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UTILISING STEM-BASED PRACTICES TO ENHANCE MATHEMATICS TEACHING IN VIETNAM: DEVELOPING STUDENTS' REAL-WORLD PROBLEM SOLVING AND 21ST CENTURY SKILLS

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Abstract

In Vietnam, STEM-based teaching approaches have been recommended for schools since 2018 with the integration of multiple courses in schools. Teachers' perspectives on integrated STEM education, and how to design a STEM lesson that supports students' learning are critical for ensuring that an integrated STEM curriculum is to be implemented successfully. This paper aims to describe a study examining STEM education practices in teaching Mathematics, in particular "Trigonometry ratio of an acute angle" in Vietnam. This study utilized mixed methods approaches with three phases: the first stage employed a quantitative phase to examine Vietnamese teachers' perspectives on STEM education. The second phase was an experiment on teaching while applying STEM education to design and organize a mathematics lesson, and the third, final phase, was to employ a qualitative study to explore the Vietnamese students' experiences of STEM education connected with real-world problem-solving and 21st-century skills development. A total of 47 teachers and 85 students participated in this study and data was collected from multiple research tools such as questionnaires and semi-structured interviews. Findings showed Vietnamese teachers' perspectives on the necessity and importance of applying STEM education practices; however, they reported facing numerous challenges. A lesson designed as a STEM education application and the students' feedback in relation to real-world problems. Learning outcomes connected with 21st-century skills in this study were expected to provide further knowledge for further discussions and practices to enhance teaching and learning STEM and mathematics education in Vietnam.

Keywords – STEM education, Teacher perspective, Student learning outcomes, Real-world, The 21st skills.

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1. Introduction

During the past decades, STEM (Science, Technology, Engineering, and Mathematics) education was emphasized to encourage developing students with 21st-century skills to meet the needs of today's society. STEM education reform programs demanded integrated STEM education techniques in which students learn how to solve issues by linking information and practices from multiple STEM domains (Ryu, Mentzer & Knobloch, 2019).

Previous studies indicated that "STEM education is an interdisciplinary approach to learning in which students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise, allowing them to develop STEM literacy and, with it, the ability to compete in the new economy" (Tsupros, Kohler & Hallinen, 2009). STEM education is an interdisciplinary approach to learning that integrates the four fields into a single teaching and learning paradigm (Morrison, 2006; Tsupros, et al., 2009). It also emphasizes the importance of education fostering creative problem-solving skills to become competitive in the global age and prepare for all future challenges (Honey, Pearson & Schweingruber 2014; Nguyen, 2019) as well as directs learners to solve real-life problems through practice (Honey et al., 2014; Nguyen, 2019; Yakman & Lee, 2012). However, reviews show that several studies regarding STEAM education focus on engineering, which is rather limited in mathematics-related topics (Sarac, 2018; Wahono, Lin & Chang, 2020).

In Vietnam, the Ministry of Education and Training issued Circular No. 32/2018/TT-BGDT to guide STEM education in teaching and learning in Vietnam. In which the state of the art highlighted the integration of multi-subjects of "…create a connection the mathematical ideas, between mathematics and reality, between mathematics and other subjects and educational activities, especially Science, Natural Science, Physics, Chemistry, Biology, Technology, Informatics subjects to implement STEM education" (Ministry of Education and Training, 2018). In response to this call, an integrated STEM education methods course was developed for Vietnamese secondary preservice teachers in STEM disciplines; however, STEM education practice in Vietnam faces many barriers, and Vietnamese students were judged to have high theoretical knowledge, but low practical skills in solving problematic situations in real contexts (Hau, Cuong & Tinh, 2020). Unfortunately, previous studies in Vietnam mainly highlighted the benefits of STEM education focusing on student learning multi-subjects integration, lack of studies identifying teachers' perspectives of STEM education, what challenges teachers were facing in STEM lesson designing, and whether STEM education outcomes connect with the 21st century, such as high order thinking skills, practical skills, emotional energy and so on. This study aims to address of following research objectives:

1. To examine the Vietnamese teacher perspectives on STEM education.
2. To develop a framework for Mathematics lesson designing in STEM education.
3. Explore the Vietnamese students' perspectives on STEM education outcomes connected with real-world problem-solving and 21st-century skills.

2. Literature Review

2.1. Teachers' Perspectives on STEM Education

The teachers' perspectives on STEM education play an important role in successfully organizing class, applying effective pedagogy, and helping the student achieve STEM outcomes. According to Yildirim and Selvi (2016), during the STEM learning process, teachers organized learning activities requesting students to link knowledge and skills from multiple STEM subjects to constructive new knowledge. This way will help collaborative work be the main focus on which students' learning is geared toward and achieve higher-order thinking skills. Notably, instructors' learning was examined from a variety of aspects, including the contexts in which teaching practices take place and the resources of knowledge those individual teachers bring to their classrooms (Ryu et al., 2019). In reality, the rapid development and functional effects of STEM education programs in Western countries have piqued the interest of many researchers and policymakers from other countries, including Asia (Wahono et al., 2020). However, different educational cultures and systems in different countries have led to different perspectives of steam education models (Sheffield, Koul, Blackley, Fitriani, Rahmawati & Resek, 2018; Timms, Moyle, Weldon & Mitchell, 2018). For example, students in ASIA countries are usually less interested in studying subjects of sciences and technology than students in western culture (Kim, Chu & Lim, 2015; Yildirim & Selvi, 2016); they also face challenges in global competition (Kim et al., 2015). In addition, the eastern educational system is exam-driven. When compared to western-culture education, eastern-culture education is more methodical, with a fixed syllabus and timetable (Tytler, 2020). Teachers' performance is influenced by time (length), as they must go over textbooks to prepare students for final exams (Tytler, 2020). As a result, finding time to prepare for STEAM education was difficult for them. On the other hand, teachers from various disciplines had varied ideas about STEM education, and the teachers' perceptions of STEM education transitioned immediately into their written curriculum after participating in professional development (Kim et al., 2015).

2.2. STEM Education Theoretical Framework

The environmental and social effects of the twenty-first century, which put regional security and economic stability in jeopardy, maybe the driving force behind the global desire to strengthen STEM education in which science, technology, engineering, and mathematics are applied to real-world situations. According to Kennedy and Odell (2014), the current state of STEM education has evolved into a meta-discipline, an integrated effort that does away with the traditional barriers between these subjects and instead focuses on innovation and the practical process of designing solutions to complex contextual problems using current tools and technologies. Programs must incorporate technology and engineering into the teaching of science and mathematics, encourage scientific inquiry, and support the engineering design process in order to engage students in high-quality STEM education. Integrated STEM education is an endeavor to incorporate any or all of the four disciplines of science, technology, engineering and mathematics into one class, unit, or lesson that is based on links between the fields and real-world problems" (Moore & Smith, 2014).

Some strategies in designing STEAM education connect with Real life situations:

The most effective way to integrate STEM subjects is through engineering design (National Research Council, 2010). Additionally, a STEM education delivery strategy based on engineering design creates a perfect entry point for incorporating engineering principles into the current secondary curriculum. To put all four STEM fields on an equal footing, engineering design must be used as a catalyst for STEM learning. Students can use a methodical approach to solve difficulties that frequently arise organically in all STEM subjects because of the very nature of engineering design. The second requirement of successful STEM education is that students must learn it in a relevant context and be able to apply it to real-world circumstances. In order to implement an inquiry-based approach to learning, teachers must promote and model the skills of scientific inquiry, as well as the curiosity, openness to new ideas, and scepticisms that characterize science. Authentic science inquiry requires "minds-on" (meaning?) experiences that are integrated into constructivist methods of learning; practical and procedurally oriented hands-on activities in themselves are not a substitute for true scientific inquiry. Considering technology in STEAM education, according to Herschbach (2011), there are two widely held perspectives on technology: an engineering perspective and a humanities perspective. According to the engineering perspective, also known as the instrumental approach, technology is equated with the manufacturing and usage of material objects–that is, artifacts. However, the humanities' perspective on technology emphasizes the human purpose of technology as a response to a particularly human endeavor; as a result, the human purpose is what gives technology additional meaning (Achterhuis 2001). Related to mathematics, students usually desire to know both how to finish a mathematical assignment and why they must acquire mathematics in the first place. Williams (2007) remarked that contextual teaching can give mathematics meaning. They are curious about how mathematics relates to their daily life (page 572). Students can study mathematics and make connections between what they learn in school and the abilities needed for STEM careers by incorporating STEM practices that incorporate the mathematical analysis required for evaluating design ideas (Burghardt & Hacker 2004). Furthermore, previous studies refer to this as genuine peripheral involvement when learning occurs in a community of practitioners helping the learner advance from a beginner's grasp of information, skills, and practices to mastery when they engage in a social practice of a community. Both newcomers and seasoned practitioners can benefit by observing, querying, and actively participating alongside those with more or different experiences in a community of practice. When newcomers and seasoned practitioners structure their work in ways that give everyone involved the chance to view, discuss, and partake in common practices, learning is facilitated (Levine & Marcus, 2010).

2.3. The Impact of Teachers' Beliefs on STEM Values

Various studies on the relationship between teacher belief in STEM values and STEM teaching efficacy have been reviewed. Teachers' perceptions about their efficacy and the importance they place on STEM education appear to have an impact on their willingness to engage in and administer STEM curricula. They have a high level of self-efficacy when they believe they have the knowledge and skill sets to implement STEM activities. Teachers with inadequate STEM knowledge and experience may feel unable to contribute to classroom learning when participating in STEM activities. Teachers believed that STEM leads to higher expectations for students after high school and that advances in scientific literacy are beneficial because they force students to think critically about present issues and their future ramifications (Bruce-Davis, Gubbins, Gilson, Villanueva, Foreman & Rubenstein 2014; Thibaut, Ceuppens, De Loof, De Meester, Goovaerts, Struyf et al., 2018; Herro, Quigley, Andrews & Delacruz 2017). Teachers have an impact on their ability to learn and grow as STEM educators when they believe in the importance of STEM education, otherwise, student learning is limited when teachers' knowledge and understanding are deficient (Margot & Kettler, 2019).

2.4. Teacher Reports of Challenges in Teaching STEM in Practice

Although various studies highlight the significant benefits of STEM education for student learning outcomes, a review of the literature reveals that teachers face numerous hurdles when teaching STEM practices. STEM pedagogy necessitates certain basic modifications in how teachers create classroom environments and educate, and these shifts are not always favorable for some teachers. Teachers believed it was challenging to create fresh STEM issues while integrating diverse subjects. They also stated that it was difficult to combine the STEM instructional method with their traditional topic conceptions (Ejiwale, 2013; Bruce-Davis et al., 2014).

Teachers in STEM education must have a philosophy of instruction that aligns with the authors of the STEM curriculum. They must be able to relinquish control and allow pupils to navigate the lesson on their own, which may include unexpected directions (Holmlund, Lesseig & Slavit, 2018).

STEM pedagogy, according to teachers, necessitates a fundamental shift away from teacher-led learning and toward student-led instruction. When time is limited and students must study a variety of subjects, this could lead to the class becoming difficult to manage (Dare, Keratithamkul, Hiwatig & Li, 2021; Margot & Kettler, 2019).

Another barrier is that class scheduling inhibited the interdisciplinary nature of STEM instruction, particularly when separate teachers teaching various disciplines did not allow for interdisciplinary work. Teachers from different topics were unable to coordinate on planning due to the comparable timeframe. Teachers complained that they didn't have control over the pacing of the curriculum or the sequence of instruction when they tried to integrate different disciplines for authentic STEM lessons (Holmlund et al., 2018).

Notably, teachers felt administrative and financial support could be a challenge to STEM implementation. Another concern was a lack of technology resources available to students. In the real context, the requirements of finance for the project need more. Without enough finance, student computers, and other technology tools available, it was difficult to integrate the technology piece into STEM lessons (Wang, Moore, Roehrig & Park 2011). Besides that, the assessment of STEM lessons also argues that they are much more complicated in different stages.

2.5. STEM Education Practices in Vietnam

In Vietnam, schoolteachers principally focused on content knowledge rather than the students' practical competencies. Therefore, STEM education has concerned an innovation model to address existing issues in the new general education curriculum (Dung, Vu-Nhu & Nga, 2020; Hau, Cuong et al., 2020).

The core characteristics of STEM education include: (1) an integrated approach to four fields: science, technology, engineering, and mathematics; (2) emphasizing learning through practice, combining theoretical learning with the application of theories in complex practical situations; (3) help learners acquire the necessary skills and competencies to compete and thrive (Chute, 2009; Tsupros et al., 2009; Honey et al., 2014; Tho, 2016; Nguyen, 2019). In Vietnam, the STEAM program in their science class, allowed the student to have a better understanding of the problem-solving process and connect with the local context (Tinh, 2019). For example, teachers organized the STEM lesson with integrated science, technology, engineering, and mathematics (STEM) education through active experience in designing technical toys for students in schools (Quang, Hoang, Chuan, Nam, Anh and Nhung (2015). Another STEM project connects with the context of Tan Cuong Tea village in Vietnam to develop a product stage for students' experiences to create the Tea dryer machine, fertilizers, or system of growing the tea plant, a short film for advertising the Tan Cuong tea village STEM education tourist places (Tinh, Duc, Yuenyong, Kieu and Nguyen (2021). Vietnamese instructors, on the other hand, faced difficulties in terms of transdisciplinary knowledge and teaching methods, curriculum, practical limits, and ideas about effective STEM education. The findings of teachers' ideas about effective STEM education and the tension between their beliefs and teaching aims were particularly related to local cultural values and schooling system expectations (Le, Tran, & Tran, 2021).

With fast technological breakthroughs and globalization, future STEM professionals will need to be skilled in critical thinking and creativity to solve real-work problems, collaborate successfully, and communicate effectively, called 21st-century skills (Dare et al. (2021), however, the studies of a very few numbers regard to applying STEM education in teaching Mathematic in Vietnamese school to adapt with requirements of the today society requirements. This study will fill this gap.

3. Research Methodology

This study utilizes a mixed-method study with three phases:

Phase 1: This phase employed a quantitative study to examine the Vietnamese teachers' perspectives of STEAM education. A total of 47 Mathematics teachers in the schools located in Thu Duc District, Ho Chi Minh City, selected randomly participated in this study. An adaptable questionnaire constructs 2 parts relevant to STEM education. The first part covers 5 subtitles: 1) necessity; 2) suitable for the innovative trend of teaching and learning; 3) challenges; 4) integration of STEM subjects; 5) Real-world in STEM education. While the second part concentrated on the challenges of applying STEM education in teaching Mathematics. The statistics focus on descriptive analysis using Excel.

Phase 2: This phase implemented experiment teaching

- *Purpose:* Identify the challenges when applying STEM education in teaching in Mathematic and designing lesson content connected with real-world problem-solving developing students' 21^{st}-century skills.
- *Location and sample*: 04 lecturers in universities, 05 teachers, and 14 9th-grade students were involved in this experimental process. We conduct experimental teaching in an extra class in Thu Duc District, Ho Chi Minh City. This experiment was carried out for 2 weeks, from February 20, 2021, to March 4, 2021, including planning to guide students and teach in class for two periods on February 28, 2021, and March 3, 2021.
- *Real-world situation:* In this study, we apply STEAM education in teaching the lesson of "Trigonometry ratio of an acute angle" by connecting with a real story to help students apply the mathematics knowledge and skills to solve a problem in real life. The real story selected for this

study was that a disabled person using a wheelchair moves at home, and the steps interfere with him. He wishes that he can move on his own to limit the support of people around him. One of the things that can assist him is wheelchair ramps. The ramps are designed for people in wheelchairs to be able to move on themselves and must be complied with construction regulations. The learning outcomes expect not only for students to satisfy the core characteristics of STEM education but also to help students develop a sense of community and improve practical skills in society.

Phase 3: Qualitative study

- Purpose: To explore the Vietnamese students' experiences of STEAM education outcomes connected with real-work problem-solving and 21st-century skills. Based on this, the new knowledge will share the Vietnamese context in applying STEM education in teaching and learning.
- A total of 85 students involved in this study will participate in the survey to get general feedback after studying the STEM lesson mentioned above. 15 students who directly joined as project members participated in the focus group interview. All interviews were transcribed verbatim before coding and analysis. Data analysis with theme development and support by N-Vivo software.

4. Results

4.1.. Phase 1: Teacher Perspectives on STEM Education

4.1.1. Teacher Perspectives of STEM Education Practice in Teaching Mathematics in Vietnam

4.1.1.1. The Necessity of Applying STEM Education

90% of respondents in this study believe that applying STEM in teaching Mathematics in Vietnam is necessary. In addition, more than 90% of respondents believed that using STEM education in teaching Mathematics is "highly suitable" and "suitable" so STEM education is adaptable to the innovation trends in teaching and learning Mathematics.

4.1.1.2. Challenges Level in Applying STEM Education in the Teaching of Mathematics

Most respondents were aware of the importance of using STEM education in teaching mathematics, only 10.6% of respondents were using this approach in their teaching practice, 27.7% were looking for solutions, and 48.9% were unsure of their understanding of STEM education and were studying about it to apply in their teaching practice. These results show that respondents face many challenges in applying STEM education in their teaching practices.

4.1.1.3. The Frequency Level of Integration of STEM Education

	Often	Sometimes	Seldom	Never
The frequency level of integration of STEM education in teaching Mathematics	6.4%	48.9%	36.2%	8.5%
The frequency level of using the real-life situation in STEM education	46.8%	48.9%	2.2%	2.1%

Table 1. The frequency level of integration of STEM education

While teaching Mathematics using STEM education has been informed as a good idea in Vietnam, the use of STEM education in teaching Mathematics practice is not well-known.

The findings revealed that real-life situations have been concerned with integrating mathematics into the classroom; nevertheless, the rate of teachers who use this strategy is not high.

4.1.2. Teachers' Perspectives of Challenges and Opportunities in the Lesson Designing in Applying TEM Education in Teaching Mathematics Grade 9

4.1.2.1. General Challenges

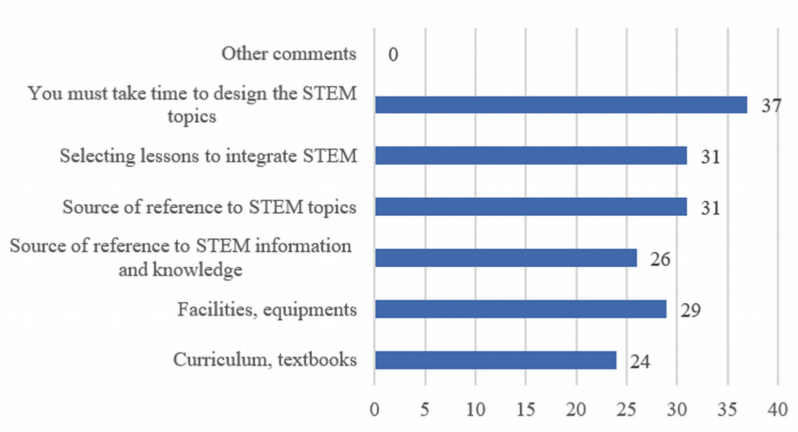

Figure 1. Difficulties in organizing Mathematics classes according to STEM education

Figure 1 describes the general difficulties for the teacher when implementing lesson design and applying STEM education in teaching mathematics. Although the STEM education focus has yielded some positive results, teachers continue to encounter other challenges. To begin with, there is a paucity of STEM education advice in the curriculum and texts. Teachers confront numerous challenges in not only designing classrooms according to the prescribed curriculum but also ensuring that skills are promoted through STEM-oriented instruction. Second, the crowded class does not guarantee the availability of facilities and types of equipment. Furthermore, intense STEM lessons necessitate a significant investment on the part of professors. Third, not only are the resources for STEM information and expertise restricted but so are the resources for STEM topics. As a result, when teachers implement STEM-oriented instruction, it is vital to guide STEM topics to help teachers structure their lessons. As a result, teachers will be more effective.

4.1.2.2. Specifical Challenges in Teaching Geometric theme Mathematics 9 Integrates with STEM Education

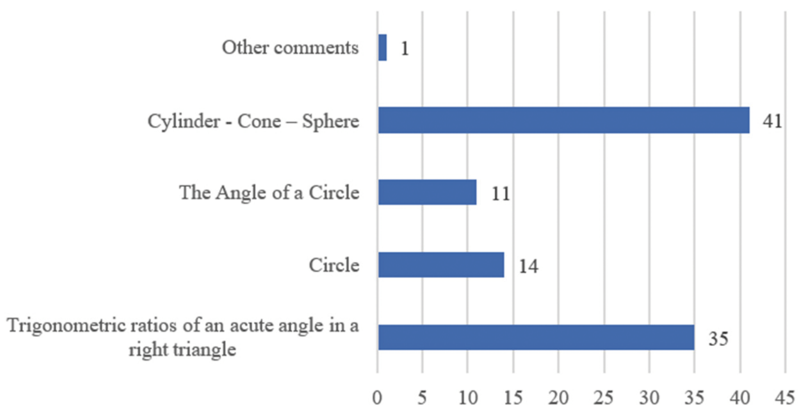

Figure 2. Geometric theme Mathematics 9 can be designed according to STEM education

According to Fig 2, respondents in this study approved that the popular Geometric themes in Mathematics 9 that can be designed according to STEM education are "Cylinder – Cone – Sphere" and "Trigonometry ratio of an acute angle".

4.1.2.3. The Practical Content in the Theme "Trigonometry Ratio of an Acute Angle"

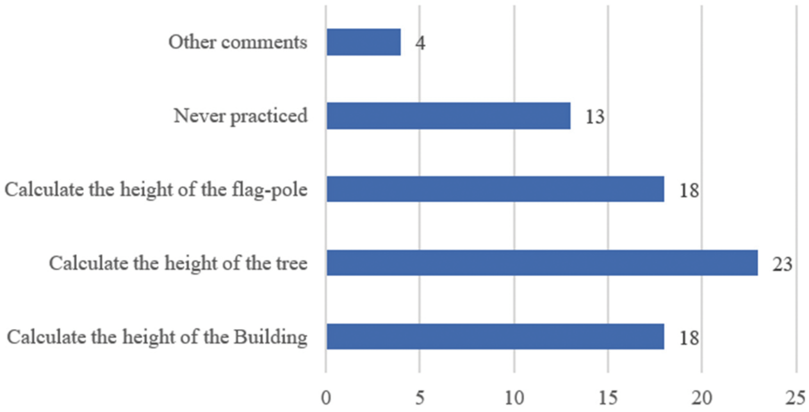

Figure 3. The practical content in the theme "Trigonometry ratio of an acute angle" is taught by the teacher to students

According to Figure 3, the practical content in the theme "Trigonometry ratio of an acute angle" that the teachers often teach to the students is "Calculate the height of the building, of the tree, of the flag-pole". So, the practical content about the "Trigonometry ratio of an acute angle" is easy to be misunderstood by students as measuring an inaccessible height.

4.2. Phase 2: Applying STEM Education in Designing the Lesson "Trigonometry Ratio of an Acute Angle" when Teaching Mathematics in Grade 9.

Students in the normal class are often unsuccessful in applying Mathematics in real situations. However, in this study, teachers have well-designed plans and instructions for students to achieve this. The action plan is described as follows:

The result of the pedagogical experiment:

Activity 1:

During the working process, the groups must state the advantages and disadvantages of the option that the group chooses. In each group, the leader divides specific tasks among members. Students confirm the requirements and constraints that the teacher proposes for this activity.

Student's name	Responsibility
Ho Xuan Khiem; Quach Huu Tho	Design model
Pham Nguyen Que Tran	Draw model
Doan Gia Han	Calculate
Tran Thi Ngoc Quyen	Prepare

Table 2. Worksheet 1. Specific tasks to members of Group 1

Responsibility group: Design a wheelchair ramp; with frames and wood.
Product's group: Safety, beautiful; comply with construction standards.

Table 3. Worksheet 1. The results of Groups

Figure 4. The member of Group 1 tries to ride up available ramps
that are not according to construction specifications

In Activity 1, the situation is presented with clear, reasonable characters, circumstances, locations, background knowledge, and practical needs. Teams know how to divide work according to each member's ability. In addition, they know the direction of their work. Students identify the task and the criteria of the ramp. Students experiment with wheelchairs walking on ramps that are not according to construction standards to understand the role of correct ramps as well as understand the difficulties experienced by people in wheelchairs. Students understand the difficulties of people in wheelchairs and the role of building ramps under technical regulations (Figure 4). Since then, students are also interested in asking themselves why they can't ride up an available ramp that is not in accordance with construction standards, creating opportunities for students to discuss and research knowledge in activity 2.

Activity 2

Study the knowledge related to the design and manufacture of ramps. Through worksheet number 2, students identify the technical parameters of the ramp.

Student 1: The minimum width and maximum length are available, and the slope does not exceed. So how many degrees?
Student 2: This ratio is the height of the doorway to the ground. It means the ratio of the length of the side opposite and the length of the side adjacent to the angle, so we use the tangent ratio.
Student 3: The angle measure is $4^0 46'$.
Student 4: So how do we calculate the ramp length?
Student 5: The step and the ground make a right triangle. The length of the ramp is the hypotenuse. Regarding the hypotenuse, we use the sine ratio or cosine ratio.
Student 3: The height of the step is 8cm, we must use a sine ratio. It makes us calculate the length of the ramp easily.
Student 1: Calculate the ramp length. It exceeds 9m, does it not?
Student 4: Does not exceed!

Table 4. Worksheet 2 of Group 2. Results of group 2's search information were obtained.

In Activity 2, students used exactly the "sine ratio" and calculated the ramp length correctly. In addition, they are aware that the calculation results are consistent with construction standards.

Activity 3

Students choose the design. Groups synthesize required materials. Give the design of the ramp. Collect the essential materials.

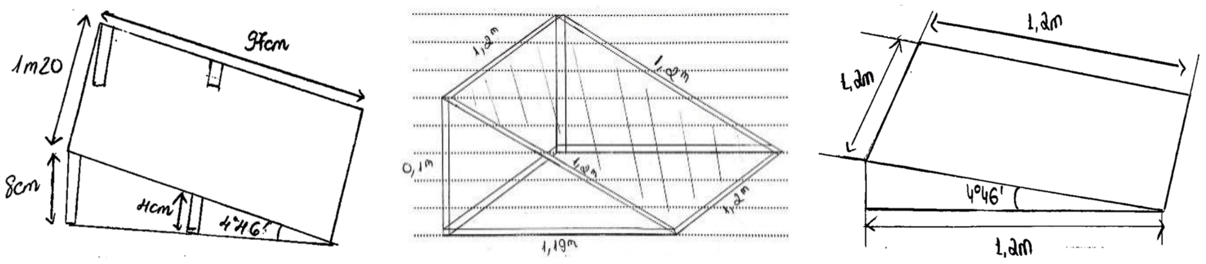

Figure 5a. Worksheet 3 of Groups. The design of the ramp

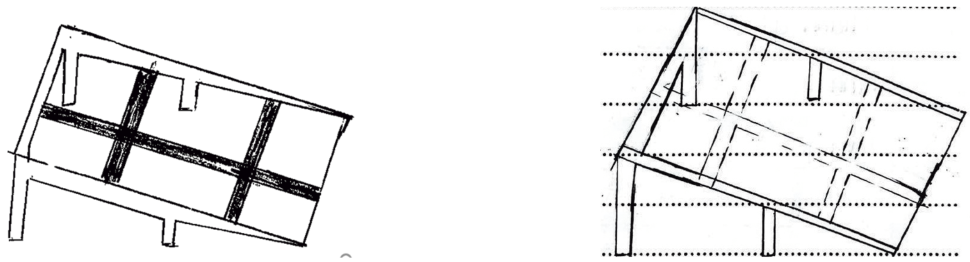

Figure 5b. The design of the ramp of Group 2

Materials	Total
Wooden plank	1 plank or 1,44 m^2
Wooden sticks	6 sticks
Screws	100
Wood saws	2
Hammer, pincer, tape measure	1

Table 5. Worksheet 4 of Groups

Students of group 1 ask questions and group 2 answers are summarized as follows:

Student 1: Our group chose the option to make the slope with $4^0 46'$ the slope length is the shortest but still ensures that the disabled person can go up the slope.

Student 2: Do you think the 120 cm size has much deviation from the original angle?

Student 1 says that student 3 has an error in calculating: The original angle $4^0 46'$ the angle after being rounded to the length of the slope is $4^0 46' 48.69''$. Divide $4^0 46' 48.69''$by $4^0 46'$and multiply by 100.

Student 3: 100.3.

Student 1: This is a 0.3% deviation from the criteria. Although the angle measurement is larger than specified, the error is relatively small, so the group still chooses this size (Figure 5a).

Teachers ask questions to students: Among the criteria: are compliance with construction standards for wheelchairs; saving raw materials. According to them, the order of priority of the above 3 criteria.

Student 1: Comply with construction standards for wheelchairs; saving raw materials; sure.

Student 2: Comply with construction standards for wheelchair users; sure; save raw materials.

Teacher: If the ramp is uncertain or unsafe, can people in wheelchairs use it?

Student: No.

Teacher: Group 1 should think about what the group needs to do to make the slope more stable.

Through this activity:

- *Students can determine the ramp model.* Group 2 went with the option of additional support frames to assure the ramp's stability. To make it easy to move as well as construct, Group 1 elected to make it out of wood rather than cement. The groups submitted measurements for their concepts as well as the materials to be used.

- *Students interacted with each other to reach a consensus and synthesize comments into worksheets*. With this activity, students better understand the knowledge and application of knowledge to solve practical problems. Then, each group will give a presentation on the option that the group has chosen. In the presentation, it is necessary to give advantages and disadvantages. The presentation of group 1: Group 1 chose the option made of wood and without a support frame (Figure 5b).
- *Students can self-assess their knowledge*. When students work in groups, they can jointly analyze the requirements set by the teacher and synthesize the necessary information for the group's product.

Activity 4

The teacher has a brief interview for group 2:

TEACHER: Why did the group make wooden slats and stakes in the middle?

STUDENT: To prevent the wood from bending when the wheelchair passes.

TEACHER: Why did the group choose wood to make the ramp?

STUDENT: Transportation is convenient if needed and construction is also easier.

During the construction process, both groups completed the product. Both groups tested by using a wheelchair through the ramp.

Through this activity:

- Students know how to take advantage of all the materials that teachers provide.
- Students were equipped with the necessary knowledge in previous activities, and the construction process of the students took place very easily. Due to being equipped with the knowledge required in the previous activities, the construction process for the students is very easy.
- Students know how to apply background knowledge and rationally use materials teachers provide for the construction of their group's products.

Activity 5

Through activity 5, we see that:

Students make progress in defining product requirements.

Students make technical progress and find solutions to improve the group's products to make product work better (Figure 6).

Students know how to use the provided materials to solve problems related to the product.

Students know how to apply mathematics in life, specifically: Students have used the formula "Trigonometry ratio of an acute angle" to create ramps for people with disabilities in wheelchairs (Figure 7).

After the groups finished presenting their group product, the teacher started to test the availability of the products. The teacher let a student in a wheelchair go uphill. The teacher checks the firmness of the ramp. Both groups successfully performed the test and ensured safety.

Figure 6. Worksheet 5. The construction of groups

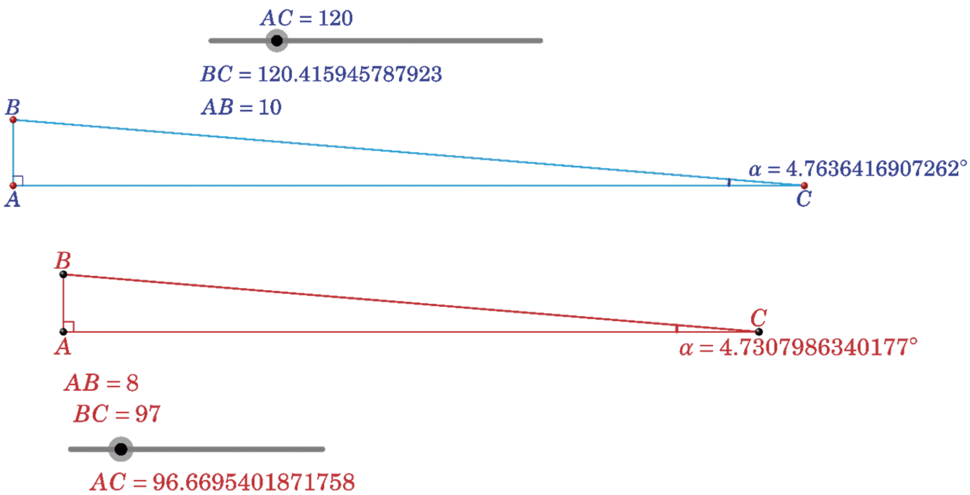

Figure 7. Worksheet 5. The technical drawing of groups on Geogebra

Figure 8. Groups 1 and 2 check the availability of products

Two groups still want improvements to make the ramp greater certainty. Particularly, the second group wants to improve the handle to make it easier for people in wheelchairs to move (Figure 8).

Science	Technology	Engineering	Math
Materials science: properties of materials used. Construction: Technical regulations in construction: Ramps, slopes. Physics: Friction force.	Assess technology. Use GeoGebra not only to make technical drawings but also to represent the relationship between angle and edge.	Technical drawings. Product creation process. Measure, cut, paste, and create products.	The trigonometry ratios of an acute angle. Determining the trigonometry ratios for acute angles. Using the trigonometry ratios to determine the measure of an angle. Using the trigonometry ratios to calculate lengths.

Table 6. The Science, Engineering, Technology, and Math elements that students need to master are used to solve problems

From the result of the pedagogical experiment, we seek information to answer Q2 "Q2. How do 9th graders in Vietnam adapt to teaching-oriented STEM education in teaching Mathematics, in particular, "Trigonometry ratio of an acute angle?". These are: Group 1 chose the option of making wood instead of cement to make it easier to move as well as easier to construct. Group 2 chose the option with additional support frames to ensure the certainty of the ramp. Students can self-assess their knowledge.

4.3. Feedback from Students After Studying

4.3.1. Students' Excitement/Satisfaction when Learning Mathematics Integrate with STEM Education

Most students who study Math according to STEM education are highly excited; only 3.8% of them said that it is not exciting. So, learning Mathematics with lesson designing integrated with STEM education is attractive, and alluring to students.

4.3.2. Students' Difficulties when Learning Mathematics Integrate with STEM Education

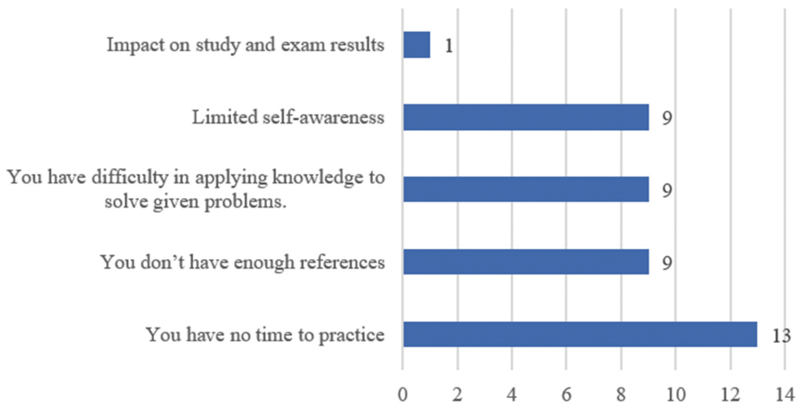

Figure 9. The difficulties when students study in class according to STEM education

According to fig 9, there are many kinds of difficulties for students if they study Math according to STEM education. Students make technical progress and find solutions to improve the group's products to make the product work better. Students know how to use the provided materials to solve problems related to the product.

4.3.3. Student Feedback on Learning Outcomes Connect with Real-World and the 21st-Century Skills Development

4.3.3.1. Real-World Problem Solving

Theme	Brief Description	Example Quote
Real-world for learning STEM lessons together	Real-world is a complex context, which is why the real world is a good situation to apply STEM education. When students learn in the real world, they can learn integrated STEM lessons which have grounded them in the real world.	When studying in the real world: + I can learn to integrate Mathematics, Technology, Engineering, and Sciences knowledge and skills when designing a wheelchair ramp and making a wood frame in learning the lesson of "Trigonometry ratio of an acute angle" in the real world. + Not only Mathematics lesson, but we also need to apply multi-knowledge in STEM in this lesson + Real-world context really attracted me to invest time and studying not only for learning but also to help disabled people.
Real-world for student learning problem-solving.	A problem in the real world for studying in STEM requires students to identify exactly the issues, search for information and knowledge, make a plan, and do actions for real-world solving problems. The overlap with using a real-world problem as a context for learning, but in other cases, teachers referred to general problems that were relevant to students.	+ When learning and working together to design a wheelchair ramp and make a wood frame in learning the lesson of "Trigonometry ratio of an acute angle" to help the disabled man in the real world, we can learn the process of how to solve a problem. + When communicating with the disabled man, we understand what he needs and make the process to make the product to help him to be convenient in moving with the wheelchair. Students know the procedure for problem-solving. + This is different from the lesson in the class because all steps connect with the real situation. + We have discussed and given some solutions and then finally, decided which is effective and suits the needs of disabled people.
Real-world for students improving positive emotion.	Real-world with real people in a different context will be a good environment for students to interact, communicate understand together, and support together for community development. Through this case, students will be improving, enriched by human love, and sympathy, wanted her students to make a connection to their local environment for an integrated STEM unit related to recycling.	After this lesson: + I feel that some disabled people around us need help and we need to support them in what we can. + I was so happy when I contributed my knowledge, time, and efforts to help disabled men in my local area. + When seeing his smile when successfully applying a new product made by us, we were so happy, this inspired us to explore new knowledge in STEM to apply in solving the real problem more and more. + We also debated and were angry sometimes, but the process helped us learn from each other, respect different ideas, and finally, we were happy with our success. This is teamwork.

4.3.3.2. The 21st-century skills development

Theme	Describe	Quote
Critical thinking	Students can look for evidence or give examples to support their opinions or claims and beliefs. They usually ask and answer critical questions during the study. Students can encompass effective reasoning, systems thinking, making judgments and decisions, and problem-solving.	+ We listen to the disabled man sharing his difficult situation and looking for ways to help him. + When he said he needed a wood frame for a wheelchair to move easier our group discussion with many questions. For example: How to have a product like this? What materials do we need? How to measure exactly? What knowledge of Mathematics apply? Can I write a real story as a Mathematics exercise and solve the problem? etc.

Theme	Describe	Quote
Creative	Students have multifaceted skills that lead to innovation and effective problem-solving. It comprises the generation of multiple ideas and solutions to problems and making associations between remote concepts.	+ We were requested to make a very good wood frame and use it effectively in a real situation; therefore we need to do it carefully at each stage. For example: + Make a detailed plan. + Apply multi-knowledge, such as Mathematics, technology, engineering, and Physics in the plan. + Accounting how much money to buy? Where to buy it? Where is the cheapest and good quality? Who will do it? + What tools do we need to use? How can I make it beautiful with no mistakes? How do you combine group member tasks effectively? What criteria ensure products are quality and effective use?
Collaboration	Students work in a group -collaboration or teamwork. This is an essential skill in problem-solving and the construction of knowledge. It is manifested when	We have the experience of working together for two weeks. Every member communicates with each other to understand clearly what we will do. + Everyone has the responsibility to reflect an opinion in the group chat box when the group leader shares a question or asks something. + We discuss and agree together before we make decisions collectively. + Sometimes, we do not agree with everything and discuss it again. We learn how to manage conflicts; build trust with each other. These experiences make us mature in the discussion.
Communication	Communication comprises information delivery, and interpersonal skills, interactive communication, and even teamwork, among others.	+ Different from the study in class we usually communicate in the classroom only, however, when studying STEM education with a real project, we communicate with diverse people at different times, inside and outside class. + We were not only communicating in a group but communicating with local people and sharing many things. + Group leaders communicate with teachers, experts, and local people and share in the group. We feel happy when talking to each other.

5. Discussions

Concerning the first research objective, Vietnamese teachers in this study have a high perspective on the necessity to apply STEM education and STEM education is adaptable to the innovation trends in teaching and learning. However, respondents in this study report face many challenges in applying STEM education in teaching mathematics. Most of them felt like they were inquiring when they were not interested. They seldom or sometimes integrated STEM education into teaching mathematics. Interestingly, most of the respondents connect the mathematics lesson with a real-life situation.

About the second research objective:

Activity 1: Identify the problem: The teacher assigns students a task that children expect real-world connections to what they are learning, or else they may completely disengage. This step is very important because it determines the success of the lesson. This finding provides the process of how teachers work in lesson designing and task-based learning applying when employing STEM education in teaching and learning in mathematics. The real situation becomes a clue to attract students to critical thinking to find solutions. The problem-solving process applied in this lesson for students' practice will bring enormous benefits to them to achieve learning outcomes as well as to know how to solve an issue in a real situation.

About the third research objective:

The teacher assigns students a task that children expect real-world connections to what they are learning, or else they may completely disengage.

In Vietnam, STEM education has been attractive in several studies as mentioned in the literature review. However, this is the first study to apply the mix-method with a process of three stages, including examining the teacher's perspective, designing a lesson that connects with the real-world situation to support disabled people in the local context, and exploring the student's feedback on learning outcomes. The learning outcomes were focused not only on knowledge content but also connected on human emotion development and the 21 skills to prepare the young generation to adapt to modern society's requirements. The findings have significantly supported the previous studies such as Dare, Ellis and Roehrig (2018) and Ryu et al, (2019) when emphasizing the role of the teacher perspective on the importance of STEM education and how to integrate STEM subjects in teaching STEM lessons.

The second interesting finding in this study is the real-world situation that was selected involving students applying STEM education to support disabled people in the local context. This STEM lesson not only helps students in learning new knowledge content but also educates students on local humanities concerns and emotional personality development, such as human love, caring people, equal society, etc. The lack of previous studies mentions this point and this finding contributes to the review of meaningful STEM education for sustainable community development.

The project-based learning strategies applied in the STEM lesson design and the student learning outcomes connected with the 21st skills in this study reflect the new trend of applying STEM education in teaching Mathematics in ASIA. Wahono et al. (2020) realized that in ASIA, like Korea, Malaysia, and Japan, … STEM education policies are expected to prepare the young generation for the 21st skills to adapt to high standards of competition in global labor markets. That was different from the Western culture which mainly supports students' interests and satisfaction with the STEM education environment. This finding has been significantly supported by a previous study in Vietnam by Hau, Tinh and Van (2020) when authors suggested that STEM education pedagogy connects with project-based learning theories and practices to help teachers overcome challenges and bring enormous benefits for students' development.

6. Conclusions

This study provides successful evidence of applying STEM education in teaching mathematics subjects in Vietnam. Designing a wheelchair ramp is a practical and topical STEM lesson that was designed by the four steps process. Through the progression of activities in STEM lessons, students not only learn the knowledge of Mathematics, Physics, and some knowledge of science, engineering, and technology integrate to solve real problems but also equip themselves with reasoning ability, critical thinking ability, teamwork ability, time management ability, problem-solving ability, ability to search and select information as namely the 21st skills. Teaching-oriented STEM education in teaching Mathematics in particular "Trigonometry ratio of an acute angle" in other aspects such as designing a sunshade roof, designing a water park slide model to help children not only learn well and practice well but also develop a sense of community and improve practical skills in society. The study design and findings are expected to provide successful evidence for further discussion and practice to improve the effectiveness of teaching and learning STEM education in Vietnam.

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References

Achterhuis, H. (Ed.). (2001). *American philosophy of technology: The empirical turn*. Bloomington: Indiana University Press

Bruce-Davis, M.N., Gubbins, E.J., Gilson, C.M., Villanueva, M., Foreman, J.L., & Rubenstein, L.D. (2014). STEM high school administrators', teachers', and students' perceptions of curricular and instructional strategies and practices. *Journal of Advanced Academics*, 25(3), 272-306. https://doi.org/10.1177/1932202X14527952

Burghardt, M.D., & Hacker, M. (2004). Informed design: A contemporary approach to design pedagogy as the core process in technology. *Technology teacher*, 64(1), 6-8.

Chute, E. (2009). *STEM education is branching out: Focus shifts from making science, and math accessible to more than just the brightest.* Pittsburg Post-Gazette.

Dare, E.A., Ellis, J.A., & Roehrig, G.H. (2018). Understanding science teachers' implementations of integrated STEM curricular units through a phenomenological multiple case study. *International Journal of STEM Education*, 5(1), 4. https://doi.org/10.1186/s40594-018-0101-z

Dare, E.A., Keratithamkul, K., Hiwatig, B.M., & Li, F. (2021). Beyond Content: The Role of STEM Disciplines, Real-World Problems, 21st Century Skills, and STEM Careers within Science Teachers' Conceptions of Integrated STEM Education. *Education Sciences*, 11(11), 737. https://doi.org/10.3390/educsci11110737

Dung, T.M., Vu-Nhu, T.H, & Nga, N.T. (2020). Teachers and STEM Education: Collaboration across Disciplines and Implementation of Lessons in Two Subject Areas. *Universal Journal of Educational Research,* 8(9), 4122-4128. https://doi.org/10.13189/ujer.2020.080938

Ejiwale, J. (2013). Barriers to the successful implementation of STEM education. *Journal of Education and Learning,* 7(2), 63-74. https://doi.org/10.11591/edulearn.v7i2.220

Hau N.H., Cuong, T.V., & Tinh; T.T. (2020). Students and teachers perspectives of the importance of arts in steam education in Vietnam. *Journal of Critical Reviews*, 7(11), 666-671.

Hau, N.H., Tinh, T.T., & Van, N.T. (2020). Steam Education Route in Vietnam: Framework and Students' Perspective. *International Journal of Psychosocial Rehabilitation,* 24(05), 258-273. https://doi.org/10.37200/IJPR/V24I5/PR201690

Herro, D., Quigley, C., Andrews, J., & Delacruz, G. (2017). Co-Measure: developing an assessment for student collaboration in STEAM activities. *International journal of STEM education*, 4(1), 1-12. https://doi.org/10.1186/s40594-017-0094-z

Herschbach, D.R. (2011). The STEM initiative: Constraints and challenges. *Journal of STEM Teacher Education*, 48(1), 96-122.

Holmlund, T.D., Lesseig, K., & Slavit, D. (2018). Making sense of "STEM education" in K-12 contexts. *International journal of STEM education*, 5(1), 1-18. https://doi.org/10.1186/s40594-018-0127-2

Honey, M., Pearson, G., & Schweingruber, H. (2014). STEM integration in K-12 *education*: S*tatus, prospects, and an agenda for research.* Washington D.C.: The National Academies Press.

Kennedy, T.J., & Odell, M.R. (2014). Engaging students in STEM education. *Science Education Internationa*l, 25(3), 246-258.

Kim, Y., Chu, H.E., & Lim, G. (2015). Science curriculum changes and STEM education in East Asia. In *Science Education in East Asia* (149-226). Springer, Cham. https://doi.org/10.1007/978-3-319-16390-1_7

Le, L.T.B, Tran, T.T., & Tran, N.T. (2021).Challenges to STEM education in Vietnamese high school contexts. *Heliyon*, 7(2021), e08649. https://doi.org/10.1016/j.heliyon.2021.e08649

Levine, T.H., & Marcus, A.S. (2010). How the structure and focus of teachers' collaborative activities facilitate and constrain teacher learning. *Teaching and teacher education*, 26(3), 389-398.

Margot, K.C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: a systematic literature review. *International Journal of STEM education*, 6(1), 1-16. https://doi.org/10.1186/s40594-018-0151-2

Ministry of Education and Training (2018). *Circular No. 32/2018/TT-BGDĐT; Promulgation of the new general education curriculum.*

Moore, T.J., & Smith, K.A. (2014). Advancing the state of the art of STEM integration. *Journal of STEM Education: Innovations and Research*, 15(1), 5.

Morrison, J. (2006). *TIES STEM education monograph series: Attributes of STEM education.* Baltimore, MD: TIES.

National Research Council (2010). *Preparing teachers: Building evidence for sound policy*. Washington, DC: National Academic Press.

Nguyen, T.H. (2019). STEM/STEAM education: From hands-on to minds-on. Vietnam: Tre Publishing House.

Quang, L.X., Hoang, L.H., Chuan, V.D., Nam, N.H., Anh, N.T.T., Nhung, V.T.H. (2015). Integrated Science, Technology, Engineering and Mathematics (STEM) Education through Active Experience of Designing Technical Toys in Vietnamese Schools. *Journal of Education, Society and Behavioural Science*, 11(2) 1-12. https://doi.org/10.9734/BJESBS/2015/19429

Ryu, M., Mentzer, N., & Knobloch, N. (2019). Preservice teachers' experiences of STEM integration: Challenges and implications for integrated STEM teacher preparation. *International journal of technology and design education*, 29(3), 493-512. https://doi.org/10.1007/s10798-018-9440-9

Saraç, H. (2018). The Effect of Science, Technology, Engineering and Mathematics-STEM Educational Practices on Students' Learning Outcomes: A Meta-Analysis Study. *Turkish Online Journal of Educational Technology-TOJET*, 17(2), 125-142.

Sheffield, R.S., Koul, R., Blackley, S., Fitriani, E., Rahmawati, Y., & Resek, D. (2018). Transnational examination of STEM education. *International Journal of Innovation in Science and Mathematics Education*, 26(8).

Timms, M.J., Moyle, K., Weldon, P.R., & Mitchell, P. (2018). *Challenges in STEM learning in Australian schools: Literature and policy review.* Australian Council for Educational Research (ACER)

Thibaut, L., Ceuppens, S., De Loof, H., De Meester, J., Goovaerts, L., Struyf, A. et al. (2018). Integrated STEM education: A systematic review of instructional practices in secondary education. *European Journal of STEM Education*, 3(1), 2. https://doi.org/10.20897/ejsteme/85525

Tho, C.C. (2016). Lessons on changes in training teachers from stem festivals and math open days in Vietnam. *Journal of Science of HNUE, Educational Sci*, 61(8A), 195-201.

Tinh, T.T. (2019). Integrating art with STEM education-STEM Education in Vietnam High Schools. *Annals. Computer Science Series*, 17(1).

Tinh, P.T., Duc, N.M., Yuenyong, C., Kieu, N.T., & Nguyen, T-T. (2021). Development of STEM education learning unit in context of Vietnam Tan Cuong Tea village. Journal of Physics Conference Series, 1835(1), 012060.

Tsupros, N., Kohler, R., & Hallinen, J. (2009). *STEM education: A project to identify the missing components*. Pennsylvania: Intermediate Unit 1 and Carnegie Mellon.

Tytler, R. (2020). STEM education for the twenty-first century. *Integrated Approaches to STEM Education*, (21-43). https://doi.org/10.1007/978-3-030-52229-2_3

Yakman, G., & Lee, H. (2012). Exploring the exemplary STEAM education in the US as a practical educational framework for Korea. *Journal of the Korean Association for Science Education,* 32(6), 1072-1086. https://doi.org/10.14697/jkase.2012.32.6.1072

Yildirim, B., & Selvi, M. (2016). Examination of the effects of STEM education integrated as a part of science technology society and environment courses. *Journal of human sciences*, 13(3). https://doi.org/10.14687/jhs.v13i3.3876

Wahono, B., Lin, P.L., & Chang, C.Y. (2020). Evidence of STEM enactment effectiveness in Asian student learning outcomes. *International Journal of STEM Education*, 7(1), 1-18. https://doi.org/10.1186/s40594-020-00236-1

Wang, H.H., Moore, T.J., Roehrig, G.H., & Park, M.S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research (J-PEER)*, 1(2), 2.

Williams, D.L. (2007). That what, why, and how of contextual teaching in a mathematics classroom. *The Mathematics Teacher*, 100(8), 572-575.

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