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Obstacles and Challenges in Implementing STEM Education in High Schools: A Case Study in the Northern Mountains of Vietnam

Tuong Duy Hai 

Hanoi National University of Education,
VIETNAM

Nguyen Quang Linh* 

Thai Nguyen University of Education,
VIETNAM

Nguyen Thi Bich 

Thai Nguyen University of Education,
VIETNAM

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Abstract: Science, technology, engineering, and mathematics (STEM) education has been successfully implemented in many countries around the world, including Vietnam. Admittedly, it appears that Vietnamese teachers are encountering several obstacles and challenges as they adopt STEM education in their classrooms. The purpose of this study was to use the Delphi method to figure out the obstacles and challenges that teachers in six northern mountainous provinces of Vietnam encounter when teaching STEM education. As per research findings, teachers confront 11 obstacles and challenges when integrating STEM education in their classrooms, including: Teacher competency, time consumption in lesson planning and guiding students to produce STEM products, teachers' beliefs regarding STEM education, inflexible programs, insufficient facilities, examination pressures, lack of timely rewards and encouragement for effective teachers, teachers' self-funding teaching STEM, students' competence, students' cultural, economic and social background, and disagreements from student's parents. These findings assist administrators and teachers in developing future strategies for successfully implementing STEM education in Vietnam.

Keywords: *Barriers, Challenges, Education in Vietnam, STEM education, STEM integration.*

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Introduction

There are three levels of education in Vietnam: primary schools (for those aged 6 to 10), secondary schools (for those aged 11 to 14), and high schools (for those aged 15 to 18). The first and second levels are compulsory, with the goal of ensuring citizens have adequate training to accomplish work in the future (after graduating from secondary school, Vietnamese students can enroll in vocational schools to prepare themselves with technical skills for a specific job) (Education Law, 2019). Despite elementary and secondary schools having been built in practically all communes, wards, and townships across the country, there are still some distant and isolated areas without secondary schools (Ministry of Education and Training [MoET], 2020a).

Since 2021, Vietnam's "General Education Program 2018" has been in place, with science, technology, engineering, and mathematics (STEM) education regarded as a key educational technique to be encouraged in high schools nationwide (Nguyen & Ha, 2019). MoET of Vietnam has organised numerous training programmes, guidance documents, and solutions to encourage teachers to implement STEM in their classes, thereby gradually and successfully achieving the goal of bringing STEM education into high schools during the implementation of the 2018 General Education Program (Le et al., 2021; Nguyen & Ha, 2019; Pham & Le, 2022; V. T. Tran, 2021). Indeed, from 2010 onward, numerous schools around the country began experimenting with STEM education in the subjects of Informatics and Robotics from grade 1 to grade 12 (Nguyen & Ha, 2019). Following that, STEM education garnered increased attention from teachers and schools alike. Years later, STEM-related competitions such as "STEM-based Teaching for High School Teachers" and "STEM Approach for Teaching" have been established to encourage teachers to participate and share their experiences with adopting STEM education in their classrooms (Hoang, 2019; Nga & Muoi, 2018; Nguyen & Kieu, 2022). Every year, the MoET releases guidelines that direct the implementation of STEM education in high schools (Do et al., 2021; T. K. A. Nguyen, 2019; Pham & Le, 2022). Furthermore, many teachers have studied the STEM Education approach and have

* Corresponding author:

Nguyen Quang Linh, Thai Nguyen University of Education, Vietnam. ✉ linhnq@tinue.edu.vn

either directly implemented or participated in professional organisations that have adopted STEM education (Le et al., 2021; Nguyen & Ha, 2019).

STEM education has become not only a trend in Vietnam, but also an obligation in order to meet the goals of the 2018 General Education Program (Nguyen & Ha, 2019). Teachers, on the other hand, have been faced with many obstacles and challenges during the implementation of STEM education in their classrooms (T. N. Nguyen et al., 2017; Nguyen & Ha, 2019). The Delphi method is utilised in this study to assess the difficulties and challenges experienced by secondary and high school teachers of Mathematics, Natural Sciences, Physics, Chemistry, Biology, Informatics, and Technology in six mountainous provinces in northern Vietnam. Primary school teachers were not selected as participants because STEM lessons have not been widely applied by those teaching at this level (Nguyen et al., 2018).

Because of unfavourable socio-economic conditions and insufficient facilities (Hoang, 2019), students in Vietnam's northern provinces have significant limitations in communication and self-expression. Teachers' competency is also lower compared to other locations (Hoang, 2019; V. T. Tran, 2021). This has produced a greater challenge in STEM education implementation in this region than in others around the country, implying that teachers in this area require more attention from administrators and educators in the future.

The findings of this research can serve to (1) provide administrators and policy-makers measures or solutions to help teachers overcome difficulties and barriers to successfully implement STEM education. By taking into account all of the conditions of each secondary and high school, these findings can be extended from Vietnam's northern mountainous provinces throughout the entire country, helping in the development of macro-policies that support the Education Sector in achieving established educational goals; (2) adapt education universities' training programmes in specific ways to ensure that pedagogical students can teach STEM subjects upon graduation; (3) offer teachers training and research centres necessary training to fill any gaps in their STEM education; and (4) aid secondary and high school teachers to be aware of their difficulties and limitations to conduct suitable self-studies.

In the following section, previous studies are explored and analysed. Obstacles and issues that teachers face when adopting STEM education in their classrooms are discussed. Following that, the Delphi technique is utilised to determine the true impediments to integrating STEM education.

Literature Review

STEM education is a teaching approach that strives to provide pupils with scientific knowledge, to later be applied in real-life activities (MoET, 2020a). The goal of STEM-themed lessons is to completely solve a problem, in which students are organised to participate in learning activities and apply their newly found knowledge to solve the aforementioned problem, thereby contributing to the development of students' competencies and qualities. (MoET, 2020a; Nguyen & Kieu, 2022; T. K. A. Nguyen, 2019). In Vietnam, depending on the characteristics of each subject and infrastructure conditions, schools can flexibly apply three forms of STEM education organization such as: teaching science subjects in the form of STEM lessons, organizing STEM experience activities, or organizing scientific and technical research activities (Do et al., 2021; MoET, 2020a).

STEM education is considered an inevitable trend in many countries, as a part in the teaching curriculum of STEM subjects (Al Salami et al., 2017; Asghar et al., 2012). STEM education has been implemented and evaluated successfully in several countries around the world, including the United States, Australia, Singapore, and many European countries (Lee et al., 2019; K. D. Nguyen, 2020). Apart from successes, various studies also have shown obstacles and problems that educators around the globe must deal with while adopting STEM education. For developing or less developed nations, these challenges are heightened.

Challenges can come from administrators, teachers, or students. STEM education is an interdisciplinary teaching approach, which asks the teachers, instead of focusing on the knowledge of one subject, to have understanding of more than one subject when solving practical problems (MoET, 2020a). However, most teachers do not have enough time to fully grasp STEM lessons (Nadelson & Seifert, 2017). This makes them less confident when confronting students' questions or problems in class. It also cannot be implemented in a short period of time (Le et al., 2021; Lee, 2019; Lesseig et al., 2016; Öztürk, 2021; Portz, 2015; Qureshi & Qureshi, 2021; Ramli, Talib, Aishah et al., 2017). Additionally, STEM-focused class planning and organization call for teachers to possess stronger pedagogical skills (Johnson, 2012). Student factors (their interests, strengths, abilities, etc.) also pose a challenge for teachers in the classroom (Qureshi & Qureshi, 2021). Teachers must be skilled at dividing students into groups, assigning work, grading them, and so on (Ramli, Talib, Hassan et al., 2017). In some circumstances, students who have little interest in STEM education must be addressed in class (Nguyen & Kieu, 2022; Nguyen & Le, 2020). Teachers also confront numerous challenges in terms of time management of the lesson as well as managing students' study time both inside and outside of the classroom.

Due to their lack of STEM education training, many teachers are unsure of where to begin with STEM education (Portz, 2015). Some teachers believe that despite having been trained or having done self-study on STEM education, the information that they find or the training process is still largely insufficient (Ismail et al., 2019). Even when the aforementioned difficulties are manageable, they must contend with an inflexible curricula (Kezar & Holcombe, 2020).

These programs also place a greater emphasis on teaching content rather than the process of organizing teaching activities to develop students' competence. They must strictly adhere to a teaching plan based on school days and school weeks, which has not only given great advantages to administrators in monitoring the program and evaluating the teachers, but also has hindered teachers due to its constraints (Lee et al., 2019; Nguyen & Kieu, 2022; Portz, 2015). Teachers' experience countless difficulties in managing students during the time they work outside classes, which is a job that should be done in most lessons that follow the STEM educational approach (Ramli, Talib, Hassan et al., 2017).

One of the difficulties and challenges that teachers face is a lack of suitable facilities (Ejiwale, 2013; Ismail et al., 2019; Johnson, 2012; Le et al., 2021). STEM lessons are derived from problems that students face in practice, and to solve those problems, they must have the support of engineering, science, and technology (Johnson, 2012; Le et al., 2021; Teo & Ke, 2014). Therefore, for the implementation of STEM lessons to succeed, it is essential to have a system of laboratories and supporting STEM rooms. Making use of either available equipment or simple, easy-to-find materials is a necessity, however, it is not enough to have attractive and diverse STEM topics (Dong et al., 2020; Le et al., 2021; Nguyen & Kieu, 2022). Additionally, they need to be given enough money for the courses to purchase supplies for students to develop and create technical models and products (Johnson, 2012; Nguyen & Kieu, 2022; Öztürk, 2021).

Testing and assessment in teaching also hinder the implementation of STEM education. The advantages of STEM education are undisputed, however, in many countries, traditional examinations or assessments give little thought to judging students' levels of competence but continue to concentrate on assessing their understanding of the subject matter (Dong et al., 2020; Kezar & Holcombe, 2020; Lee et al., 2019). This places a lot of stress on parents, students, and teachers. Although teaching STEM courses can be enjoyable for both teachers and students, it has minimal effect on traditional test scores. (Lee et al., 2019; Nguyen & Kieu, 2022; Nguyen et al., 2018).

Furthermore, teachers face many other challenges when teaching STEM education such as: policy regimes and lacking support from administrators (Johnson, 2012; Lee et al., 2019). Because of the program's frequent modifications, some teachers find it difficult to swiftly adjust and lose faith in STEM education altogether (Le et al., 2021). Some teachers lack time to design lesson plans that follow STEM education guidelines (Dong et al., 2020). It can be challenging to find STEM topics that are appropriate for the curriculum and the economic and social context in which students live (Le et al., 2021).

Methodology

Research Design

The research team used the Delphi research approach to identify the obstacles and challenges that teachers experience when implementing STEM education in high schools. In the 1960s, the RAND Corporation introduced this strategy for obtaining expert consensus in a study (Tran et al., 2020). More recently, it has been used in many different fields including educational research (Judd, 1972; Zawacki-Richter, 2009). The Delphi method is an iterative procedure that uses a series of questions interspersed with feedback to collect and distil expert assessments. The purpose of this method is to iteratively build consensus forecasts from a group of experts (Anh, 2021). Studies with Delphi usually use a minimum of two rounds. Round 1 comments are based on the researcher's initial views and opinions, but additional ideas can also be included. However, these additional remarks may not always reflect the views of all responders. As a result, additional rounds are required to poll this opinion. Some of the expressions in round 1 must be adjusted as well (depending on the study), and these changes will be corrected in round 2. Given these characteristics, the Delphi method has been deemed appropriate to achieve the goal of this research.

Initial Ideas

The collection of published data on the difficulties and challenges that teachers face when implementing STEM education is the first step in the study. The research team made preliminary recommendations - or in other words, the anticipated challenges and barriers that the teachers are facing - based on findings from the actual implementation of STEM education in Vietnam's northern mountainous provinces in recent years (as seen in Table 1). These recommendations were then followed by interviews with three secondary and high school teachers from three different provinces in Vietnam's northern mountainous region (Table 2). These teachers have been implementing STEM education in their schools. Teachers in the central area and have better teaching conditions (1st item), while others teach in areas with average socio-economic conditions (2nd item), and others still are in remote areas (3rd item).

During the interview process which lasted between 25-40 minutes, the research team started with the prompt, "Please share the advantages, disadvantages and experiences of implementing STEM education in your classroom." The interview was created in a comfortable and cozy atmosphere for teachers to share their opinions. Special attention was paid to the difficulties and challenges that teachers face when implementing STEM education in secondary and high schools. The interviewer also encouraged teachers to describe their difficulties and challenges that they encountered in teaching beyond the initial suggestions of the research team. Results show that teachers often face challenges that need to be overcome as seen in Table 1.

Table 1. Challenges Teachers Face When Implementing STEM Education in High Schools

No.	Difficulties and Challenges Encountered	Note
1	Inflexible program	
2	Poor physical facilities	
3	Loss of time in developing lesson plans and guiding students to complete STEM products	
4	Exam pressure	
5	Teacher's competence	
6	Student's competence	
7	Teachers have to spend more money to buy materials for students to make STEM products	
8	Teacher's interests and beliefs	
9	Support from professional teams, schools	
10	Students are still passive; only some students perform when the group is assigned a task	Suggested by the teachers
11	Cultural, economic, and social context where students' study	

Table 2. Information of Three In-Depth Interviewees

No.	Full name	Years of teaching	Teaching area	Interview period	Interview form	Subject in charge of/ education level
1	Van Thi Yen	12	Thai Nguyen City, Thai Nguyen	June 24, 2022	Direct	Natural Science, Technology Secondary School
2	Nguyen Thi Thu Hang (*)	22	Huu Lung, Lang Son	June 24, 2022	Online (phone)	Natural Science, Engineering Secondary School
3	Dinh Van Thao	12	Muong Nhe, Dien Bien	June 26, 2022	Online (zoom)	Physics, Technology High School

(*) The teacher is also the manager.

Delphi Method

The research was conducted following Delphi method, which started with a questionnaire, followed by two rounds of investigation. In the first round, the researchers conducted the interview with the completed questionnaire. After that, the questionnaire was adjusted according to the principles in Delphi method to continue interviewing experts in the second round. In both rounds, participants were asked to complete questionnaires with rating scales for each question. They were also asked to explain their responses and were encouraged to suggest modifications to the questionnaire if necessary.

The questionnaire consisted of four parts:

Part 1: General description of STEM education: definition and characteristics

Part 2: Collection of general information of interviewees: Full name, age, gender, number of years worked, type of school teaching, learning about STEM education, and the number of STEM topics made.

Part 3: Questions: Each interview question consisted of two parts: (1) factors that have hindered the implementation of STEM education in secondary and high schools (this part is designed on a 5-point Likert scale) and; (2) request for a more detailed explanation of his or her response to the interview question.

Part 4: Open-ended questions: This section asked the interviewee to (1) adjust the terminology of the expressions used in the question in part 3 and; (2) propose more influences on the implementation of STEM education in secondary and high schools.

Sample and Data Collection

The research team selected teachers from six provinces in the northern mountainous region of Vietnam. The teachers interviewed were those who have taught at least one STEM topic (in Vietnam, each STEM topic is taught in 2-3 classroom lessons (45 minutes each lesson)), and are between 26 to 55 years old (deemed an appropriate age with enough experience and desire to approach new teaching methods). They were randomly selected from both secondary and high schools. Initially, 60 teachers were selected, and after several discussions, 45 teachers were willing to participate in the first interview (accounting for 75% of the initial sample size). This data is acceptable because the number of interviewees is within the recommended range of 20 – 50 people (Arthur et al., 2013; Endacott et al., 1999). In the second round of interviews, the number of participants decreased significantly, mostly because they were busy with their work. The number of interviewees in the second round was 31 people (68.9% compared to the first round), which still suffices the quality of the study and is a common occurrence when doing Delphi research (Judd, 1972; Tran et al., 2020).

In order to analyse the consistency and stability of the ratings given by experts, the data collected from the survey rounds were aggregated and analysed based on the KAMET principle (Knowledge Acquisition for Multiple Experts with Time scales) (Chu & Hwang, 2008). The questionnaire from the second round was developed and conducted based on the summary of the previous round's assessment. Accordingly, the scores were reviewed, corrected and analysed from the previous round. The results of the questionnaires were tabulated, and the mean, standard deviation, and percentage of consensus (% of consensus) for each item of the questionnaire was calculated. When one of the two following situations applied, the item was eliminated from the questionnaire and no further discussion was necessary: (i) either come to an agreement or (ii) dropped from the questionnaire as being determined as unimportant.

Round 1

In the first round, an online survey was sent to 45 participants who agreed to participate in the study (Table 3). In order to shorten the research time as well as to create more favourable conditions in arranging the time to answer the interview form, an online survey via Google Form was selected instead of a traditional survey on paper. Since every participant is a teacher familiar with teaching and working online, the use of an online survey was familiar to them and did not compromise the quality of the survey results (Mondal et al., 2018).

The main content of the questionnaire included 11 factors affecting the implementation of STEM education by teachers in secondary and high schools. Each of these factors was designed with a 5-point Likert scale.

Round 2

In the second round, the questionnaires included 13 items, of which 11 were based on the first round, while the other two were "Disagreement from the student's parents" (12th item) and "Lack of timely reward and encouragement for teachers who do well" (13th item) (Table 5) were added on additional request from the researchers in the first round.

The second round was conducted with the same process as the first round. The members of the research team were assigned to contact 45 teachers who participated in the 1st round (via phone, text, or email) to invite them to participate in the second round. The participants were all willing to participate in the research, however, due to being too busy with work and the short turn-around time for round two (within 1 week), only 31 participants completed the second round. The dropout rate for the second round was 14/45 (or 31.1%). Despite the decrease in the number of participants, the research was still considered acceptable and normal for a Delphi-styled study (Gnatzy et al., 2011).

Data Analyses

Table 3 below presents the personal characteristics of 45 survey participants. Specifically, out of these 45 participants, 24 participants (or 53.3%) were male; and 21 participants (46.7%) were female. Most of the participants were either 26–35 years old (22 people, 48.9%) or 36–45 years old (20 people, 44.4%). None of the participants were aged under 26 or over 55. In terms of qualifications, 35 participants (or 77.8%) had bachelor's degrees, while 10 (or 22.2%) had master's degrees. No one had an associate degree. Every participant has had experience teaching STEM education and have implemented STEM education lessons in their classrooms. This is especially important because, as required by the Delphi method, participants must be experts or experienced in the subject of the study (Chu & Hwang, 2008). The research participants were also teachers with sufficient teaching experience, as evidenced by the number of teachers with six years or more teaching experience accounting for 39 people (or 86.7%).

Table 3. Description of Participants

Description of Participants	Round 1 (n=45)		Round 2 (n=31)	
	Frequency	%	Frequency	%
Gender				
Male	24	53.3	14	45.2
Female	21	46.7	17	54.8
Age				
26-35	22	48.9	13	41.9
36-45	20	44.4	15	48.4
46-55	03	6.7	03	9.7
Qualification				
Bachelor	35	77.8	23	74.2
Master	10	22.2	8	25.8
Years of Teaching				
15 years	6	13.3	5	16.1
6-10 years	26	57.8	16	51.6
Over 10 years	13	28.9	10	32.3

Table 3. Continued

Description of Participants	Round 1 (n=45)		Round 2 (n=31)	
	Frequency	%	Frequency	%
Number of STEM Lessons/Activities Held in Class				
1-2	16	35.6	14	45.2
3-4	25	55.6	14	45.2
More than 4	4	8.9	3	9.7
Education Level Being Taught				
Secondary School	27	60	17	54.8
High School	18	40	14	45.2

Table 3 also lists the personal characteristics of the 31 teachers who agreed to continue to round 2. In round 2, 14 were male (or 45.2%) while the rest were female. Most of the factors were equivalent to round 1. The survey group's ages ranged from 26–35 years old (13 people, 41.9%) or 36–45 years old (15 people, 44.4%). None of the participants were under the age of 26 nor over 55. In terms of qualifications, 35 participants (or 77.8%) had bachelor's degrees, while 10 (or 22.2%) had a master's degree. No one had an associate degree. They have also experienced teachers and have organized STEM education classes in their classrooms.

Findings/Results

Table 4 displays the results of the two questionnaires. The collected data were analysed in Microsoft Excel using the AVERAGE (for Means) and STDEV (for standard deviation) formulae.

Table 4. Results of Two Questionnaires by the Delphi Method

No.	Difficulties, Challenges	Round 1 (n = 45)			Difficulties, challenges	Round 2 (n = 31)		
		Mean	Standard deviation	Consensus ratio		Mean	Standard deviation	Consensus ratio
1	Inflexible program	4.727	0.458	100	Inflexible program	4.548	0.506	100
2	Poor physical facilities	4.250	0.688	86.7	Facilities do not meet demand*	4.355	0.608	93.5
3	Loss of time in developing lesson plans and guiding students to complete STEM products	4.818	0.387	100	Loss of time in developing lesson plans and guiding students to complete STEM products	4.581	0.502	100
4	Exam pressure	4.795	0.405	100	Exam pressure	4.484	0.570	96.8
5	Teacher's competence	4.432	0.657	91.1	Teacher's competence	4,000 won	0.447	90.3
6	Student's competence	4.341	0.603	93.3	Student's competence	4.161	0.583	90.3
7	teachers have to spend more money to buy materials for students to make STEM products	4.114	0.745	77.8	teachers self-finance when teaching STEM *	4.129	0.670	83.9
8	Teacher's interests and beliefs	4.159	0.673	84.4	Teacher's beliefs about STEM education*	4.097	0.651	83.9
9	Support from professional teams, schools	3.841	0.737	64.4	Support from professional teams, schools	3,774	0.669	64.5

Table 4. Continued

No.	Difficulties, Challenges	Round 1 (n = 45)			Difficulties, challenges	Round 2 (n = 31)		
		Mean	Standard deviation	Consensus ratio		Mean	Standard deviation	Consensus ratio
10	Students are still passive, only some students perform when the group is assigned a task	3.864	0.706	66.7	Student interest *	3,903	0.651	74.2
11	Cultural, economic and social context in which students study	4.114	0.745	77.8	Cultural, economic and social context in which students study	4.032	0.657	80.6
12	/	/	/	/	Disagreement from the student's parents **	4.194	0.749	80.6
13	/	/	/	/	Lack of timely reward and encouragement for teachers who do well **	4.290	0.693	87.1

(*) Items have been adjusted in terms of terminology as suggested by Round 1 respondents.

(**) New entries were included in Round 2, as suggested by Round 1 respondents.

The main results of Round 1 are presented in Table 4. Along with the mean and standard deviation associated with each item, Table 4 also shows the consensus ratio, which is an integral part of using the Delphi method. The content was considered to have reached consensus from the interviewees when at least 75% of the respondents gave a score of either completely agree (i.e., 5 on a 5-point Likert scale) or agree (i.e., 4 on a 5-point Likert scale) (Keeney et al., 2001).

As the results of the first-round show in Table 4, out of 11 items, 9 items reached the consensus level (from 75% or more). There were two categories that did not reach consensus: (1) "Support from professional groups and schools" (9th item) and (2) "Students are still passive, only some students do work when the group is assigned tasks" (10th item). There are four items (2, 7, 8 and 10) that received proposals to adjust terminology, and two items were proposed to be added (12th, 13th items) in the next round of the study.

Table 4 shows that, among the results from the second round, teachers who participated in the survey agreed on 11 out of the 13 topics (Categories from 1 to 9, 12, and 13). While the content in item 9 and 10 did not reach consensus the rate at 64.5% and 74.2%, respectively. Notably, the two items added from the surveyors' opinions in round 1 (items 12 and 13 in Table 4) achieved a higher consensus with rates of 80.6% and 87.1%, respectively.

After two rounds of Delphi method, the research discovered 13 factors, corresponding to 11 items of consensus in the questionnaire, which are the difficulties and challenges that teachers face when teaching according to STEM education in secondary and high schools. These are: "Inflexible program", "Failure to meet the needs of the facilities", "Loss of time in developing lesson plans and guiding students to complete STEM products", "Exam pressure", "Teacher's competence", "Student's competence", "Cultural, economic and social context in which students study", "Teachers' beliefs about STEM education", "Cultural and economic contexts, society where students study", "Parents' disagreement", and "No timely recognition and encouragement for teachers who perform effectively."

Discussion

The Delphi research method employed in the study aided in discovering 11 problems and obstacles that teachers encountered among the studied population. These problems and difficulties can be classified into three categories: factors originating from the policy regime, from teachers themselves, and other factors. (Figure 1)

Originate from teachers themselves	Originate from the policy regime	Other factors
<ul style="list-style-type: none"> •Teacher competence •Loss of time in developing lesson plans and guiding students to complete STEM products •Teachers' beliefs about STEM education 	<ul style="list-style-type: none"> •Inflexible program •Failure to meet the needs of facilities •Exam pressure •There is no timely reward and encouragement for teachers who do well. •Teachers spend their own money when teaching STEM 	<ul style="list-style-type: none"> •Student competence •Socio-cultural context in which students study •Disagreement from the student's parents

Figure 1. Difficulties and Challenges Teachers Face When Implementing STEM Education in Their Classrooms in Vietnam

From the Teachers

After completing 12 years of high school, students in Vietnam who are admitted to the University of Education must study there for 4 years in order to be qualified to teach in high schools (Luong, 2014). Despite receiving the core knowledge of science, teaching methods, pedagogical skills, etc., students still need a lot of help to properly instruct their classes. They frequently need to practice self-study or receive mentorship to improve their instructional abilities (Nguyen & Hoang, 2019). For most teachers, however, utilizing a STEM-based approach to teaching is a relatively new teaching style (and are not trained to teach in STEM education). Because of this, up to 91.1% of teachers think that incorporating STEM education into their classes is demanding and difficult.

Due to limited training or learning resources, it is extremely difficult to construct and organize lessons with STEM education (Nguyen & Kieu, 2022; Nguyen et al., 2018). The research findings show that 100% of the teachers who responded to the survey agree that "it takes time to design lesson plans and coach students to complete STEM products", which the authors of the current study consider a new finding compared to previous studies. It is the ability of the teachers, not the difficulties of the STEM education teaching approach itself that accounts for the consumption of time in creating lesson plans and directing pupils. Additionally, it is crucial to define which of the teachers' abilities are weak, and which is not. When creating lesson plans, "it actually took me a lot of effort to make the connection between the content of the course and real-life problems," said Ms. Van Thi Yen, a teacher at Nha Trang Secondary School in Thai Nguyen City. "It took me a lot of time to develop those lessons after connecting the content of the lesson with the practice."

However, some teachers in Vietnam either do not think STEM education would be successful or do not have confidence in its success. In rounds 1 and 2, 84.4% and 83.9%, respectively, of teachers in Table 4 indicated strong agreement that it is a challenge. Naturally, if teachers lack trust, it is difficult to implement any teaching strategy effectively (Le et al., 2021). Mr. Vu Tuan observed, "I find that teachers today constantly have to learn new teaching methodologies" (Son Duong High School - Tuyen Quang). Sometimes, I lose hope in the effectiveness of new teaching strategies because they are evolving too quickly and dramatically.

From the Policy Regime

Both variables "policy regime" and "programme flexibility" showed absolute agreement (100%) in both rounds. This demonstrates how these two issues are a significant obstacle to the introduction of STEM education in secondary schools. Teachers must adapt some lessons, and eliminate others, to have time to organise a STEM lesson (MoET, 2020b; Nguyen & Kieu, 2022; T. N. Nguyen et al., 2017). Nevertheless, the curriculum is so limited, and it is incredibly difficult for the teachers to apply STEM training in their classes. Extra classes after school are inevitable which is an inconvenience for both teachers and students.

Vietnam experiences strong competition pressure (K. D. Nguyen, 2012). This problem affects administrators, instructors, and students alike. However, there has not yet been an increase in exam scores as a result of teaching in line with STEM education (K. D. Nguyen, 2012; Tran et al., 2020). According to the research findings, which reveal that 100% (round 1) and 96.8% (round 2) of participants have a high consensus that "exam pressure" is one of the hurdles and difficulties that teachers must deal with while implementing STEM education in their classrooms. "With the ninth graders that I am teaching, children are extremely delighted and eager when I organize teaching according to STEM education," said Ms. Nguyen Thi Hang (teacher at Huu Lung Secondary School - Lang Son Province). In order to improve their test scores, many parents and students in this class request a leave from conventional class to attend after-school sessions.

The lack of facilities was another element receiving the strong consensus (93.5%, round 2) and an obstacle that educators must overcome. The majority of instructional materials used in Vietnam's public schools are provided once by local governments and reused over several years. These tools, which largely consist of simple experimental equipment, are meant to assist students and teachers in the creation of STEM-related goods. (Nguyen et al., 2017). Since then, the fact that teachers have had to pay for themselves to construct STEM activities attained a high consensus of 83.9% among participants. The research team attempted to separate these two components in order to gain a better understanding of the difficulties and obstacles that teachers face in Vietnam. "Teachers spend their own money when teaching STEM," seems to be a key factor, as well as "Facilities have not matched the needs", but these should be separated to help see the obstacles teachers are facing more clearly. This is also a newly recorded factor compared to previously reviewed studies.

"No timely recognition and encouragement for teachers who perform effectively," was the final category. This content achieved 87.1% consensus among the study's participants in the second round after the study team consulted the experts from the first round. This was significantly higher than anticipated. Like the former factor of "Teachers spend their own money when teaching STEM," this factor was unexpected. Clearly, emulation and reward activities are required to inspire employees to be more motivated at work. (N. D. Nguyen, 2020). Yet, these activities are still insufficiently carried out in Vietnam's high schools, and as a result, teachers have not contributed fully to actual practise (Dao, 2019; N. D. Nguyen, 2020). Teachers' attitudes towards STEM education are influenced by how their schools evaluate their performance each semester or school year. It is disheartening when teachers' efforts in STEM instruction are not acknowledged in evaluations, emulation, or rewards.

Other Factors

So many teachers brought up "students' competence" when discussing the obstacles and difficulties they faced when implementing STEM instruction in high schools. Teachers that participated in the study attained a high level of agreement on this topic in rounds 1 and 2, at 93.3% and 90.3%, respectively. Despite the Vietnamese Ministry of Education and Training has sponsored and organised several trainings for teachers on new teaching methods and strategies in recent years, only a small number of teachers employ them in the classrooms (Tran & Le, 2017). Although student engagement in the classroom has increased dramatically in recent years, students still encounter several challenges and unanticipated events when STEM lessons are taught. Particularly at the high school level in Vietnam, there are very few students studying (to take exams) courses from the STEM-related subjects, at a range of only 30–35% of students annually (Anh, 2021). These students are competent and enthusiastic about STEM education, but the same cannot be said for students who have not been included.

The students' parents provide one of the other challenges and difficulties for teachers while implementing STEM education in their classrooms. Round 2 of the research included the factor "Parents' disagreement," which received a high level of agreement from participating teachers at 80.6%, representing the fourth new factor. The situation perhaps occurs due to parents' misconceptions about STEM education, such as how STEM can squander students' time while doing nothing to improve their academic achievement. Instead of engaging in these educational activities, parents believe that traditional academic instruction with lectures, exercises, and books will help their children earn higher grades and gain admission to better schools (Le et al., 2021; Qureshi & Qureshi, 2021). Many parents believe that if their children participate in these activities, they will be distracted from learning.

The participants of this study agreed highly on the factor of "The cultural, economic, and social context in which students learn," at 80.6%. This is mostly due to the requirement that STEM-related instruction is tightly connected to both practice and students' daily lives. Every community has unique economic, cultural, and social characteristics. This calls on teachers to think about real-world scenarios relevant to their courses. This is another significant difficulty and challenges they face.

Factors That did not Reach High Consensus

Two factors did not reach a consensus from the participating teachers in the study: "assistance from the school" at 64.5% (round 2) and "students' interest" at 74.2% (round 2), respectively. It was unexpected that the factor "assistance from the school" was removed, because many teachers believed that the school should provide greater assistance and that a community of STEM teachers should be established so that they may share ideas and learn from one another (Ejiwale, 2013; Ismail et al., 2019). This demonstrates that the schools' administrators have listened to the teachers' voices and, thanks to information technology, communication among the STEM instructor community is now quicker and more available. This improvement, admittedly, occurs solely at the administrative level, which does not help teachers much in terms of money, curricular changes, or having access to better facilities, etc. To properly integrate STEM education, macro-management is needed.

It makes sense that the teachers who took part in the survey did not have a strong agreement on "students' interest" in the process of engaging in STEM classes. From the above analysis, students consistently express interest in learning activities set up in accordance with innovative teaching methodologies (Do et al., 2021; K. D. Nguyen, 2020). Students have more time and

greater freedom to discuss, voice their opinions, and exchange their ideas with other students with little regard for the course material. Under STEM guidance, topics open for discussion may go well beyond the scholarly information provided in textbooks. Additionally, students are typically proud of what they create (regardless of quality) (Shahali et al., 2017). Therefore, a lack of student motivation (if any, often results from inadequate support from teachers to their students) is the primary reason that hinders the implementation of STEM education in high schools.

Conclusions

Education in Vietnam, like many other countries, has shifted away from content-focused instruction and towards learner-centered instruction. STEM education has been employed in Vietnamese schools for some time, and teachers have encountered numerous obstacles and issues while implementing STEM in their classes. In this study, the Delphi method was utilized to determine the difficulties and obstacles that teachers face. Eleven problems were found, along with potential solutions. These problems and obstacles were divided into three categories: those caused by the policy system, those caused by teachers, and those caused by various other external factors. Four new challenges were discovered from the research, namely: "Loss of time in developing lesson plans and guiding students to complete STEM products", "Parents' disagreement", "Teachers spend their own money when teaching STEM", and "No timely recognition and encouragement for teachers who perform effectively."

Recommendations

Educational policy-makers, administrators, and teachers might use the research findings as recommendations for establishing remedial measures in order to appropriately integrate STEM education in high schools in the future. This research was conducted with teachers from Vietnam's six northern mountainous provinces, but the findings can also be applied to other places, including towns and centres with favourable socio-economic conditions. These findings enable Vietnam to take action in promoting STEM education.

First, it is necessary to provide teachers with more prompts and methodical re-training programs to give them knowledge and strategies for creating lesson plans and organizing instruction following STEM education. This will help teachers feel more confident and better prepared when teaching in accordance with STEM education. They should be prepared to face obstacles and challenges in teaching, not just when adopting STEM education but also when using any other teaching learning styles, and they should have the requisite self-study abilities. Another excellent recommendation for administrators is to establish a network of STEM educators. Inadvertently, this network would serve as a "re-training course." By doing this, they could share educational resources, lectures, and experiences with incorporating STEM education into their classroom settings (Portz, 2015).

Second, STEM education must become a compulsory part of the nation's educational strategy and be encouraged in all high schools. Additionally, the curriculum must be more adaptable in order to make it easier for teachers to integrate new teaching strategies.

Third, a framework for training STEM human resources must be established, starting with higher education institutions (Le et al., 2021). Administrators should also create a favourable legal environment and policies to encourage foreign investors to open high-quality STEM schools in Vietnam, or encourage domestic organisations and individuals to establish (or cooperate to establish) STEM education centres in provinces or at teacher training and retraining facilities.

Fourth, it is important to invest in the schools' infrastructure. The six components of STEM education are: objectives, content, techniques, means (facilities), organization models, and testing and assessment (T. N. Nguyen et al., 2017). Experiences and product orientation are two activities that create the main distinction between STEM education and other educational approaches. As a result, the facilities for STEM education (STEM classrooms, learning materials, visual aids, laboratory equipment, workforce, etc.) take on an even greater significance and specialization, significantly influencing the quality of STEM education. Although STEM-based teaching can be implemented in poor physical conditions (by using recycled materials, for example) (Nguyen & Kieu, 2022), there are many content areas in STEM education that call for investment in cutting-edge teaching facilities and equipment, such as robotics, computer science, etc. Therefore, it is necessary to gradually invest in suitable facilities and instructional equipment in order to fully execute STEM education.

Fifth, testing and assessment are crucial in determining topic choice and teaching techniques as well as advancing teaching and learning as a whole. Testing and assessment in high schools must be innovated. For STEM education, using such outdated evaluation methods (like written tests, memorization drills, and problem-solving activities) will limit the success of STEM education.

Further research can be either the effects of all these factors or the feasibility of all these five recommendations in helping teachers overcome the obstacles and challenges in implementing STEM education in Vietnam's high schools.

Limitations

The study's first drawback is that it did not offer a more in-depth analysis of the groups of participants polled (e.g., the gender factor). The second limitation lies in the sample of participants - the administrators and teachers at secondary schools. It is likely that they do not have a very explicit theoretical knowledge of STEM education, despite the fact that they can successfully implement STEM education in the classroom. The Delphi method's inherent characteristics lead to the final restriction. Although this research method aids in identifying the obstacles and challenges that teachers experience when teaching STEM, it does not demonstrate the significance of these findings. Additional research can be combined with other research methods, such as the Analytical Hierarchy Process (APH), structural equation modelling, and a Structural Equation Model, to produce more comprehensive research results (SEM) in the future.

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Conflicts of Interest

The authors declare no conflicts of interest.

Authorship Contribution Statement

Linh: Data collection and analysis, drafting the manuscript. Hai: Data collection and analysis, critical revision of the manuscript. Bich: Data collection and analysis, secure funding.

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