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Developing competencies of natural science teachers for designing and organizing STEM education activities in Vietnam

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ABSTRACT

STEM education has gained attention in many countries around the world and is asserted to be of great importance in teaching at all school levels. In this research, the authors proposed a process for developing the capability to design and organize STEM activities in secondary schools for Natural Science Teachers (NSTs), teaching the basic topics integrated in Physics, Chemistry, Biology, and Earth Science contents according to the new secondary education program in Vietnam - 2018. The research was carried out in three steps: (1) Professional training to improve NSTs 'competence for understanding STEM education; (2) Designing assessment tools for the NSTs capability in designing and organizing STEM activities; (3) Assessing the NSTs' capability using the tools. The research methodology was conducted with 122 Vietnamese NSTs to measure the pre-and post-intervention results. The findings revealed that the participants made significant progress in their teaching performances (the average points for their capability to design and organize STEM education increased from 1.58 to 2.33). This NSTs improvement can be seen as an excellent case study that will encourage other teachers to implement STEM education more frequently in Vietnamese schools contributing to building sustainable education systems.

Contribution/Originality: The research proposes a process of developing the capacity for designing and organizing STEM educational activities for natural science teachers, to be implemented in 3 stages: Professional training, designing a tool to evaluate the NSTs capability, and assessing the NSTs' capability using the tools for STEM topics for science teachers.

1. INTRODUCTION

Over the past three decades, the field of STEM education has gained significant momentum in numerous countries worldwide. The term "STEM" originated from the acronym SMET (Science, Mathematics, Engineering, and Technology), which was first introduced in the 1990s (Ritter, 2020). As a result, several definitions have been developed and explored. STEM education can include one subject, interdisciplinary, or multidisciplinary, which can be a specific major. According to Rodger (2015) and Sanders (2009), STEM education primarily focuses on solving scientific issues related to practicality, nature, and the everyday life of humans. As such, integrated STEM education entails approaches to teaching and learning that involve two or more STEM fields and/or between a STEM field and one or more other fields in schools, outlining the elements of the constructivist approach present in integrated STEM education (Rodger, 2015; Sanders, 2009).

STEM education has gained attention from many educators and experts. Research studies on STEM education have rapidly increased over the years, with the international reach and status of STEM education journals becoming more evident (Jayarajah, Saat, & Rauf, 2014; Lee, Kang, & Park, 2019; Li, Wang, Xiao, & Froyd, 2020). The Vietnamese government is increasingly supporting training of the human resources in STEM education and for the modernization and industrialization of the discipline. While there is ongoing training for STEM teachers and administrators, providing incentives for teachers to work on their new STEM approach to teaching and learning, and for universities and companies to collaborate to train quality human resources, are also needed. The booming interest in interdisciplinary STEM education in Vietnam has support and investment from the government as well as from bilateral, and international organizations (Chen, Lutomia, & Pham, 2021).

Currently, STEM educational activities are required to be implemented in the new general education program in Vietnam (Ministry of Education and Training, 2018). However, STEM teaching is not considered as a subject, and STEM independent modules are integrated into the curriculum, creating many difficulties related to teaching STEM lessons. These difficulties mainly relate to teachers' lack of interdisciplinary teaching methods, practical constraints, and their low belief in effective STEM education (Le, Tran, & Tran, 2021).

As most teachers have not been formally trained in STEM or have had challenges in grasping the content and appropriate teaching methods, this research aimed to contribute to the development of design and organizational capabilities of STEM educational activities for NSTs in Vietnam (Chu, 2016; Tung-Hieu, Huy, Phat, Anh, & Wong, 2020). Therefore, this study proposed a process for developing the capacity to design and organize STEM activities for teachers. The research findings will assist teachers in designing and implementing STEM lessons more easily.

2. LITERATURE REVIEW

STEM education has gained popularity worldwide due to its demonstrated success in developing high-quality human resources (Sheffield et al., 2018; Timms, Moyle, Weldon, & Mitchell, 2018). The role of STEM education in preparing students for the Industrial Revolution 4.0 has been emphasized by school leaders and scientists (Le et al., 2021). STEM education provides students with a strong foundation in science, technology, engineering, and mathematics, which are essential for success in today's rapidly changing world. STEM education can be enhanced by combining different learning methods or models. Problem-based learning, project-based learning, or the 6E learning model have been used successfully in conjunction with STEM education (Chung, Lin, & Lou, 2018; Mustafa, Ismail, Tasir, & Mohamad Said, 2016; Zainil, Kenedi, Rahmatina, Indrawati, & Handrianto, 2023). These approaches emphasize hands-on activities and real-world problem-solving that engage students and promote deeper understanding of STEM concepts. The modification or combination of STEM with other methods or learning models have great potential in creating conditions for effective implementation (Martín-Páez, Aguilera, Perales-Palacios, & Vílchez-González, 2019). In South Korea, Thailand, Malaysia, and some other countries, STEM education is a compulsory part of the national education program (Cho, 2013; Mohd-Shahali, Halim, Rasul, Osman, & Zulkifeli, 2016). Some studies have indicated that, in Asian countries, STEM education began in 2013. To date, STEM education has become a major, compulsory part of the national education system of many countries (Catherine, 2022; Wahono, Lin, & Chang, 2020).

STEM education is a relatively new concept in Vietnam, with its introduction only dating back to 2014 (Mau Duc, Quang Linh, & Chokchai, 2019; Quang Linh, Mau Duc, & Chokchai, 2019). The Vietnamese government has recognized the importance of STEM education and has implemented policies to promote it (Mau Duc, Quang Linh, & Chokchai, 2019). However, there are still challenges that need to be addressed, such as a lack of resources and training for teachers (Thuy, Van Bien, & Quy, 2020). STEM education has become increasingly important in Vietnam due to the rapid development of technology and society. Developing practical competence in teaching natural science for 8th graders using STEM education orientation is essential to improve the quality of in Vietnam (Hoang & Nguyen, 2020). STEM education is an important tool for developing high-quality human resources and preparing students for future success. Combining different learning methods or models can enhance the effectiveness of STEM education. Policymakers and educators should work together to promote STEM education and ensure that it is accessible to all students, regardless of their background or socioeconomic status (Le et al., 2021).

In order to achieve high efficiency when designing and organizing STEM activities, natural science teachers need a wide range of competencies such as (1) content knowledge (the teacher's understanding about teaching contents of the STEM topics); (2) pedagogical knowledge (teachers' ability to organize learning and teaching processes to help students reach their fullest potential through STEM activities); (3) technology knowledge (teachers' ability to apply technology flexibly and effectively in STEM lessons) and (4) design knowledge (teacher's ability to design effective learning experiential tasks) (Kuo, Tseng, & Yang, 2019). Due to various reasons, there are still Vietnamese NSTs' teachers who are under-qualified, lower than the desired level. This shortage is due in part to the fact that many teachers are not trained specifically in natural science but rather have general training in education. To address this issue, it is essential to provide teachers with ongoing professional development opportunities that focus on content knowledge.

One study conducted by Nguyen, Dang, and Pham (2020) found that teachers who participated in a professional development program on STEM education reported an increase in their content knowledge (Nguyen et al., 2020). The program included workshops, seminars, and hands-on activities that focused on natural science concepts and their application in STEM education. The study also found that the teachers' confidence in teaching STEM increased after participating in the program. Developing competencies of natural science teachers for designing and organizing STEM activities is essential to improve the quality of chemical teaching in Vietnam (Mau Duc, Quang Linh, & Chokchai, 2019; Mau Duc, Quang Linh, & Yuenyong, 2019). To effectively design and organize STEM activities, natural science teachers must possess certain competencies including content knowledge, pedagogical knowledge, technological knowledge, and design knowledge. Professional development programs that focus on these competencies can help teachers improve their teaching practices and increase their confidence in teaching STEM. However, there is still a need for more resources and training for teachers in Vietnam to effectively integrate STEM education into their teaching (Linh, 2020; Mau Duc, Quang Linh, & Yuenyong, 2019).

STEM education in Vietnam also has experienced numerous challenges with many reasons like other countries around the world (Quang et al., 2015). One of the most positive solutions addressing this situation is to form and develop the teachers' capacity of organizing STEM educational activities. This is a decisive factor for the success of STEM education in the direction of developing learners' competences and qualities, forming responsible, personal and professional citizens with sufficient capacity in different fields like science, technology, mathematics and engineering, meeting the needs of high-quality human resources in modern society. This study identifies that STEM educational activities are the design and organization of teaching and learning STEM subjects to form and develop general and core competences in science, technology, engineering and mathematics for students. The capacity of teachers in organizing STEM educational activities is their ability in organizing of learning activities for students effectively in order to achieve learning outcomes and meet the need of output standards of general education curriculum. On top of that through these activities, learners will be interested in the STEM education and increase their emotion and motivation leading to have a career STEM-related orientation.

2.1. Research Questions

a) What are the requirements for designing and organizing STEM educational activities for natural science teachers?

b) What are the steps in the process of developing the teachers' capacity in designing and organizing STEM educational activities?

c) How can the teachers' capacity in designing and organizing STEM educational activities be assessed?

3. METHODOLOGY

3.1. Research Design

To examine the design and organization competence of STEM education activities of NSTs in teaching according to the new general education program in Vietnam, a mixed-methods research was carried out with three tasks, namely: Task 1: Identifying the needs for design and organization competence of STEM education activities for NSTs. Task 2: Building and implementing a process to develop the design and organization competence of STEM education activities for NSTs in teaching specific topics. Task 3: Establishing the feasibility and effectiveness of the proposed measures through the results of the teaching experiment.

3.2 Research Participants

The participants of this study were selected through the purposive sampling method. A sample size of 122 NSTs (teaching physics, chemistry, and biology) from two education and training departments: Lang Son Department of Education and Training, was finalized. This sample comprised 8 Secondary schools with 56 participants, and Binh Duong Department of Education and Training, comprising 9 Secondary schools and 66 participants for the experiment. In addition, 18 lecturers also participated in the pedagogical experiment in the roles of STEM trainers for 122 NSTs and assessors evaluating teachers' competence to design and organize STEM lessons. All lecturers were extensively experienced experts in STEM education coming from 6 different universities in Vietnam (Hanoi National University of Education, Thai Nguyen University of Education, University of Education – Hue University, University of Education - Vietnam National University, Hanoi Metropolitan University, Thu Dau Mot University). The research was conducted in the school year of 2020-2022.

3.2. Data Collection and Analysis

3.2.1. Requirements for the Design and Organization of STEM Education Activities for NSTs Must be Met

NSTs need to have basic knowledge of the scientific content of subjects such as physics, chemistry, biology, and Earth Science. They also need to have a foundational understanding of STEM education theory (theory of constructing and designing STEM curriculum topics) in secondary schools. Furthermore, they need to have the ability to build STEM education topics in Natural Sciences; the ability to conduct STEM education activities during teaching natural sciences; and the ability to assess student's performance in terms of their products and learning processes when teaching these STEM education topics.

3.2.2. The Process of Developing the Teachers' Competence in Designing and Organizing STEM Educational Activities

During the study, a process for developing the ability of teachers in teaching STEM education activities was built, consisting of three stages, with the first stage being a prelude to the subsequent stages. Each stage focused on developing certain components of the STEM education activity design and organization capabilities. Teachers need to participate in and complete all activities from Stage 1 to Stage 3 in the process. The specific tasks of each stage in the process were as follows:

Phase 1. Professional training for teacher capacity building in teaching STEM.

NSTs capacity-building modules were also built for teaching STEM subjects based on the content of Natural

Science (a new subject of general education program 2020 in Vietnam). The guidance documents on STEM education comprised objectives of developing the NSTs' capacity of designing and organizing STEM education. These professional development modules to teach Natural Science on STEM topics included:

Module 1: Providing self-learning materials introducing some general issues on teaching STEM, and theories of constructing and designing STEM lesson plans in secondary schools. *Module 2*: Organizing online self-training activities at home, in-class through a blended learning model to form the capacity of designing and organizing STEM activities for lecturers teaching Natural Science.

Phase 2. A tool was designed to evaluate the NSTs teachers' competence to design and organize STEM educational activities. This tool also helped in determining NSTs' competency framework of designing and organizing STEM activities with two components and eight three-level criteria to be achieved, and their expressions. Next, assessment forms were designed for lecturer's assessment and self-assessment of NSTs, which were based on the competency framework of design and organization of STEM education activities for NSTs. There was also evaluation form of STEM experts to evaluate secondary-school teachers' ability to plan and structure STEM education activities.

Finally, an evaluation form was designed for the use by professional STEM experts (lecturers) to assess the capacity of secondary-school teachers in the design and organization of STEM educational activities consisting of eight criteria, each of which was rated according to the three levels described in Table 1. The experts used this form regularly during all three stages and observed teaching activities and evaluated teachers' academic portfolio to determine their level of achievement in each criterion. The total score of competence or the average score of each skill criterion was calculated and compared with the scale of three levels (Table 1). This was done to evaluate the design and organization skills of STEM educational activities of the individual teacher or group of teachers. Based on the previous studies of the STEM competency framework (Nguyen et al., 2020; Thi Thuy Trang, 2021), a competency framework was proposed for teachers in designing and organizing STEM educational activities as shown in Table 1:

Table 1. Framework of competence and criteria for evaluating the design and organization of STEM educational activities for natural science teachers.

Component skills	Evaluation criteria	Degree of manifestation of criteria		
		Level 1 (1 point)	Level 2 (2 points)	Level 3 (3 points)
The ability to design STEM topics through teaching natural science subjects	1. Identify the practical problem that needs to be solved, and its connection to the knowledge content of the natural science (Physics, Chemistry, Biology, Earth Science) subjects to construct STEM topics.	The issue of practicality has been identified but is not yet feasible. The context and selection of suitable STEM topics have not yet been determined.	Identify the problem of STEM subjects that needs to be solved, as well as solve the STEM problem accurately with the knowledge learned, and precisely.	The problem to be solved has been identified, with its testability and the problem being solved accurately and thoroughly using the knowledge learned. The context has been determined and an appropriate STEM topic has been chosen to fit the context.
	2. Propose a name and identify the basic information of the STEM topics (Objectives, tasks, contents, products, and evaluation criteria of the STEM topic).	The proposed name does not fit with the basic information of the STEM topic. It has not been determined yet what the basic information of the STEM topic is.	Determine the context, and select the STEM topic that is not suitable for the context. Suggest a suitable name for the basic information of the STEM topic. Identify the basic information of the STEM topic that is	Suggest an appealing name that is appropriate for the basic information of the STEM topic. Determine the basic information of the STEM topic thoroughly and clearly.

Component skills	Evaluation criteria	Degree of manifestation of criteria		
		Level 1 (1 point)	Level 2 (2 points)	Level 3 (3 points)
			incomplete and unclear.	
	3. Design the teaching organization process, select teaching methods, positive teaching techniques, and ICT use in teaching the STEM topic.	Build a teaching process for the STEM topic but it is not yet logical, clear, and complete. Select teaching methods, teaching techniques, and Information & Communications Technologies (ICT) to use in organizing the teaching of the STEM topic that are not yet suitable.	Construct a teaching process for the STEM topic that is organized, and clear but incomplete. Select appropriate teaching methods, teaching techniques, and ICT for teaching the STEM topic.	Build a well-structured, clear, and comprehensive teaching process for STEM topics. Select diverse, flexible, and appropriate teaching methods, positive teaching techniques, and ICT for teaching STEM topics.
	4. Design specific learning activities for the STEM topic.	The design is not yet complete with specific learning activities for the STEM topic.	Design a complete and clear but not suitable teaching activity for the STEM topic.	Design a comprehensive, clear, feasible, and feasible set of specific STEM learning activities.
The ability to organize and implement STEM topics through teaching natural science subjects.	5. Gather and coordinate the necessary resources (Human, and physical resources) for the activities within the topic.	Not yet able to gather and coordinate the necessary resources for activities in the STEM topic.	Gather and coordinate the necessary resources for the activities in the STEM topic.	Assemble and coordinate the necessary resources (for activities in the STEM topic).
	6. Implement the teaching activities of the STEM topic according to the designed teaching plan.	Unable to implement a part of the planned learning activities.	Implement most of the designed teaching activities.	Ensure that the activities for teaching the STEM topic are carried out according to the plan in a disciplined and creative manner.
	7. Design and use assessment tools for students through the STEM topic and process the collected data.	Inadequate design and unable to use assessment tools to assess student capabilities in the STEM topic. Not knowing how to collect and process data.	Design but not fully use the assessment tools for the student's ability in the STEM topic. Know how to collect and process data but not analyze and respond to the information from the data.	Design and effectively use assessment tools for students on STEM topics relevant to the activity content. Know how to collect, process, and analyze data fully and respond to information well.
	8. Self-assess the teaching plan, adjust the design activities and implementation activities of teaching STEM.	Do not know how to self-assess, evaluate teaching and learning activities and implement STEM teaching.	Know how to self-assess, evaluate but not actively, not regularly, and not flexibly adjust the teaching plan and teaching STEM.	Know how to self-assess, evaluate and be flexible in adjusting design activities and implementing STEM teaching activities.

Note: The self-assessment form for teachers to evaluate STEM educational activity design and organization competence.

The form used by the lecturers to assess the NSTs' competence was also used for these teachers to assess themselves (self-assessment). This self-assessment was carried out from the beginning of the research process (pre-intervention test) to help identify strengths and weaknesses in participants' design and organization ability in teaching STEM topics in science classes. Through the assessment results, the teachers could track their progress in teaching the STEM topics, and also identify which components were not yet satisfactory, and needed to be improved to develop their design and organization competence for STEM educational activities.

Phase 3. The assessment of design and organization competence for STEM topics for science teachers was conducted. Teachers in at some secondary schools in Binh Duong and Thai Nguyen provinces Vietnam were contacted and experiments in teaching Natural Science were conducted to evaluate the effectiveness and feasibility of the process on a large scale. Firstly, each group of teachers was required to design a lesson plan for a selected STEM topic from the Nature Science curriculum. Then it was edited and adjusted, and completed until the plan was adequately qualified to implement in the classroom. Secondly, one teacher in the group taught the STEM topic according to the steps of the process for developing design and organization competence for STEM educational activities according to the technical design process as shown in Figure 1.

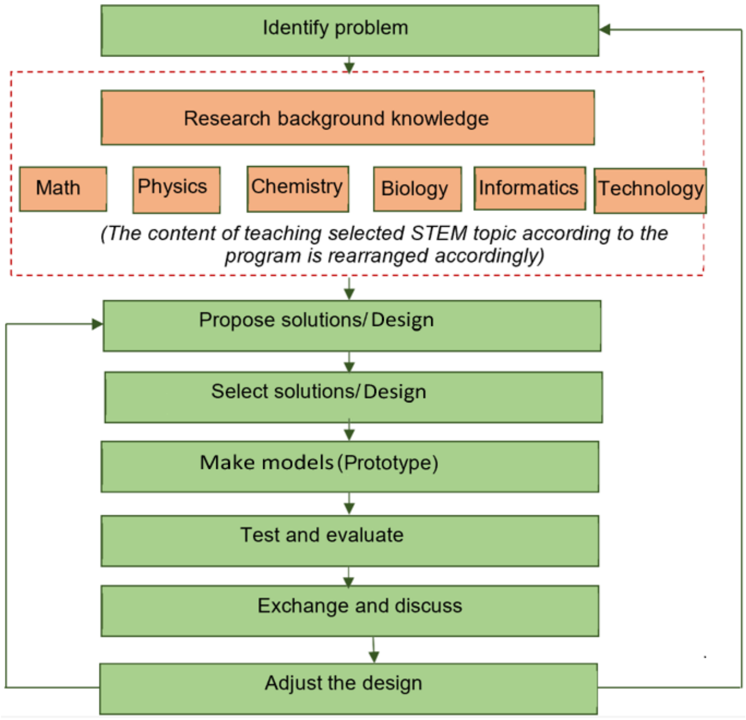

Figure 1. The process of teaching the selected STEM topic.

After the teaching session, the teachers analyzed the lesson plan through professional activities based on the research-based learning model, evaluated and self-evaluated, drew on experience, perfected the teaching and learning activities. To collect and evaluate the quantitative results of the methods and develop teachers' capacity in organizing STEM education activities two steps were taken:

Step 1: Select the Research Design. A research design was used that assessed the pre-and post-intervention test of a single teacher group in order to evaluate the progress of the teachers before and after the intervention.

Step 2: Measure. Statistical methods were used to process the scores to describe, compare data, analyze, and evaluate the progress, design development and organizational capabilities of STEM education activities of teachers. To assess the development of the teachers' design and organization competence for STEM educational activities, the following steps were undertaken:

- Organize self-assessment for teachers to self-assess their design and organization competence for STEM educational activities at two points before and after the intervention through the teacher self-assessment form. The results of the self-assessment of the teachers' competence to some extent verified the objectivity of the assessment results of the teachers' effectiveness of the two interventions.
- To describe the orientation of the data, we created distribution tables of design capability scores and organized STEM educational activities in experimental classes at pre-intervention and post-intervention points, calculated the average scores, and statistical parameters such as standard deviation (SD) to describe the

dispersion of the data.

- To evaluate the impact, we compared the average scores at the two intervention points and evaluated the significance of the process and development measures of design capability and STEM educational activities for teachers using the p-value of the paired t-test between the two points: pre-intervention and post-intervention.
- To compare the data, we performed a t-test (calculating the p-value) dependent or paired between the two points to compare the average values of the same group to determine whether the score differences occurred randomly or not. In which, the difference between the two points was significant if $p < 0.05$. The standardized mean difference (SMD) of the pre-intervention and post-intervention test results were used to evaluate the effect size (ES) of the measures on the development of capabilities.

Upon concluding the impactful measures, we used questionnaires from the lecturers and teachers regarding their attitudes, enthusiasm for teaching, etc. to affirm the effectiveness of the measures to develop the capacity of designing and organizing STEM educational activities. At the same time, we continued to collect feedbacks on the advantages and disadvantages of the actual implementation of the measures to find ways to improve and perfect the subsequent impacts. Most of the teachers who participated in the research to collect the data were high-qualified teachers who have been teaching subjects related to STEM education for many years.

4. FINDINGS

We conducted an experiment in order to evaluate the feasibility and effectiveness of the proposed process in the paper on developing STEM educational activities for NSTs based on the analysis of the obtained results. The results of the experiment were as follows:

The process of evaluation for NSTs' competence by the lecturers and NSTs' self-assessment rated the level of development of the design and organization of STEM educational activities through the application of the proposed process Figure 1, through the teaching process of STEM, and through the calculation of statistical parameters. This process helped in determining the competence improvement in each of the eight criteria at two points before and after the intervention. The average scores of all eight criteria were collected through the evaluation of the teacher ability of the design and organization of STEM educational activities before and after the intervention.

Table 2. Progress Chart of the design and organization capacity of STEM educational activities of the teachers participating at Binh Duong through the assessment of the lecturers (n=122).

Criteria (C)	**Pre-impact group**				**Post-impact group**			
	Number of teachers achieved scores			**Average score of each criterion**	**Number of teachers achieved scores**			**Average score of each criterion**
	Level 1 (1 point)	Level 2 (2 point)	Level 3 (3 point)		Level 1 (1 point)	Level 2 (2 point)	Level 3 (3 point)	
C1	28	21	7	1.63	5	19	32	2.48
C2	27	21	8	1.66	6	21	30	2.46
C3	32	15	9	1.59	6	20	27	2.27
C4	28	20	8	1.64	4	20	32	2.50
C5	31	18	7	1.57	4	23	29	2.45
C6	32	18	6	1.54	7	20	29	2.39
C7	36	15	5	1.45	8	25	23	2.27
C8	29	19	9	1.68	6	21	29	2.41
Average score of design and organization of STEM educational activities pre-impact group				1.60	Average score of design and organization of STEM educational activities post-impact group			2.40
Standard deviation pre-impact group= 0.70					Standard deviation post-impact group= 0.76			
Dependent t-test p (p) = 1.26×10^{-3}								
Effect size (ES) = 1.15								

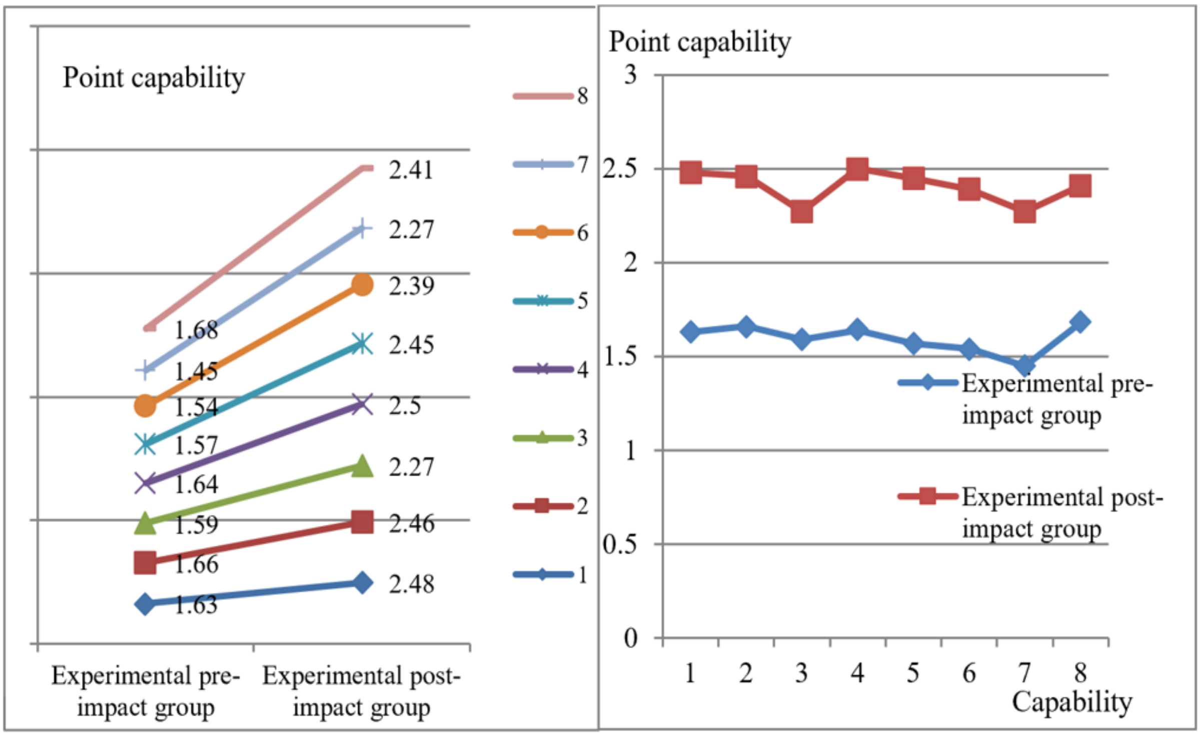

Figure 2. Progress Chart of the design and organization capacity of STEM educational activities of teachers participating at Lang Son through the assessment of lecturers.

Table 3. Table of assessment of the progress of design and organization of stem educational activities of the teachers participating at Binh Duong through the assessment of lecturers(n=122).

Criteria (C)	Pre-impact group				Post-impact group			
	Number of teachers achieved scores			Average score of each criterion	Number of teachers achieved scores			Average score of each criterion
	Level 1 (1 point)	Level 2 (2 point)	Level 3 (3 point)		Level 1 (1 point)	Level 2 (2 point)	Level 3 (3 point)	
C1	33	24	9	1.59	12	21	33	2.32
C2	31	26	9	1.62	13	22	31	2.27
C3	35	20	10	1.54	14	24	28	2.21
C4	33	23	10	1.60	12	23	31	2.29
C5	36	22	8	1.53	12	25	29	2.26
C6	37	21	8	1.51	13	22	30	2.23
C7	39	20	7	1.47	15	28	23	2.12
C8	34	23	9	1.57	12	23	31	2.29
Average score of the design and organization of STEM educational activities pre-impact group				1.55	Average score of design and organization of STEM educational activities post-impact group			2.25
Standard deviation pre-impact group= 0.72					Standard deviation post-impact group= 0.83			
Dependent t-test p (p) = 1.12 x 10^{-3}								
Effect Size (ES) = 0.97								

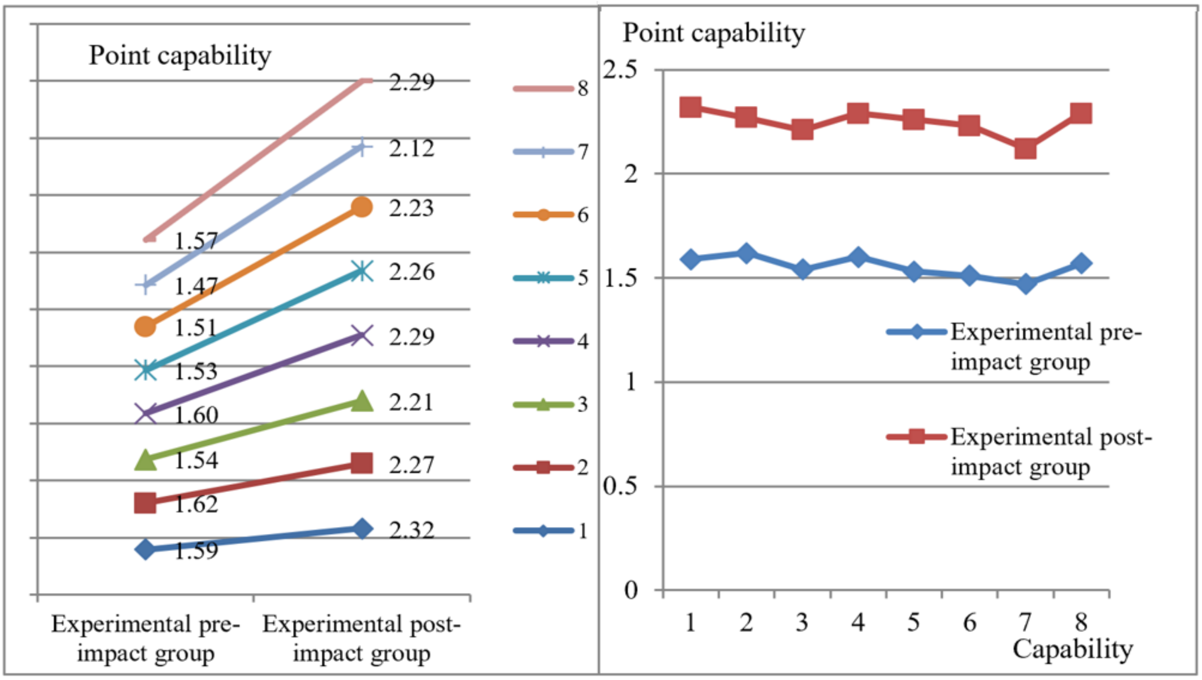

Figure 3 Chart of the progress of the design and organization capacity of STEM educational activities of the teachers participating at Binh Duong through the assessment of the lecturers.

Based on the average scores in each criterion and the average scores in all eight criteria of STEM educational activities of NCTs from the experimental groups in the two education departments of Lang Son and Binh Duong, as described in Figures 2 and 3, there is a clear difference in the level of expression of competence and the average competence scores increased gradually through the pre- and post-intervention points. The average score of the criteria for evaluating the design and organization of STEM educational activities in the group of teachers participating in the experiment after the intervention was higher than that of the experimental class before the intervention. The difference in average value showed that the experimental measures have had a positive impact on the development of the design and organization of STEM education activities for teachers.

According to Tables 2 and 3, the design and organization abilities of the participants in the experiment increased during the training process, and the average scores of the experiment class after the intervention were higher than those of the experiment class before the intervention. The effect size of the two groups of teachers participating in the teaching practice in the two education bureaus was 0.97 and 1.15 respectively, showing that the organization of the project had a great influence on the development of the design and organization abilities of the teachers. All the p-values were much lower than 0.05. In other words, due to the continuous training of the teachers in the design and organization of STEM activities during the instructor's intervention, there was a large difference in the expression level of the design and organization abilities of the teachers between before and after the intervention.

A chart showing the average scores of the design and organization abilities of STEM educational activities of teachers at two points before and after the intervention is presented in Figures 4 and 5:

- Based on the average scores of all criteria at the pre- and post- intervention in the experimental classes, it was found that the teachers' competence of the design and organization of STEM activities was much developed.
- The images showed a clear increase in the average scores of the design and organization of STEM education activities for teachers between the two points before and after the three phases of the development process of design and organization of STEM educational activities. The difference in average scores in each criterion had values from 0.65 to 0.86. The difference in average scores of designs and organization of STEM educational activities between the post-intervention and pre-intervention points was 0.7 and 0.8, respectively.

From the analysis results above, it can be seen that the teacher training results were conducted on different teachers, at each different secondary school, but the obtained findings were identical. Therefore, we can conclude that the impacts of the process of NSTs' capacity development in building and implementing STEM education activities are feasible, positive, and highly stable. After the teacher training, the initial step has brought about positive effects on the development of the capacity for designing and organizing STEM education activities for NSTs. The competence level of the experimental groups in the schools at the post-intervention time point all increased, and developed higher than the competence level at the pre-intervention time point. This confirms that the application of the 3-phase process to develop STEM teaching capacity has contributed to the renewal of teaching methods for teachers in Vietnam's secondary schools.

4.1. Results of the Teacher Self-Assessment of the Ability to Design and Organize STEM Educational Activities

Along with the evaluation by the lecturers of teacher's capacity on implementing STEM activities, we used the teachers' assessment. We organized the teachers to participate in the self-assessment of the design and organization of STEM education activities for themselves at pre-and post-intervention points after participating in the research process through two modules (building a teacher training document on STEM teaching, and applying the blended learning model). The average scores before and after the intervention are presented in Figure 4 and 5.

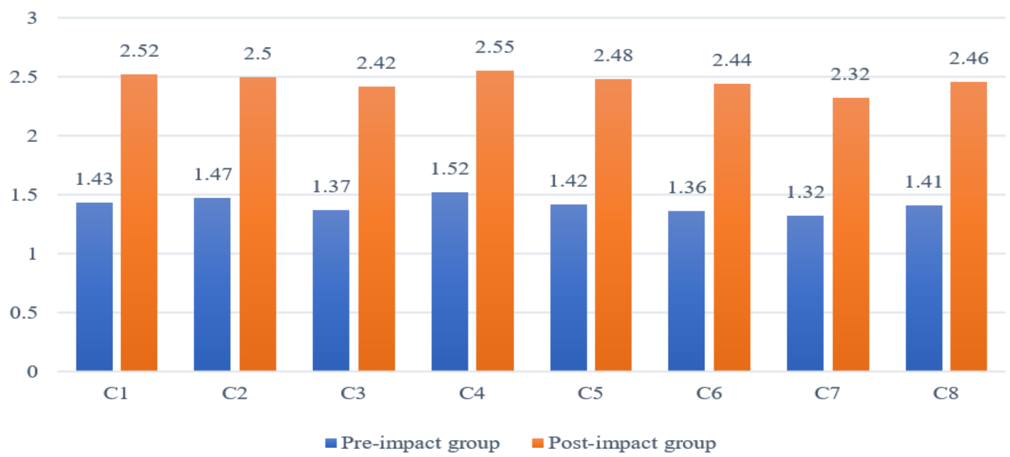

Figure 4. Results of teacher self-assessment of design and organization skills for STEM education activities of the teacher group participating in the experiment in Binh Duong. (Note. C= Criterion).

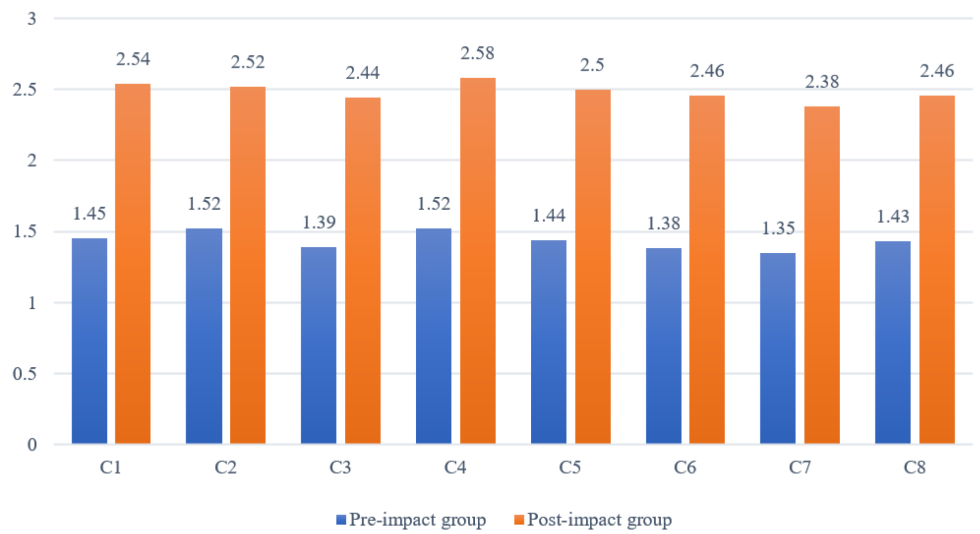

Figure 5. Results of teacher self-assessment of design and organization competence for STEM education activities of the teacher group participating in the experiment in Lang Son. (Note. C= Criterion).

The results of the self-assessment of 122 teachers participating in the teacher training program showed a clear difference in the average scores of the competency criteria between the pre-intervention and post-intervention points. The average competency score for each criterion at the pre-intervention point was self-assessed by teachers to range from 1.32 to 1.52. However, after the intervention, teachers noticed that their own competency had developed beyond all criteria, with the average competency score for each criterion ranging from 2.32 to 2.58. The self-assessment results of the teachers showed that they had made a clear improvement in their competency in designing and organizing STEM educational activities after taking part in the pedagogical training phase (Phase 1) by the lecturers, which was fully in line with the lecturers' assessment results. This has reaffirmed the effectiveness and feasibility of the competency development process for designing and organizing STEM educational activities for teachers.

5. CONCLUSION

The role of STEM education has been researched, affirmed, and developed in many countries in recent decades. In this context, the teachers' competence is the decisive factor in achieving the target requirements of STEM in the general education program. This research has identified the requirements for teacher competence in designing and organizing STEM education activities through Nature Science subjects in secondary schools. The competence consists of two components: (1), the ability to build STEM topics through teaching natural science; (2) the ability to organize and implement the STEM education topics, with eight criteria and three levels of expression, with specific evidence of each level. This is the basis for designing evaluation criteria for teachers to assess teachers and self-assess design and organization skills for STEM education activities. Through the assessment results, teachers can track progress and adjust teaching strategies accordingly when designing learning activities for students in STEM education topics. To form design and organization ability and implement STEM education topics, this research proposed a process comprising three stages of developing design and organization skills for NSTs.

The three stages of the research model involving 122 NSTs in two provinces of Binh Duong and Thai Nguyen, Vietnam were conducted. To verify the feasibility and effectiveness of the proposals, this paper designed an assessment tool to evaluate the design and organization of STEM education activities for NSTs participating in the experiment. The results of the teacher assessment and self-assessment of their own abilities before and after the intervention showed that the Effect size effect of the two groups of teachers participating in the teaching practice in the two education departments of the two provinces of Vietnam were 0.97 and 1.15 respectively, indicating that the proposals had a great impact on the development of the design and organization of STEM education activities for NSTs; all the p values were much less than 0.05 in all the teacher groups participating in the teaching practice, indicating that the teacher's ability was developed after the intervention of the research, not by chance. At the same time, the ability of the teachers was formed and developed beyond the level in all criteria, with the average ability value of each criterion ranging from 2.32 to 2.58. This confirms that the application of the three-stage process to develop the design and organization of STEM educational activities has provided guidance for teachers to use to assess the ability of students, contributing to improving the teaching ability of NSTs in two provinces of Vietnam.

However, while new research has focused on proposing a process for developing design and organization capabilities for STEM education activities for high school teachers, many studies have also pointed out that current STEM education models only focus on a few large provinces and cities. Many localities still have not accessed and understood STEM education. The organization of these activities has not yet been systematized, and there is no step-by-step process that can be widely applied to secondary schools. The reasons for these limitations are various, including the knowledge base of students in science, technology, engineering, and mathematics (STEM) formed in elementary education, which can impede students from STEM learning (Nadelson et al., 2013); Vietnamese teachers are trained as single-subject teachers, with limited interdisciplinary understanding and lack of quality STEM education models for developing students' capabilities, thus they are in trouble in developing their expertise to teach STEM. Acknowledging the numerous limitations in the current system and structure of education, some approaches have been proposed to reduce the challenges and maximize the strengths that veteran teachers have established (Ryu, Mentzer, & Knobloch, 2019).

Therefore, in order to improve the quality of STEM education and ensure the set goals are achieved, the quality of STEM teachers needs to be improved in a synchronized and expanded manner. The two main aspects necessary for creating high-qualified STEM teachers are the 'teaching and learning skills' and 'knowledge and understanding' (Nasri, Nasri, & Talib, 2020). The formation, development of design, and organization ability for STEM education activities for teachers need to be approached from a situational perspective to illuminate the context in which teaching is practiced. Emphasis and development of the STEM background knowledge for teachers is a decisive factor for their success in teaching STEM. At the same time, the training program for NSTs needs to be redesigned, emphasizing the formation and development of basic knowledge, and integrated interdisciplinary natural science knowledge. Coordinated cooperation from the national levels like government, regional levels, educational sectors, and professional teacher associations necessary for collaboration and investment in the development of education.

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