Research article

Challenges to STEM education in Vietnamese high school contexts

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A R T I C L E   I N F O

A B S T R A C T

STEM education has been considered foundational to economic growth by many countries. It has received great attention from various educational systems, but the actual implementation has triggered several problems, especially in developing countries in Asia. This qualitative study investigated the challenges to STEM education in public high schools in Vietnam. The participants were ten experienced teachers from ten different schools in a Vietnamese central province. The data were collected from in-depth semi-structured interviews. Analysis of the transcripts of the interview recordings showed that the teachers faced many challenges regarding their interdisciplinary knowledge and teaching methods, curriculum, practical constraints, and beliefs about effective STEM education. Notably, the findings concerning the teachers' beliefs about effective STEM education and the tension between their beliefs and the teaching goals were closely related to the local cultural values and the expectations of the schooling system. The findings of the study were discussed in relation to the local contextual factors and cultural values. Implications for teacher pedagogy and professional development regarding STEM education for Vietnamese high school contexts, and beyond, are discussed.

1. Introduction

STEM stands for Science, Technology, Engineering, and Mathematics. STEM education has been understood as an interdisciplinary approach of education that aims to connect the independent disciplines to help students to solve authentic problems. STEM education has the potential to motivate students to study and participate in the STEM field in their future careers (Lee et al., 2019; Margot and Kettler, 2019). STEM education is, therefore, believed to be able to equip students with the transdisciplinary knowledge and skills to tackle problems that occur in their daily life as well as their future complex society. As a consequence, STEM education is considered an inevitable trend of the modern education systems to prepare future global workers. STEM education has been part of the curriculum in many educational systems (Al Salami et al., 2017; Asghar et al., 2012; Bagiati and Evangelou, 2015; Margot and Kettler, 2019), and it has been implemented successfully in some countries, such as the United States, Australia and other Western countries (Lee et al., 2019). However, it was reported that teachers faced many problems in STEM education (Lee et al., 2019; Margot and Kettler, 2019; Ryu et al., 2019). This is particularly the case in developing countries in Asia. Lee et al. (2019), in an epilogue to a special issue on STEM

education, call for more studies investigating teachers' implementation of STEM education in Asian countries. In such countries as Vietnam, little is known about how STEM education is being implemented and what can be done to improve the effectiveness of STEM education. This study is, therefore, timely to provide a more nuanced understanding of teachers' need to inform effective teacher professional development to foster STEM learning.

In order to move STEM education forward, it is necessary to understand the reality of STEM integration from the voices of various stakeholders. This study was designed to gain insights into STEM integration in Vietnam through the voices of high school teachers. It employed a qualitative research design to examine the teachers' experiences, challenges, and beliefs regarding integrating STEM into their existing curriculum. This study can, therefore, offer some pedagogical implications and inform teacher professional development programs and curriculum reform for effective STEM education in Vietnam and other similar contexts.

2. Literature review

STEM education has been considered an important component and implemented across many countries. However, the difference between

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the teaching methods for STEM and other traditional subject domains, the implementation of STEM has triggered many problems for teachers, school administrators, school leaders and other stakeholders. This brought about increasing research attention investigating the difficulties in STEM education in order to inform effective educational approaches and curricula. In a recent systematic review, Margot and Kettler (2019) analyzed 25 studies investigating teachers' perceptions of STEM education, revealing six main areas of challenges that teachers faced, namely, pedagogical challenges, curricular challenges, structural challenges, student concerns, assessment concerns, and teacher supports.

Teachers tend to think that in order to successfully integrate STEM education, they need to shift their existing teaching principles. This thinking leads some teachers to believe that they are not ready for STEM integration, which becomes an inhibiting factor. Lesseig et al. (2016) and Park et al. (2017) reported that teachers thought that STEM integration required them to shift away from teacher-led instruction to student-led instruction. Teachers are also concerned that they would not be able to interpret and align their pedagogy with the STEM curriculum pedagogy (Bagiati and Evangelou, 2015; Holstein and Keene, 2013). In addition, teachers are concerned about the ability to meet the needs of diverse students in terms of individual differences and cognitive abilities (Herro and Quigley, 2017; Park et al., 2017). Another concern is that STEM integration may interfere with their teaching of proper content and science concepts (Dare et al., 2014).

Regarding curriculum challenges, some teachers perceived the integrated nature of STEM education as a challenge because they are worried about following other people's curriculum plans (Bagiati and Evangelou, 2015). They are also concerned about integrating STEM curriculum into their existing curricula. Teachers sometimes consider that STEM curriculum is inflexible (Bagiati and Evangelou, 2015; Lesseig et al., 2016). Secondary teachers in Asghar et al. (2012) study felt that their domain-specific courses (e.g., Biology, Geometry) did not integrate well with other STEM disciplines. In addition, secondary teachers are concerned about the miscommunications between teachers of different subject domains, causing anxiety for teachers and failure for the interdisciplinary STEM curriculum (Asghar et al., 2012; Bell, 2016; El-Deghaidy et al., 2017).

School structures are also perceived as challenges to the implementation of STEM education. The confines of class scheduling had negative effects on the interdisciplinary nature of STEM lessons, and teachers of different specific subjects are not able to conduct interdisciplinary work and co-plan their lessons properly (Asghar et al., 2012; Dare et al., 2014; Lesseig et al., 2016). Teachers' lack of control over the pacing of curriculum and its consequence on instruction are also seen as challenges to teachers' seeking to integrate interdisciplinary subjects for authentic STEM lessons (Herro and Quigley, 2017). Other structural barriers included administrative and financial supports (Asghar et al., 2012; Clark and Andrews, 2010; Hsu et al., 2011; Park et al., 2016, 2017) or a lack of technology resources for students such as computers (Wang et al., 2011).

Student concerns are another barrier to integrating STEM education. Teachers sometimes believe that students are not capable enough or unwilling to be actively involved in STEM integration. Teachers sometimes underestimate their students' abilities to solve STEM issues (Al Salami et al., 2017; Asghar et al., 2012; Bagiati and Evangelou, 2015; Goodpaster et al., 2012; Van Haneghan et al., 2015). Many teachers believe that some content areas are too difficult for students, which might demotivate them. Teachers in rural areas are concerned that many of their students are low performers, and modifying the curriculum to meet the needs of these students is a challenging task (Goodpaster et al., 2012). These concerns may influence the intention, methods, and effectiveness of teachers' implementation of STEM instruction (Holstein and Keene, 2013).

Another major challenge to teachers' implementation of STEM integration relates to the lack of quality assessment tools, planning time, and knowledge of STEM disciplines. Nadelson and Seifert (2013) found that teachers felt that there are not sufficient standardized assessments for STEM programs, making STEM assessment a challenging task for teachers. Some teachers are concerned about the group assessment, believing

that some form of individual student assessment may be needed (Herro and Quigley, 2017).

Teachers are concerned about the extra workload caused by planning and integrating STEM lessons into their existing curriculum. They have to allocate more time to work with teachers of other subjects and to prepare materials for students. It seems that the lack of time is one of the biggest and most common challenges for many teachers in implementing STEM lessons (Bagiati and Evangelou, 2015; Goodpaster et al., 2012; Hsu et al., 2011; Park et al., 2016).

Teachers often feel that they lack subject matter knowledge regarding STEM lesson content, while pre-service and in-service teacher training is reported to be inadequate in preparing teachers for STEM implementation (Al Salami et al., 2017; Hsu et al., 2011; Nadelson and Seifert, 2013). Teachers were also concerned about whether they were able to meet high expectations from schools and other authorities, and student parents. Therefore, although teachers are positive about the importance of STEM integration, they are not confident enough to implement STEM lessons effectively, which may negatively influence their teaching efficacy (Bagiati and Evangelou, 2015; Clark and Andrews, 2010; Holstein and Keene, 2013).

Although research has pointed out some difficulties faced by teachers while implementing STEM education, less research has been conducted in developing countries in Asia. In a recent review, Lee et al. (2019) showed that 65% of the STEM education studies were US-based, while only 8.5% of the studies were conducted in Asian countries (including China, Korea, Singapore, etc.). Vietnam, for example, is a populous country (over 95 million people) with a large population of high school students, and STEM has been highly regarded by the Ministry of Education and Training (Chen et al., 2021; Ho et al., 2020). However, little is known about how STEM education is delivered in Vietnam. This study was designed to address this gap. The following research question was proposed to guide the current study:

What are the challenges to STEM education at high schools in Vietnam?

3. Methods

The current study employs a qualitative research design (Yin, 2009) to gain in-depth insights into the experiences and beliefs of high school teachers regarding STEM education. As Burns (2000) argues, qualitative studies are used "to gain in-depth understanding replete with meaning for the subject, focusing on process rather than outcome, on discovery rather than confirmation" (p. 460).

3.1. Contexts

The study was conducted at ten high schools (Grades 10–12, students aged 15–17) in a Vietnamese central province. Compared to primary schools (Grades 1–5) and lower secondary schools (Grades 6–9), high schools have received more attention and investment regarding STEM teaching. Therefore, we decided to choose high school contexts in order to make a more significant contribution to the STEM education in Vietnam, and possibly other similar contexts. In Vietnam, high schools consist of twelve subjects: Maths, Physics, Chemistry, Biology, Technology, Literature, History, Geography, Civil Education, Physical Education, and Foreign Language (mostly English), and Information Technology. The teaching and learning follow a uniform national curriculum. STEM is not considered as a subject, but independent modules of STEM are expected to be integrated into the curriculum. The level of integration of STEM varies among schools depending on the available resources and other arrangements. Schools can flexibly apply different forms of STEM education such as interdisciplinary STEM lessons, experiential activities or scientific research activities. The schools where the participants of this study came from were public high schools. Each school had between 28 and 42 classes, and each class had about 33–45 students.

3.2. Participants

The participants were ten teachers, five males and five females, from ten public schools (see Table 1). The participants were selected based on a purposive sampling method (Cohen et al., 2002). Accordingly, among the ten participating teachers, two teachers taught one same subject among Maths, Chemistry, Biology, Physics, and Technology. They were in between 35 and 41 years of age (Mean = 39.1). They were all experienced teachers with 11–20 years of teaching experience at high schools (Mean = 15.7). To ensure confidentiality, pseudonyms were used for all the teachers. They all held Bachelors' degrees before they started their teaching career, and they all taught at high schools from the beginning. All the participating teachers had some experience in teaching STEM. In terms of teacher professional development, these teachers participated in regular professional development programs organized by their schools and the provincial Department of Education and Training.

3.3. Data collection and analysis

Data collection started after written consent from the participating teachers was obtained. The teachers were explained clearly that the interview was for research purposes only, and the confidentiality was secured. The teachers were encouraged to honestly share their experiences and challenges in teaching STEM.

The data were collected using semi-structured interviews. The questions of the interviews were developed based on extensive review of the literature on teachers' beliefs, concerns, and difficulties in teaching STEM (e.g., Bybee, 2013; Margot and Kettler, 2019). The interview questions were piloted with 3 teachers from three different schools. These teachers were not included in the main study. The teachers were encouraged to comment on the comprehensibility and the content of the questions. The piloting interviews helped us to revise the wording of some questions and estimate the duration for the main interviews. Due to the semi-structured nature of the interviews, the questions were formulated in a way that, on the one hand, they could guide the participants to focus on the main topic of the research; on the other hand, they were broad enough to give the participants the flexibility to go in-depth into their individual experiences with STEM teaching. The final interview was guided by ten questions (see Appendix). The interviews were conducted in mid 2021 by one of the authors online through zoom due to the restriction of the COVID-19 pandemic. The teachers were encouraged to express as much as possible their knowledge, understanding, beliefs, feelings, and the challenges they faced in integrating STEM into their existing curriculum. The interviews were in Vietnamese, the shared first language of the teachers and the researchers. Each interview lasted between 35 and 55 min. All the interviews were video-recorded for subsequent data transcription and analysis.

Thematic analysis (Braun and Clarke, 2006) was applied to analyze the qualitative interview data. Firstly, the video recordings were transcribed verbatim into Vietnamese. Only quotes used in this current paper were translated into English. Next, the transcripts were read repeatedly many times for a complete understanding of the data. Then, sentences and phrases which conveyed similar ideas were grouped together into codes. These codes were revised and refined to avoid any potential overlap or redundancy. After that, similar codes were regrouped into more abstract ones to form broader themes. The following result section reported these themes.

4. Results

4.1. Inadequate teacher preparation for STEM integration

All the teachers considered that they lacked STEM knowledge. They said that they were trained to teach a particular subject domain such as Physics, Maths or Chemistry, while STEM integration required the interdisciplinary knowledge of Science, Technology, Engineering and Maths. They thought that they did not have sufficient interdisciplinary knowledge to design and carry out effective STEM lessons. Also, although the teachers had some experience in teaching STEM, they considered that STEM was new to them and felt that they were insufficiently prepared to teach STEM. For example, Mr Thinh said that the biggest challenge for him was the lack of in-depth insights into STEM integration in terms of STEM knowledge, the design and the procedure of a STEM lesson. Mrs Han, a Chemistry teacher, who taught a lesson on the topic of 'electric chemical battery production' said that this lesson required the knowledge of both chemistry and physics because it is necessary to understand the electrolyte and how to make an electric battery. Mr Quan said that the Ministry of Education and Training had attempted to include STEM integration into the national curriculum for a few years. However, teachers had never been formally trained to teach STEM.

In terms of teaching methods, the teachers acknowledged that their existing teaching methods were traditional, which focused on transmitting knowledge from the teachers to students rather than helping students practicing using the knowledge or discovering knowledge. Mr Hoa, for example, said that it was difficult for him to transfer traditional methods into STEM teaching methods. He considered that students often learned passively by listening to teachers' presentations and lectures. Mrs Than stated that he had applied STEM methods such as teaching projects and teaching hands-on experiments, observing that these methods were effective. She wanted to be equipped with further STEM teaching methods to improve his teaching outcomes. She said that traditional teaching methods were not suitable for teaching STEM, and their long-lasting traditional teaching habits prevented them from trialling new teaching techniques or methods for teaching STEM. Mr Hanh said that although he used active teaching methods such as project-based teaching to teach STEM, he was not able to define a specific teaching method for STEM teaching. Similarly, Mr Quan stated,

> My first challenge is that my knowledge about STEM teaching is limited. I was very hesitant to change my teaching methods to suit STEM. I thought that I should face the challenges and took initiatives in reading about STEM, exchanging knowledge and experience with other colleagues to improve my ability in teaching STEM.

4.2. Lack of a curriculum framework, teaching materials, and assessment guidelines

The teachers were concerned that they lacked a curriculum framework, materials, and appropriate models for STEM education. The existing curriculum was designed specifically for individual subject domains with the purpose of equipping knowledge of basic fields, so the teaching materials and equipment they were provided with were solely for the subject domains they covered and not for interdisciplinary

Table 1. A brief summary of the participants' background.

Name	Gender	Age (years)	Teaching experience (years)	Teaching subject
Hanh	Male	40	16	Chemistry
Han	Female	42	20	Chemistry
Hoa	Male	35	12	Biology
Thu	Female	41	18	Biology
An	Female	40	16	Physics
Quan	Male	41	17	Physics
Thinh	Male	39	15	Math
Hoai	Male	38	16	Math
Than	Female	35	11	Technology
Thiet	Female	40	16	Technology
Range		35–41	11–20	
Mean		39.1	15.7	

teaching purposes. They often had difficulties in searching STEM ideas and lacked an orientation to integrate STEM into the program. Mrs Thu said that the greatest challenge for her was to find an interesting idea for a topic to suit the curriculum. She suggested that there should be an overall national curriculum framework, and teachers could adapt to suit their teaching contexts. Mr Hanh said that the existing STEM teaching materials were theory-oriented. Practical guides, concrete examples, and teaching equipment were insufficient and incompatible. Mrs Han said that the existing curriculum focused on individual subjects, and there was no unified STEM integration. She thought that there should be a separate STEM subject that was equal to other subjects in terms of credits, materials, guidelines, and teacher preparation. Similarly, Mrs Han said that there was a lack of a unified STEM curriculum, and each teacher or each school was doing in their own ways based on their strength and weaknesses.

When it comes to assessment, all the teachers reported that they experienced difficulties in assessing students' performance in STEM education due to the limited guidance from school leaders. The teachers believed that their traditional methods of assessing students' knowledge based on paper format tests were not appropriate for assessing students' performance in STEM learning activities. They understood that students' products and the process of involving in STEM activities should be assessed. However, the teachers were concerned about the sense of fairness for their students because students worked in groups while their traditional assessment was for individual students. Mr Hoa said that a challenge in STEM education was designing a set of assessment criteria, a capacity assessment tool to suit each individual student. Mrs Thu expressed a similar concern, highlighting that each student showed a different level of involvement, engagement, enthusiasm and abilities. She said it was too difficult for her to create an assessment toolkit. In the same vein, Mrs An said,

> At first, I was very confused about evaluating students' abilities. Assessing students' STEM performance is really time-consuming. I took a lot of time for me to get used to STEM teaching and assessment. Fairness is important in group assessment because unfair assessment could influence students' emotions and motivation to learn.

4.3. Limited equipment, resources and inflexible school structure

Successful STEM integration requires adequate resources such as time and space for collaboration, time for preparation, and technological equipment. When conducting STEM lessons, teachers have to work collaboratively with colleagues across different disciplines. However, the teachers in the current study reported that they lacked space and time for collaboration. Mrs An, for example, said that it was time-consuming to work with other teachers in preparation for STEM lessons. The teachers were busy with their full teaching schedule. Preparing for STEM lessons in cooperation with other teachers added extra workload to their busy schedule. Mrs Thu explained,

> Time constraint is one of the biggest challenges. It is evident that not everyone can assess my topic and questions right away. With one STEM topic, it is impossible for me and my colleagues to teach for only 45 minutes as a normal lesson [a lesson of a specific subject domain].

Mrs Thiet said that each week her Technology subject was allocated for only one teaching period, while it took about three consecutive teaching periods to organize a STEM lesson successfully. Therefore, she could only do STEM lessons in extra-curricula activities or when she managed to adapt the timetable with other teachers. Mrs An said that teaching allocation was confirmed at the beginning of the semester, and there were no compulsory STEM lessons. It was expected that STEM lessons would be combined with extra-curricular activities. It took a large amount of time to contact different departments in the school to organize a STEM lesson regarding time, space, equipment and human

resources. Mrs An thought that there should be an official STEM curriculum, which should be set up properly from the beginning of each school year.

Regarding school structure, the teachers felt that the existing school structure and curriculum structure were barriers to integrating STEM education. Teachers perceived that there was no congruence because the class structure was not suitable for organizing STEM teaching activities. There were many classes with different levels, and the class size was large, while there was a lack of teaching facilities such as technological equipment for STEM teaching. Mr Hoa, for example, said that each class had between 40 and 45 students sitting in rows of desks, which was not conducive to group work. Similarly, Mrs Thu said that she had tried her best and could manage to organize 20 STEM lessons. However, she and her colleagues took the initiative to arrange teaching equipment from different sources, such as students' parents. She did not receive adequate support from her school.

4.4. Teachers' beliefs about STEM integration

The teachers felt that their engagement in teaching STEM was dependent on their own motivation and desire for innovation in teaching methods. The teachers reported that STEM was a new trend of education that required them to be competent at both new subject matter knowledge and teaching methods. Some teachers reported that they were actively involved in designing, preparing, and teaching STEM lessons, while some other teachers were relatively hesitant. One of the constraints influencing teachers' motivation was that STEM was an optional component in the overall teaching curriculum. This means that STEM teaching was not included in the criteria for teacher evaluation. Mrs An, for instance, said that STEM integration was optional, and it was dependent on the creativity, flexibility and initiatives of the teachers. STEM was not considered or discussed in professional and academic meetings. Teachers needed to arrange everything by themselves to organize STEM lessons. Only highly responsible and enthusiastic teachers were able to conduct STEM teaching successfully. Mr Hoai, a math teacher, said,

> Maths is a more academically heavy subject than Chemistry, Biology or Physics. It is difficult for me and other Maths teachers to design and teach STEM lessons. Also, Maths is a core subject, and we have to spend more time on it than teachers of other subjects.

Regarding teachers' beliefs about the importance of STEM teaching and other goals and commitments, there were some tensions. Mrs Than said that, in reality, the overall teaching and learning objectives were exam-oriented. Exams were mostly paper-based, using multiple-choice questions to test students' understanding and memorization of theoretical knowledge. The innovative teaching and learning outcomes from STEM integration were not applied in high-stakes exams. Therefore, many students did not really care about STEM lessons. In some schools, teachers only conducted STEM lessons for classes at grade 10 or 11 when students were not preparing for university entrance exams (which occurred at the end of Grade 12). Mrs Than complained, "when I assigned students STEM tasks, they asked me what they learned them for because they did not use them for their university entrance exams". Similarly, Mr Hoai said,

> The teaching and learning focused heavily on targeting selective schools or university entrance exams. Students and their parents mostly care about their testing scores rather than their knowledge development. Therefore, I think that for STEM education to be effective, there's a need for a change in the overall goal of the national curriculum. Accordingly, teachers can focus on developing students' skills and knowledge rather than practicing for subsequent exams.

In terms of teachers' beliefs about their students, the teachers felt that STEM education could promote students' interest and achievements, but

the results were dependent on the students' attitude, abilities, and learning conditions. Mrs An said that each group of students could influence teachers' choices of topics, teaching methods, and expected outcomes. She explained,

> For example, the lesson 'making a roly poly toy' was not engaging for students in[1] Mathematics classes, but it was the favourite lesson for the Literature classes. With the same topic, I observed differences in students' engagement and learning outcomes among different classes. Therefore, I think I need to think about the target students very carefully in choosing appropriate topics for STEM lessons.

The teachers considered that STEM education was also dependent on the socio-economic conditions of students. They said that equipment, materials, and financial conditions were limited. Their school leaders were not always supportive. Therefore, even when teachers were willing to teach STEM, it was really difficult because of the lack of resources and support from school leaders and administrators. In a rural school, for example, teachers were not able to expect contributions from students' parents in contributing materials for STEM teaching. Mr Quan said,

> At present, I usually choose topics that are familiar to students so that they can find materials easily for free of charge. It's hard to rely on the school's financial support for STEM lessons.

5. Discussion

The current study investigated the challenges faced by Vietnamese high school teachers in STEM integration. In line with previous studies in other educational contexts, the teachers in our study faced various difficulties in their designing, preparing, and teaching STEM modules (Bybee, 2013; Dare et al., 2014; Goodpaster et al., 2012; Lee et al., 2019; Margot and Kettler, 2019). These difficulties were related to (1) the inadequacy in teacher preparation for STEM education, (2) the lack of a curriculum framework, teaching materials, and assessment guidelines, (3) the insufficient technical, time, and space resources, and (4) the teachers' beliefs about STEM education and their educational goals. These broad themes were reported in previous research in other countries (Bybee, 2013; Goodpaster et al., 2012; Lee et al., 2019; Margot and Kettler, 2019). However, some subthemes were unique in our study. That is the tension between teachers' beliefs about the need for and importance of teaching STEM and their concerns about the overall teaching goals for their students and for themselves. This tension might result from the local socio-cultural contexts of teaching and learning (Guerra and Wubbena, 2017; Ha, 2021; Ha and Murray, 2021; Ha et al., 2021; Hallinger et al., 2021; Tran et al., 2021a, b; Tran et al., 2020).

The findings that the teachers felt they lacked interdisciplinary knowledge (Liu et al. (2021) and innovative teaching methods and that they were not prepared to teach STEM were commonly reported in the literature (Lesseig et al., 2016; Margot and Kettler, 2019; Park et al., 2017). This could be because all the teachers were experienced, and their former undergraduate programs did not consist of any components of STEM education. All the teachers had more than 11 years of teaching experience, which means that they had graduated from universities for more than 11 years. This adds work to in-service teacher training to equip experienced teachers with STEM teaching knowledge and methodology. This finding suggests that regular teacher professional development programs should prioritize supporting STEM teachers to meet the need for education for change for students. For example, teachers should be made aware and equipped with knowledge and skills to ensure that instruction in any subject areas in general, in STEM education in particular, should go beyond the rote memorization of concepts. Instead, concepts

should be taught and applied to the real world problems. This suggestion may be applicable for other similar contexts in Vietnam and beyond.

Another notable finding is related to the lack of teaching materials, technological equipment and support, and time and space resources. This finding has also been repeatedly reported in previous studies, especially those conducted in rural areas and developing countries (Bagiati and Evangelou, 2015; Goodpaster et al., 2012; Hsu et al., 2011; Margot and Kettler, 2019). In the current study, all ten teachers complained that they did not have sufficient practical conditions to conduct effective STEM teaching. This can be due to the fact that these teachers worked in rural and suburban schools in a central province of Vietnam. These schools tend to lack teaching aids in general and for STEM in particular. This issue can take time and effort to be resolved. Instead, in-service teacher training and professional development programs may need to focus on developing teachers' coping strategies to enact STEM integration within the available resources in the current teaching and learning contexts. This can also ensure sustainable teaching approaches.

The most notable finding of the current study concerns the teachers' beliefs about STEM education. Particularly, the tension between teachers' beliefs about the importance of STEM teaching in developing students' abilities to solve authentic problems and their beliefs about the short-term goals of education in their local contexts influenced their motivation, involvement, and initiatives in making effective STEM lessons happen. On the one hand, the teachers were aware that STEM education was useful for students' future, and they wanted to strive for teaching STEM effectively. On the other hand, they thought that it was also important for their students to be successful in their short-term goals, that is, achieving high scores in high-stakes exams to be admitted to their desired universities or to obtain high prizes in various academic competitions of school, district, and provincial levels. This concern might influence the teachers' decision making regarding whether and how much time and effort they should allocate for STEM teaching. This kind of tension has been reported in some other subdisciplines of educational research, such as language education (Borg, 2015; Ha and Murray, 2020; Ha et al., 2021). The teachers' desire to help students achieve short-term goals might have been influenced by the exam-oriented teaching and learning contexts (Ha, 2021; Ha and Nguyen, 2021; Ha et al., 2021; Reynolds et al., 2021; Tran et al., 2021a, b).

In addition, the teachers' concern for teacher evaluation was also an important factor influencing teachers' beliefs about STEM education. The teachers mentioned that teachers' time and effort might not be appreciated because their students' performance in STEM was not taken into account in teacher evaluation. As explained by the teachers, one of the criteria for teacher evaluation was their students' learning outcomes, particularly their results in high-stakes exams, while students' performance in STEM was not considered. This influenced the teachers' motivation in investing time and effort in STEM integration.

6. Conclusion

The current study investigated the challenges to STEM integration faced by Vietnamese high school teachers. The findings showed several constraints to teachers' attempts in implementing STEM modules in their existing curriculum, including the teachers' limited knowledge and innovative methods in teaching STEM, the practical constraints such as a lack of time, space, material and technical resources. It is suggested that in-service teacher professional development programs should pay more attention to equipping teachers with updated STEM knowledge and teaching methods so that teachers will feel more confident and better prepared to teach STEM. It is also important for in-service teacher professional learning and development designers and trainers to provide teachers with the necessary skills of coping with difficulties and adapting their existing teaching contexts to suit STEM education for their schools and students.

What is notable in this study is the teachers' tension between their beliefs about the importance of STEM education and the short-term goals of teaching and learning in their local contexts. This concern was

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[1] Some schools have different selective classes, majoring in Mathematics, Physics, or Literature, etc.

influenced by the exam-oriented teaching and learning culture and the teacher evaluation practices of their schools. It also suggests that school leaders, policymakers, teachers, and other stakeholders need to review the role of STEM education in relation to other short-term and long-term goals, making it clear to teachers regarding what should be prioritized in teaching. The finding suggests that school leaders should consider teachers' STEM teaching and students' STEM performance in teacher appraisal. It should be noted that this qualitative study was conducted with teachers from one province in Vietnam, but these findings and recommendations can be applied to other parts of Vietnam and probably other Asian educational contexts where teaching and learning are heavily influenced by exam culture.

Despite the contributions discussed above, the study has several limitations that warrant further research. Firstly, the study employed a qualitative research design and was conducted with ten teachers from ten schools in one Vietnamese central province. This may limit the generalization of the study's findings. Future research could employ mixed-methods research designs to ensure both the depth and the breadth of the findings. Secondly, within the scope of the study, only voices from teachers were investigated. Future studies could investigate the challenges to STEM education in Vietnam and other similar contexts through the voices of various stakeholders, such as students, students' parents, school administrators, and school leaders. This may provide a complete picture of the teachers' challenges in STEM education.

Declarations

Author contribution statement

Lam Thi Bich Le: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Toan Thai Tran: Performed the experiments; Contributed reagents, materials, analysis tools or data.

Ngoc Hai Tran: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

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