.96	.988
PRE_NLTH4.1	180	1	5	3.03	1.090
PRE_NLTH4.2	180	1	5	2.92	1.106
PRE_NLTH4.3	180	1	5	2.83	1.061
PRE_NLTH4.4	180	1	5	3.07	1.107
PRE_NLTH4.5	180	1	5	3.01	1.070
PRE_NLDG5.1	180	1	5	2.97	1.062
PRE_NLDG5.2	180	1	5	3.22	1.053
PRE_NLDG5.3	180	1	5	2.98	.969
PRE_NLDG5.4	180	1	5	3.06	1.132
PRE_NLDG5.5	180	1	5	3.09	1.004

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2.3.2.3 Experimental Data Analysis

Following the intervention, mean scores rose across all competency areas, particularly for Competency 1 (NLNT) and Competency 2 (NLTK).

Table 2.14. Statistical results of general competence before and after the experiment.

	N	Min	Max	Mean	Std
PRE_NLCHUNG	180	1	5	3.04	0.220
POST_NLCHUNG	180	2	5	3.68	0.234

Table 2.15 Statistical results on the competence to organize STEM educational activities before and after the experiment.

	N	Min	Max	Mean	Std
PRE_NLNT	180	2	5	3.15	.556
PRE_NLTK	180	2	4	3.00	.381
PRE_NLTC	180	2	4	3.00	.445
PRE_NLTH	180	2	4	2.97	.490
PRE_NLDG	180	2	4	3.06	.492
POST_NLNT	180	2	5	3.77	.554
POST_NLTK	180	3	5	3.85	.397
POST_NLTC	180	2	5	3.53	.488
POST_NLTH	180	2	5	3.51	.510
POST_NLDG	180	2	5	3.62	.504

Table 2.16 Results of the normality test for the variables

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PRE_NLNT	.080	180	.007	.988	180	.131
PRE_NLTK	.097	180	.000	.979	180	.008
PRE_NLTC	.101	180	.000	.977	180	.004
PRE_NLTH	.119	180	.000	.979	180	.008
PRE_NLDG	.111	180	.000	.980	180	.010
PRE_NLCHUNG	.063	180	.077	.990	180	.262
POST_NLNT	.093	180	.001	.986	180	.081
POST_NLTK	.097	180	.000	.983	180	.025
POST_NLTC	.127	180	.000	.977	180	.004
POST_NLTH	.084	180	.004	.981	180	.014
POST_NLDG	.115	180	.000	.975	180	.003
POST_NLCHUNG	.068	180	.044	.991	180	.337

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2.4 RESEARCH ETHICS

- **2.4.1 Consent to Participate:** All participants voluntarily agreed to take part, establishing trust and ensuring honest, high-quality data.
- **2.4.2 Confidentiality and Privacy:** Data was used strictly for research purposes, with personal information anonymized.
- **2.4.3 Objectivity and Honesty:** All empirical data was reported honestly without manipulation, confirming scientific integrity.
- **2.4.4 Fairness and Equality:** Training, materials, and support were distributed equally among participants.
- **2.4.5 Responsible Use of AI in Research:** AI tools were used solely as writing and analytical aids. No identifying or sensitive inputs were uploaded to public platforms. Original sources were verified and assigned DOIs wherever available. The final manuscript was closely reviewed and edited by the researcher, who assumes full responsibility for its accuracy.

CHAPTER 2 CONCLUSION

Chapter 2 maps out a comprehensive methodology using a mixed-methods design. Qualitative expert panels refined the construct parameters, and EFA, CFA, and reliability checks verified the psychometric properties of the 5-dimension, 29-item scale. The intervention program was run using a single-group pre-test/post-test experimental design. Paired T-tests verified significant changes in NLNT, NLTK, NLTC,NLTH.NLDG. Data collection adhered to established ethical standards for educational research.

CHAPTER 3: RESEARCH RESULTS AND DISCUSSION

3.1 RESEARCH RESULTS

3.1.1 Construct Validation of the STEM Competency Framework

Statistical verification confirms that the framework has strong validity and reliability. Internal consistency testing shows a Cronbach's Alpha of 0.810 for the overall scale, indicating good reliability. EFA confirms sampling adequacy with KMO and Bartlett's Test showing statistical significance (Sig = 0.000). Confirmatory Factor Analysis (CFA) indicates that the 5-dimension model fits the data well.

Table 3.1 CMB test results for survey data (N=400)

KMO		0.861
Bartlett's	Chi-Square	5117.756
	df	406
	Sig.	0.000
Number of observed variables included in the analysis		29
Number of contributing factors		1
Total variance extracted for a single factor		17.696%

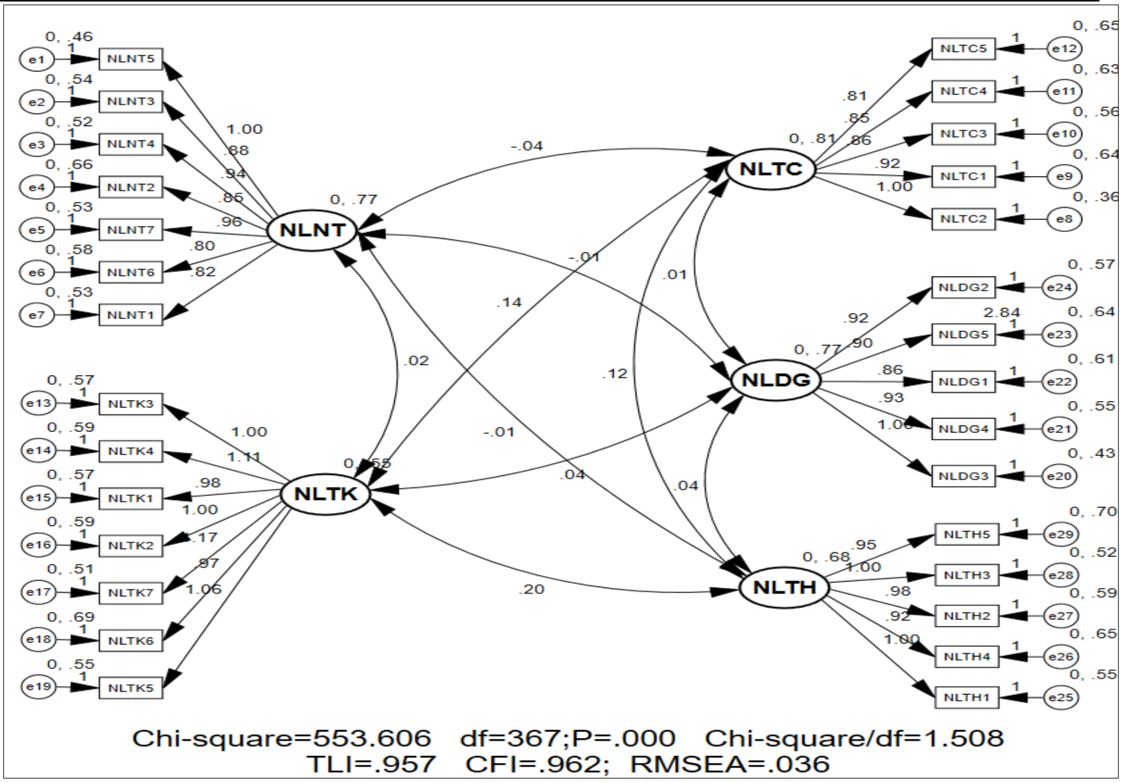

Figure 3.1. Measurement model in CFA analysis derived from the analysis results.

Pearson correlation coefficients confirm that items correlate well within their respective domains while maintaining discriminant validity. High-covariance items were merged to optimize model parsimony and structural stability. The resulting validated framework comprises 5 core domains: *conceptualization*, *instructional design*, *classroom organization*, *activity execution*, and *evaluation and reflection*. While quantitative results show high conceptual readiness, qualitative data highlights persistent practical challenges, such as integrating interdisciplinary content and handling classroom variables under real-world constraints.

3.1.2 Pre-service Teachers' Competency Development Following the Intervention

The pedagogical intervention focused on developing NLNT (STEM conceptualization) and NLTK (STEM lesson design) to test the feasibility of the model. Following the intervention, mean scores increased across all dimensions. This indicates that experiential, design-centric instruction is highly effective. Progress in execution and assessment (NLTH, NLDG) occurred more slowly, reflecting the need for extended classroom teaching experience. Paired T-tests tests confirmed these improvements were statistically significant ($p<0.05$).

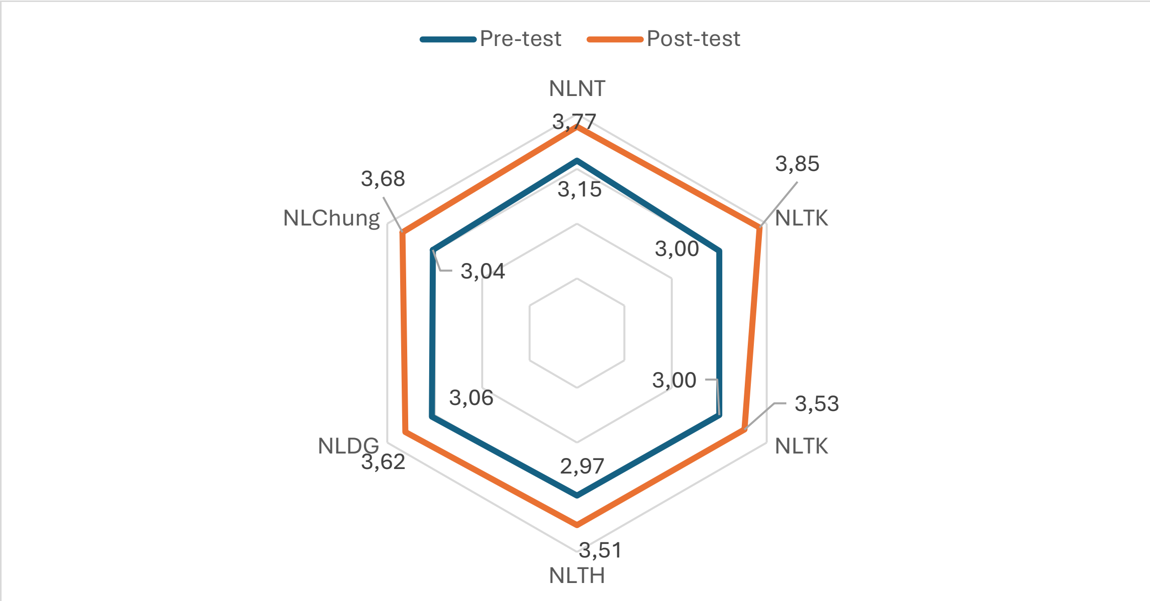

Figure 3.6 Comparison of competence in organizing STEM educational activities before and after the intervention

Table 3.7 Paired t-test results

		Mean	N	SD	SEM
Paired 1	PRE_NLCHUNG	3.04	180	.220	.016
	POST_NLCHUNG	3.68	180	.234	.017
Paired 2	PRE_NLNT	3.15	180	.556	.041
	POST_NLNT	3.77	180	.554	.041
Paired 3	PRE_NLTK	3.00	180	.381	.028
	POST_NLTK	3.85	180	.397	.030
Paired 4	PRE_NLTC	3.00	180	.445	.033
	POST_NLTC	3.53	180	.488	.036
Paired 5	PRE_NLTH	2.97	180	.490	.037
	POST_NLTH	3.51	180	.510	.038
Paired 6	PRE_NLDG	3.06	180	.492	.037
	POST_NLDG	3.62	180	.504	.038

Table 3.10 ANOVA results for post-experiment data

		Sum of Squares	df	MS	F	Sig.
ΔNLNT	Between Groups	3.828	7	.547	1.619	.133
	Within Groups	58.084	172	.338		
	Total	61.911	179			
ΔNLTK	Between Groups	.273	7	.039	.657	.709
	Within Groups	10.206	172	.059		
	Total	10.478	179			
ΔNLTC	Between Groups	.275	7	.039	.597	.758
	Within Groups	11.338	172	.066		
	Total	11.613	179			
ΔNLTH	Between Groups	.238	7	.034	.549	.796
	Within Groups	10.665	172	.062		

	Total	10.903	179			
ΔNLDG	Between Groups	.425	7	.061	.898	.510
	Within Groups	11.620	172	.068		
	Total	12.044	179			
ΔNLDCHUNG	Between Groups	.372	7	.053	1.646	.126
	Within Groups	5.556	172	.032		
	Total	5.928	179			

Qualitative feedback from instructors confirms that pre-service teachers made noticeable progress in lesson design, learning environment management, and problem-based instructional planning. Faculty recommended allocating more time for hands-on projects and establishing deeper connections with K-12 school partners.

3.2 DISCUSSION

3.2.1. The Competency Framework for Organizing STEM Educational Activities

Based on the literature review, this dissertation proposes a competency framework for organizing STEM educational activities for pre-service teachers. Quantitative results from the survey and content analysis of the interviews provide critical empirical evidence validating the validity and reliability of the proposed framework. Following refinement, the finalized competency framework comprises 5 core competencies and 29 indicators. The overall Cronbach's Alpha for the scale reaches 0.810, demonstrating that the internal consistency of the measurement instrument falls within the acceptable-to-good range according to the criteria established by Hair et al. (2010).

Table 3.8: Complete STEM Educational Activity Organization Competency Framework

No.	Competency	Component
1	[NLNT] Ability to form ideas about STEM education	[NLNT1.1] Identify the role of STEM education in addressing real-life problems. [NLNT 1.2] Present the objectives of STEM education in general education. [NLNT 1.3] Describe the integrated STEM components in STEM education. [NLNT 1.4] Apply specialized knowledge in the STEM field. [NLNT 1.5] Analyze the relationship between STEM components in the integrated STEM model. [NLNT 1.6] Apply new trends and achievements in the STEM field. [NLNT 1.7] Propose ways to solve practical problems in STEM education.
2	[NLTK] STEM teaching design competence	[NLTK 2.1] Identifying practical problems for STEM teaching topics [NLTK 2.2] Developing teaching objectives that align with practical problems for STEM teaching topics [NLTK 2.3] Selecting teaching content that integrates STEM elements [NLTK 2.4] Developing assessment criteria that align with the objectives of STEM teaching topics [NLTK 2.5] Selecting teaching materials and resources that are appropriate to the content and objectives of STEM education

		[NLTK 2.6] Selecting teaching methods, procedures, and assessment methods that align with the objectives and content of STEM teaching topics [NLTK 2.7] Planning lesson plans for STEM teaching topics with appropriate teaching and assessment activities
3	[NLTC] STEM classroom organization skills	[NLTC3.1] Arrange classroom space to facilitate interaction and collaboration in STEM classrooms. [NLTC3.2] Divide students into learning groups based on their abilities and interests. [NLTC3.3] Arrange and position equipment and learning materials appropriately and safely for teaching and assessment activities. [NLTC3.4] Build positive interactive activities in the classroom environment. [NLTC3.5] Maintain and adjust the classroom environment to be positive, safe, and appropriate after teaching and assessment activities.
4	[NLTH] STEM education activity implementation capacity	[NLTH4.1] Clearly explain the learning objectives, requirements, and content structure of the STEM teaching topic. [NLTH4.2] Flexibly use teaching methods, processes, and techniques, and encourage students to actively participate in teaching and assessment activities. [NLTH4.3] Effectively utilize learning resources and technology to support teaching and assessment activities in the STEM teaching topic. [NLTH4.4] Guide students to explore, practice, and experience to solve problems in the STEM teaching topic. [NLTH4.5] Guide students to become familiar with scientific research.
5	[NLDG] Ability to consolidate, evaluate, and adjust teaching	[NLDG5.1] Summarize, systematize, and conclude the key knowledge and problems solved in the STEM teaching topic. [NLDG5.2] Evaluate, comment on, and provide feedback on the learning process and results of students according to the criteria of the STEM teaching topic. [NLDG5.3] Comment on and provide feedback on students' learning products based on the criteria. [NLDG5.4] Design activities to develop students' competencies based on the evaluation results. [NLDG5.5] Adjust and address limitations in designing the content and lesson plan for the STEM teaching topic.

3.2.2 Changes in Pre-service Teachers' Competency to Organize STEM Educational Activities Under the Intervention Model

The pedagogical experimental results have provided authentic quantitative and qualitative evidence, confirming the close dialectical relationship between the training curriculum content and the transformation of pre-service teachers' competencies.

3.2.3.1 Development of Foundational and Design Competencies

The experimental results demonstrate that the intervention model yielded a pronounced effect on two foundational competencies of pre-service teachers: the competency to conceptualize STEM education (NLNT) and the competency to design STEM instruction (NLTK). This improvement reflects the impact of the course module designed with a cognitive-constructivist orientation, which facilitated the transition of pre-service teachers from a fragmented understanding of STEM to an integrated, theoretically grounded mindset.

Furthermore, the study highlights the potential of integrating artificial intelligence (AI) into pre-service teacher training to continuously expand these two foundational competency groups. AI not only assists in sourcing instructional materials, designing lesson plans, and analyzing learning data, but also contributes to fostering critical thinking, data-driven decision-making, and pedagogical competencies within digital environments.

3.2.3.2 Challenges in Translating Knowledge into Practical Skills

The findings indicate that while pre-service teachers showed substantial improvement in preparatory skills, such as arranging classroom spaces and organizing learning materials, they remained hesitant when managing unexpected classroom situations and guiding scientific research. Indicators associated with STEM product fabrication techniques and the organization of scientific research exhibited lower growth due to a lack of hands-on, practical experience with equipment and technology. This demonstrates that developing the competency to organize STEM educational activities must be closely linked to practical environments, laboratories, and real-world engineering projects. In fact, the group of pre-service teachers who received intensive support in scientific research over a six-month period successfully achieved scientific publications, confirming that within a suitable practical environment and under structured guidance, the competency to execute STEM activities can be sustainably developed.

3.2.3.3 The Moderating Role of Assessment and Reflective Competencies

The developmental process for this competency was operationalized through activities involving the design of assessment instruments, the utilization of rubrics and checklists, and peer assessment during microteaching sessions. The results show that indicators such as summarizing, systematizing knowledge, and evaluating student learning products improved significantly, reflecting a paradigm shift from content-based instruction to an outcome-based approach focusing on the development of students' qualities and competencies.

3.2.3.4 Differentiation in Competency Development Based on Disciplinary Specialization

The research findings reveal that the impact of the training content was distributed unevenly across different disciplinary majors.

3.2.3.5 Operational Mechanism of the Intervention Model

Synthetically, the experimental results confirm that pre-service teachers' competency to organize STEM educational activities does not develop linearly, but rather progresses along a spiral trajectory characterized by continuous accumulation and ongoing self-regulation. This process moves from Conceptualization (NLNT) → Design (NLTK) → Implementation (NLTC, NLTH) → Assessment (NLDG), subsequently returning to a higher level of cognitive awareness.

3.2.4 Contributions of the Study

Theoretically, the study enriches the theoretical foundations of developing the competency to organize STEM educational activities for pre-service teachers, defining it as an integrated capacity combining content knowledge, pedagogy, interdisciplinary thinking, and experiential learning organization. Concurrently, the study constructs a competency framework and a developmental model aligned with a competency-based approach.

Practically, the survey and experimental results demonstrate that the competency framework possesses high feasibility, supporting the formulation of assessment instruments and contributing to elevating pre-service teachers' competency to organize STEM educational activities through appropriate pedagogical interventions.

3.2.5 Alignment of Research Results with Theoretical Foundations of Competency Development

The experimental results show that the model for developing the competency to organize STEM educational activities aligns well with constructivist learning theory, Kolb's experiential learning theory, and Schön's reflective practice. Pre-service teachers develop their competency through experiencing, designing, receiving feedback, and adjusting learning activities within an integrated STEM orientation.

3.2.6 Strengths and Limitations of the Study

A major strength of the dissertation lies in its mixed-methods design, combining qualitative and quantitative research, which simultaneously captures macro-level trends and uncovers deep-seated underlying causes regarding STEM competency development in pre-service teachers. The rigorous experimental design and major-specific analysis emphasize the applicability, relevance, and practical value of the study within the current landscape of educational reform.

However, the study possesses certain limitations regarding sample size and geographic scope, as the data collection was confined to universities within Ho Chi Minh City. The short experimental duration, the absence of a control group, and the reliance primarily on self-assessment measures mean that the real-world, practical competency of pre-service teachers in K-12 school settings may not be fully captured. Consequently, future research should be expanded through longitudinal, multi-regional designs incorporating enhanced direct performance-based practical assessments.

3.2.7 Future Research Directions

Potential research avenues may focus on expanding large-scale surveys across diverse geographical regions ; developing the competency to organize and execute STEM activities through AI integration ; fostering university faculty capacity based on the intervention model ; enhancing the application of digital technologies in teacher education programs ; and building digital-platform-based STEM competency evaluation systems, such as e-portfolios, to systematically monitor the developmental trajectories of pre-service teachers.

CHAPTER 3 CONCLUSION

The empirical results confirm that the proposed competency framework is statistically valid and highly applicable to teacher education in Vietnam. While baseline assessments highlighted initial weaknesses in practical classroom management and research supervision, the intervention model produced significant gains across all core competency areas. These findings emphasize the importance of incorporating experiential, design-centric coursework into teacher training curricula to prepare future STEM educators.

CONCLUSIONS AND RECOMMENDATIONS

Concludions

This dissertation was systematically implemented to clarify the theoretical and practical foundations of developing the competency to organize STEM educational activities for pre-service teachers. The study constructed a five-component competency framework embedded with a system of clear criteria and indicators, and proposed a competency development model grounded in constructivist, experiential, and reflective learning. The survey and experimental results indicate that the competency framework possesses high reliability and that the intervention model significantly improves the competencies of pre-service teachers. Ultimately, the dissertation contributes to enriching the scientific baseline for teacher education reform and the nationwide implementation of STEM education in Vietnam.

Recommendation

This thesis proposes several recommendations to improve the quality of STEM education competency training for teacher training students. The Ministry of Education and Training needs to finalize STEM teaching competency standards and integrate them into teacher training programs. Universities should develop output standards based on the STEM competency framework, strengthen the "STEM Teaching Design" module, expand practical activities, experiences, and collaborations with high schools and technology companies. Simultaneously, it is necessary to develop STEM teaching competencies for lecturers and promote the application of digital technology and artificial intelligence in training. Teacher training students should enhance self-learning, professional reflection, and develop digital competencies. Further research should expand the scope of the survey, implement long-term research, and build a system for assessing STEM competencies based on digital technology to improve the effectiveness of teacher training in the context of current educational reforms.