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Viewpoints of Teachers of Natural Science Subjects on STEM Education at the Secondary School Level in Vietnam

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STEM education (Science, Technology, Engineering and Maths) is an educational orientation that of interest to Vietnam as well as most countries in the world. However, how STEM education should be implemented, especially in the context of developing countries like Vietnam that have certain restrictions on economy and facilities, is still a matter of concern and needs to be studied and investigated. Currently, there are still many different interpretations of STEM education, which lends itself to a very diverse and inconsistent implementation of STEM education. In order to implement STEM teaching effectively and comprehensively, it is necessary to understand the perceptions of STEM education by educators, and thereby find an appropriate way to implement this educational orientation so as to contribute to improving training effectiveness. This paper presents the ideas of 200 teachers of natural science subjects at the secondary school level in Vietnam on STEM education, from which the orientation for implementing STEM education is appropriate.

Key words: *STEM education, STEM, secondary school, teacher.*

Introduction

The STEM integrated education (commonly referred to as "STEM education") is a combination of Science, Technology, Engineering and Mathematics subjects (Banks, 2014). STEM integrated education is essentially a practical, hands-on teaching style that equips learners with the necessary knowledge and skills related to the fields of science, technology, engineering and mathematics (Whitton, 2016). STEM education is becoming a "global trend" because of the practical benefits that it can bring to learners, and its ability to suit the labour needs of the new age (Davis et al., 2019). The STEM integrated education model is still quite new to Vietnamese education, where it has only been piloted for a few years. One of the

STEM teaching models studied by Vietnamese educational researchers is the teaching of Robotics. However, this is a form of "quite", if not "very" expensive subjects, so it is difficult to popularise. If we enter the keyword phrase "STEM education" into the Google search site, we can see thousands of links displayed, but most are in the form of online newspapers or websites that have very few scientific articles on STEM education in Vietnam, proving that this educational model has not been studied methodically. However, this is not a "strange" education model because of the basic principle; the guideline for this model is to learn along with practice and to combine knowledge and practice, things that are always expressed and emphasised through the Vietnamese Education Law over the years (for example, Education Law 2005, 2009). Through learning activities that combine knowledge with practice, and technology, through design and calculation to create results that best suit the needs of society, STEM education has advantages in developing learners' capacities comprehensively, as it makes learning interesting and thereby stimulates learners' interest in learning. This is very consistent with the orientation of developing learners' capacity that the Ministry of Education and Training is aiming to implement (Ministry of Education and Training, 2018). However, the implementation of STEM currently has no synergy among educators. There is still a lot of controversy about the educational models for STEM implemented in programs and subjects, because with different understandings and beliefs, the concept of STEM education can give rise to different educational meanings and structures. Moreover, for the effective implementation of STEM education, the role of the teaching staff is extremely important. It is the teaching staff who will directly decide content and the method of teaching, as well as strategies to implement specific lessons in each specific context to ensure the educational goals. Therefore, it is essential to learn about STEM education, as well as ideas about STEM education implementation by educators, to be able to direct the most appropriate and effective implementation of STEM education for each country.

This research focuses on understanding the views of STEM teachers in secondary schools on STEM education, such as their understanding and some comments on the characteristics of STEM education; implementation capability as well as the difficulties that teachers will face when implementing STEM education. From this it will propose appropriate solutions to implement STEM education in secondary schools within the Vietnamese context.

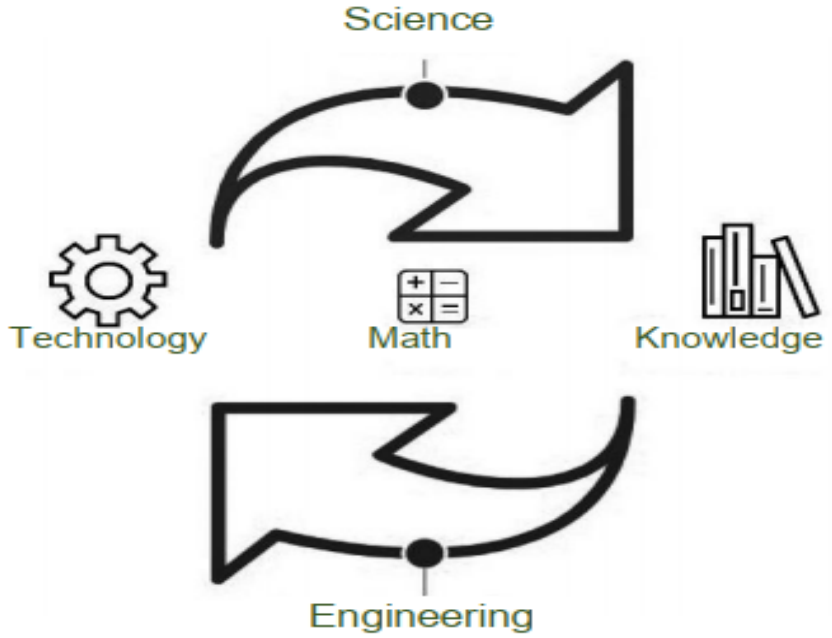
Literature Review

STEM Education Concept

STEM is an abbreviation for the words of Science, Technology, Engineering and Mathematics, often used when discussing the development policies of Science, Technology, Engineering and Mathematics of each country (R.Bybee, 2013). The development of Science, Technology, Engineering and Mathematics is described by the STEM cycle (Figure

1), where Science is the process of creating scientific knowledge; Engineering is the process of using scientific knowledge to design new technologies to solve problems; Maths is the tool used to capture results and share them with others (Breiner, Harkness, Johnson & Koehler, 2012) (R.Bybee, 2013).

Figure 1. The STEM cycle (Carla C. Johnson, Erin E. Peters-Burton, 2015)



STEM education is an interdisciplinary approach in the learning process, in which the principal academic concepts are integrated with real-world lessons, in which students apply knowledge and skills in the fields of science, technology, engineering and maths into specific contexts, helping to connect schools, communities, workplaces and global organisations, and transmitted in an interwoven and interlinked way for students on the basis of learning through practice and aiming to solve practical problems (Asghar, Ellington, Rice, Johnson & Prime, 2012). In addition, STEM education also focuses on equipping students with the soft skills necessary for success in future work, such as collaboration, teamwork, problem solving, creative thinking and critical reviewing (Banks, 2014). It can be said that STEM education does not aim to train students to become mathematicians, scientists, engineers or technicians but mainly equip students with the knowledge and skills to work and develop in today's modern technological world (Whitton, 2016) Deerinck, 2011).

STEM education creates people who can meet the work needs of the 21st century, plus meet the needs of national socio-economic development and also positively impact the change of the knowledge economy in the context of globalisation (Breiner et al., 2012). It is possible to look at the components of STEM Education from the perspective of learners' capacity development (Daugherty & Daugherty, 2010). For example, the "Technology" element of STEM Education

creates the technical competence of learners, which is expressed through the ability to solve problems that arise in real life by designing objects and systems and building the production processes to create them (Asghar et al., 2012).

Features of STEM Education

STEM education emphasises the following features:

The first is to focus on integration: STEM education is characterised by a focus on the integration of two or more subjects, with particular emphasis on science and maths. Creativity adds other factors such as art, society, literature, etc., depending on each teacher in each specific context (Carla C. Johnson, Erin E. Peters-Burton, 2015). If the curriculum in a school has many subjects and many teachers of different disciplines, and if these do not connect and complement each other, it cannot be classified as STEM education (Ronald et al., 2010).

The second is to focus on lessons in the real world: This demonstrates the practicality and applicability of knowledge in solving practical problems. Here, there is no barrier to learning theoretical knowledge with its application (Ali, Talib, Surif, Ibrahim & Abdullah, 2019). Therefore, STEM education must necessarily focus on practical activities and apply knowledge to create products or solve real-life problems (Banks, 2014).

The third is towards the development of skills for the 21st century: STEM education creates opportunities for students to train and develop the necessary target skill groups for work in the 21st century. Such skills include complex problem-solving, teamwork, critical thinking and creative skills (Banks, 2014). The skills are integrated into learning activities both inside and outside the classroom. The skills are also systematically built, continuously, and inheritant in each other (Prawvichien, Siripun & Yuenyong, 2018).

The fourth is to challenge students to overcome themselves: Exercises, study projects or field trips all require students to work on their own, or in collaboration, to exploit available resources to reach new milestones of knowledge, experience and capacity (Wongsila & Yuenyong, 2019). There will be no exercises of just learning by heart, memorising and returning lessons like in traditional ways of learning. Instead, students must apply their knowledge to solve problems, create, and change problems (Carla C. Johnson, Erin E. Peters-Burton, 2015). Therefore, STEM education is not only geared to specific local issues but must be placed in relation to the global economic context and global trends. For example: climate change, renewable energy (Series, 2019).

The fifth is the systematicity and cohesion between various lessons: This is an important feature that helps the educational process achieve high efficiency for students (Banks, 2014). If students take a lot of different experiential lessons and participate in different hands-on activities yet the lessons lack cohesion, inheritance and continuity, students will fall into gaps of knowledge and information will remain discrete (Blotnicky, Franz-Odendaal, French & Joy, 2018).

Through an integrated education approach, students are aware of the intersection of science and mathematics; they see the need for scientific knowledge to solve a problem or create a product. At the same time, students are encouraged to be creative based on their own interests, so they become more confident in the learning process and in group work. In particular, STEM education helps students experience feelings of failure and success in the learning process, which is essential for the development of emotional intelligence and motivates their maturity.

The Goals of STEM Education

From the perspective of education and application in the Vietnamese context, STEM education on the one hand fulfills the educational goals stated in the general education program. On the other hand, STEM education aims to:

***First, Develop the Specific Competencies of STEM Subjects for Students*:** This is the ability to apply the knowledge and skills related to the subjects of Science, Technology, Engineering and Mathematics, in which students know how to combine the knowledge of science and maths to solve practical problems, and know how to use, manage and access technology. They know about the process of technical design and the manufacture of products (Breiner et al., 2012).

***Second, Develop Common Competencies for Students*:** STEM education aims to prepare students for opportunities, as well as challenges, in the global competitive economy of the 21st century (Breiner et al., 2012). In addition to understanding the areas of Science, Technology, Engineering and Mathematics, students will develop their competence in solving problems and their creativity, communication and collaboration, autonomy and self learning.

Third, Guide Careers for Students: STEM education will provide students with the foundational knowledge and skills for learning at higher levels and also for their future career, since it contributes to building a competent and quality workforce, especially a STEM workforce, in order to meet the country's construction and development goals (Banks, 2014).

The Role and Significance of STEM Education in General Education in Vietnam

The introduction of STEM education into high school makes a lot of sense, consistent with the orientation of reforming general education in general, in Vietnam in particular.

First of All, Ensure Comprehensive Education: The implementation of STEM education in schools, in addition to the subjects concerned such as Maths, Science, Technology and Engineering, will also be interested and invested in all aspects of teaching staff, programs and facilities.

Next, Increase Interest in Learning STEM Subjects: STEM education learning projects aim to apply interdisciplinary knowledge to solve practical problems, enabling students to work, experience and see the meaning of knowledge within life, thereby helping increase students' interest in learning.

Third, the Formation and Development of Competence and Quality for Students*:* When implementing STEM learning projects, students collaborate with each other, proactively and independently carry out learning tasks, and get acquainted with activities of a scientific research nature. The above-mentioned activities contribute positively to the formation and development of qualities and competencies for students.

Fourth, Connect Schools with the Community: To ensure the effective implementation of STEM education, general education institutions often connect with local vocational and higher education institutions to exploit human resources and facilities for STEM education. STEM general education also aims at solving local, specific problems.

Fifth, Career Guidance, Student Stream: In well-organised STEM education in secondary schools, students will gain experience in the STEM field and assess their suitability, aptitude and interests with STEM careers. Implementing good STEM education in secondary schools is also a way to attract students to pursue and select occupations in the STEM field, occupations with a high demand for human resources in the fourth Industrial Revolution.

Sixth, Adapt to the 4.0 Industrial Revolution: With the development of science and technology, the demand for jobs related to STEM is increasing, requiring the education sector to make changes to meet the needs of society. STEM education can create people who are able to meet the working needs of the new century, and thus have a great impact on economic change.

The educational program of the 20th century mainly focused on Science (S) and Mathematics (M), underestimating the role of technology and engineering. Students need not only Maths

and Science, but in the 21st century, they also need technology and engineering, as well as other essential soft skills such as critical thinking, problem solving, teamwork and collaboration. We are living in an era of high integration between countries with different cultures. The need to exchange work and manpower is higher and increasing. In this context, education also needs to prepare students for skills and knowledge that meet global standards. STEM education, with its mission to provide the necessary knowledge and skills for the 21st century, is and will be a wide-ranging education model in the near future of the world. The STEM education method is a new educational method and takes a different approach in teaching and learning, so it needs the attention and awareness of the whole society. Studying STEM to catch up with the trend of advanced education development is a step that lays a solid foundation for Vietnam's future development.

Method

We conducted the study with the voluntary consent of 205 secondary school teachers in the subjects of natural sciences (Math, Physics, Chemistry, Biology, Technology, Natural Sciences) in Vietnam. We made it clear that the purpose of the survey was purely scientific, not for profit and that the opinions of the survey participants will be kept completely confidential.

Participants include teachers living in mountainous, rural and urban areas. The survey time is October and November 2019; at this time the teachers were participating in capacity improvement courses organised by the Ministry of Education. Each participant received the same card and answered all questions related to STEM education. Each person selected the options and filled out the questionnaire. We proceeded to collect cards, synthesise and analyse the data based on teacher answers using mathematical statistics. The number of cards collected was 200.

The survey we used was an instrument designed specifically for this research, comprised of 19 questions. They were eight (8) questions about personal information, four (4) multiple-choice style questions, five (5) open-ended questions, and two (2) questions utilising a Likert scale.

The first three survey questions were used to gather basic demographic information (sex, ethnicity and age). The next three questions were the teaching experience, qualifications and subject area of the survey participants. Questions 7 to 8 asked participants about the type of school and the location they were attending. The two next questions asked participants to draw a diagram of how they visualise 'STEM', as well as why they drew their diagram the way they did. Questions 11 and 12 asked participants about features of STEM education. In the next two questions, participants had to state their opinion on the relevance of the subjects

in STEM (Science, Technology, Engineering, Mathematics) and explain their ideas. The next question proposed teachers to suggest an effective teaching method when implementing STEM education in secondary school. Questions 16 and 17 asked participants about whether they desired STEM education be implemented, and the feasibility of implementing STEM education in secondary schools. The last two questions asked participants about the expected difficulties they will face when implementing STEM education, as well as their desire to perform well in STEM education.

Before implementation, we tested the survey on: three (3) post-graduates in educational science doctoral programs; two (2) teachers of Physics, two (2) teachers of mathematics, two (2) teachers of biology and two (2) teachers of chemistry in secondary school; five (5) final-year students in Mathematics, Physics, Chemistry, Biology and Informatics from a major pedagogical university in Vietnam. This was to learn about the applicability of the question into the context of actual investigation, and the reasonableness and clarity of the questions. At the same time, the post-graduates, teachers and students participating in the test commented on the questionnaire and made comments on the questionnaire, as well as noting problems in the process of answering this questionnaire. Participants took an average of 25 minutes to complete their responses. Based on the feedback, the questionnaire was revised in a number of details, such as the order of the questions, the language used (to make the question clearer), with additional explanations added or some unnecessary explanation removed, and some questions were added, to better serve the research objectives.

To analyse the collected survey data, we used the constant comparative methodology proposed by Glaser and Strauss (Glaser, B. G., and Strauss, 1967) in data analysis and data interrater reliability testing, based on the procedure proposed by Charmaz (Charmaz, 2006), which attaches importance to comparing individual answers simultaneously between individuals. Fundamentally, data is considered to be reliable if the opinions are consistent, relevant and complementary to each other. First, the two analysts briefly check the responses from all cards to remove data sheets that have doubts about their reliability. Encryption begins with both researchers coding a small sample (R.Bybee, 2013) to check the suitability of these built-in codes with actual data. Each researcher examines the visualisations and understands the suggestions, suggests ways to encode ideas, then discuss and agree with each other before coding, analysing and interpreting. The data analysis is conducted independently and in parallel before the meeting to compare, contrast and draw general results. Differences of conclusions will be studied, discussed and a common conclusion reached. Opinions that may lead to different interpretations are excluded again. Because the qualitative data analysis process is subjective of the analyst, the appearance frequency of key phrases and opinions is collected in order that the interpretation of the data is more authentic.

Results and Discussion

This section presents a summary of the findings of the study, and provides some examples of surveyed teacher responses to each question. Research results show that there is no significant difference in the opinions of teachers of different target groups (in terms of gender), so this study is a general statistics of the total number of teachers participating in the survey. The results are organised according to the areas of STEM education that we have tried to gather: visual conceptions, text conceptions (supporting visual conceptions) and relationships between components in STEM education; Features of STEM education; Ability to implement STEM education, and; Difficulties in implementing STEM education.

Visual Conceptions of STEM Education and the Relationship between the Components of STEM Education

In this study, to describe how to understand STEM education visually, participants were asked to create a diagram or drawing of how they understood STEM education, using S-T-E-M letters, and explain ideas of that diagram/drawing. The results we obtained in this study reflect the six most common image types. These include: a) transdisciplinary, b) sequential, c) combination, d) interconnected, e) nested, f) siled (Fig. 2). There are also some other types of images like Science-centred, Math-centred, Technology-centred, Engineering-centred, and so on (Fig. 3). Meanwhile, according to Bybee (2013), there are generally six types of visual conceptual schematic diagrams of STEM education, called: 1) nested, 2) transdisciplinary, (3) interconnected, 4) sequential, 5) overlapping, and 6) siled (Bybee, 2013). Thus the results we obtained are relatively consistent with Bybee's research.

Figure 1. Summary of visual representations

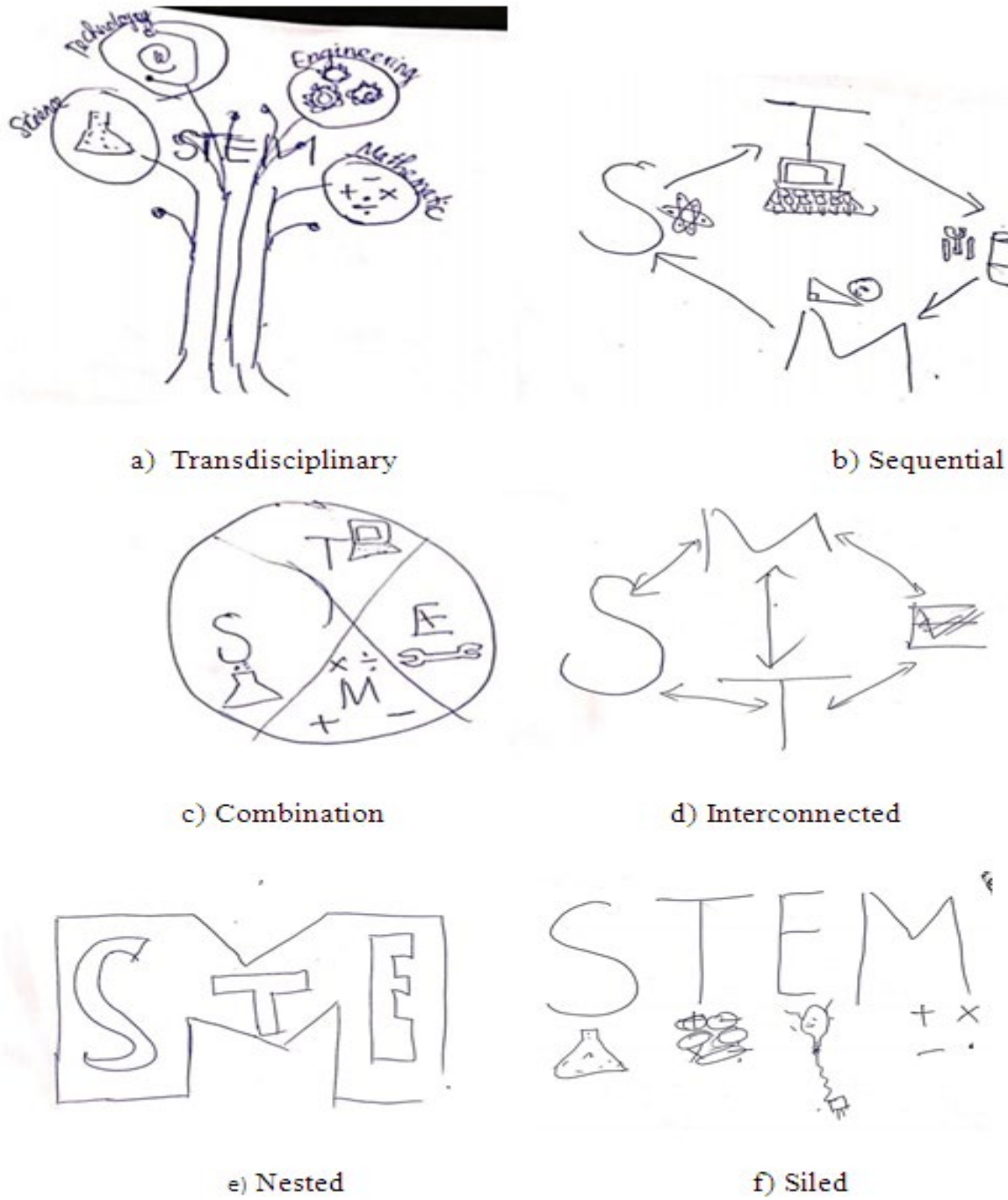


Figure 2. New visualisations

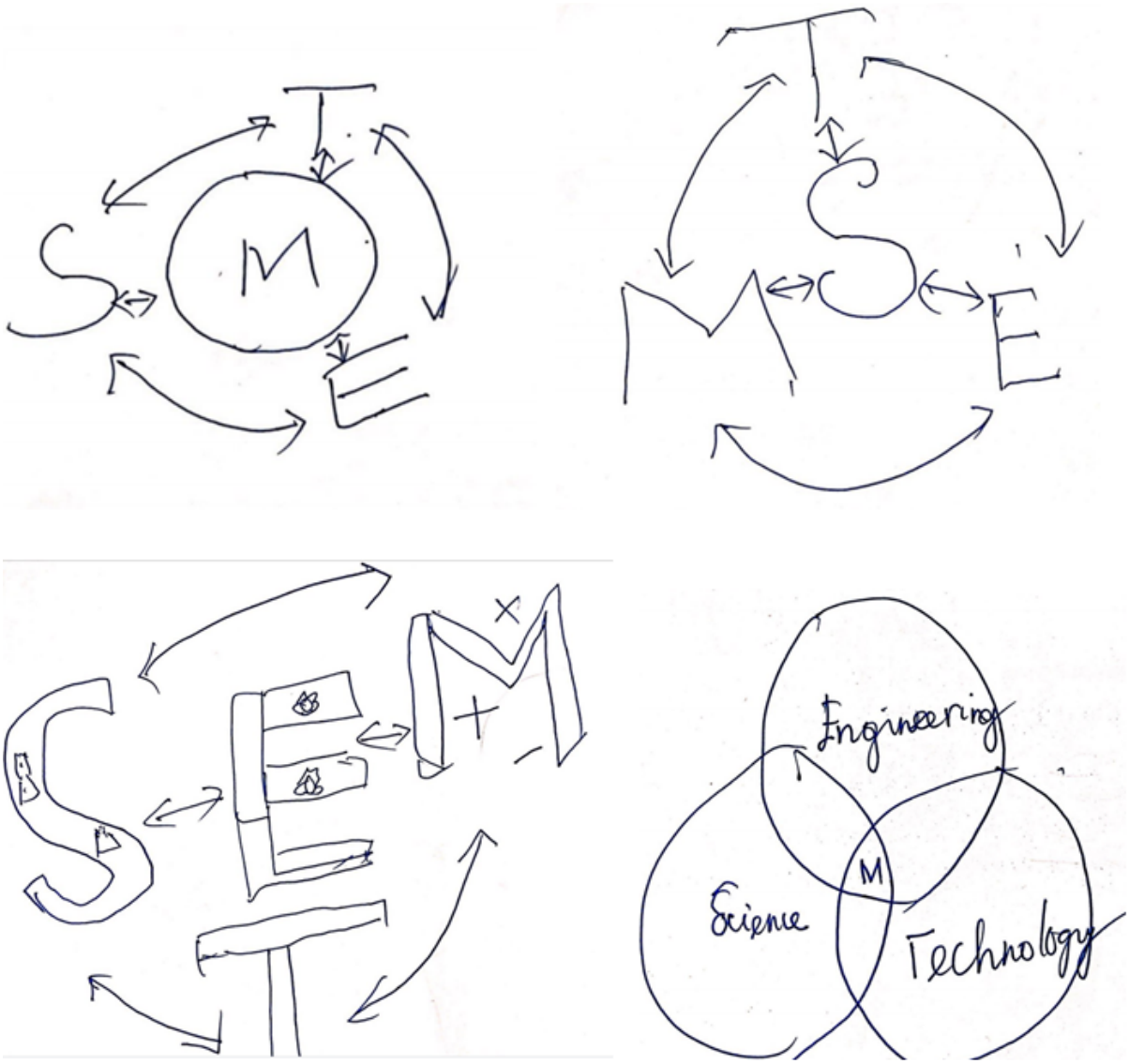


Table 1: Frequency of preservice STEM education visualisations

Type	Quantity	Rate %	Typical explanations
Transdisciplinary	35	17,5	STEM includes all 4 components of S-T-E-M, and they are closely related, support each other and have the same role in solving practical problems.
Sequential	40	20	The components of STEM are interdependent. The beginnings are problems stemming in practice related to science and ending with a scientific product under the support of mathematics as an implementation tool.
Combination	29	14,4	Components are elements in an inseparable and unified whole
Interconnected	51	25,5	Components support each other, one promotes the other and vice versa.
Nested	11	5,5	Mathematics is a key element, a tool to study the remaining components
Siled	13	6,5	The components of STEM can go together, or may miss some of the components in a particular problem.
Non	6	3	
New	15	7,5	- Maths is the foundation for all sciences. - Science is a key component of all fields.
Total participants	200	100	

In this issue, the research aims to find out the opinions of the participating teachers about the relevance of the four (4) subjects in STEM education and the results obtained are as follows: (Table 2).

Table 2: Feedback on the relevance of subjects in STEM education

Relevance	Number of selectors	%
Very relevant	84	42
Relatively relevant	112	56
Less relevant	4	2
Irrelevant	0	0
Have no idea	0	0
Total	200	100

There are no teachers who have no opinions, nor did any choose the option of “irrelevant”. Only four (4) teachers selected “less relevant” (2% of the total survey). Based on the explanation of the teachers surveyed, two levels of "very relevant" and "relatively relevant" were chosen the most, with a total of 84 comments (42%) and 112 comments (56%). Typical reasons are given as: "To solve a specific problem or a learning task, the learners need to have theory, know to calculate, perform technical manipulations, ..."

Regarding Characteristics of STEM Education

According to statistics, 96.00% of the total number of teachers surveyed said that the characteristic of STEM education is to integrate Science - Technology - Engineering - Maths subjects to help "students not only understanding the principles but also practicing" or making "the knowledge practical and comprehensive". A total of 39.00% of teachers surveyed said that STEM education is characterised by the connection between practice, hands-on and experience instead of just teaching "empty theory". In addition, 32.00% of respondents believe that STEM education is characterised by developing problem-solving and creative capacity for students. Other opinions such as "Developing collaborative capacity", "Using friendly and close materials around us" and "Creating products" were also selected by teachers with an average level from 25.00% to 32.00%. In addition, ideas such as "Combining many teaching methods", "Developing critical thinking", "Developing students' technical thinking" were selected by a small number of teachers from 17.00% to 21.00%. Finally, there are a number of other ideas, that the characteristics of STEM education include "Positive teaching", "Active learning", "Soft skills development" and be "Student-centred”. (Table 3).

Table 3: Feedback on the characteristics of STEM education

Characteristics of STEM education	**Quantity**	**%**
Integrate science, technology, engineering and maths subjects	192	96
Associate with practice, hands-on and experience	78	39
Create a product	50	25
Develop capacity to solve problems and Creative	64	32
Combine many teaching methods	42	21
Develop students' technical thinking	34	17
Use friendly and close materials around us	56	28
Develop critical thinking	36	18
Develop collaborative capacity	59	29,5
No idea	0	
Other ideas: - Strengthen group activities - Develop soft skills - Student-centred - Positive teaching - Active learning	9	

The Ability to Implement STEM Education and Teaching Methods in STEM Education

Most of the teachers interviewed agreed and expected the implementation of STEM education in secondary school. However, there are still 8.00% (equivalent to 16 respondents) who are not satisfied with the implementation of mass STEM education, with the additional explanation that it is necessary to have a roadmap, to have a careful preparation both for expertise and facilities, as well as other conditions, before deploying. Specific results are shown in Table 4.

Table 4: Comments on the possibility of implementing STEM education in secondary schools

Level	**Number of selectors**	**Rate (%)**
Completely disagree	0	0
Disagree	16	8
Normal	65	32,5
Agree	67	33,5
Completely agree	52	26
Total number of participants	200	100

On teaching methods in STEM education, according to Johnson and Peters-Burton (2015), key teaching methods and techniques in STEM education include real-world application and

context, creative and critical thinking, discovery or hands-on learning, problem-based learning (PBL), student-centred instruction, and working in groups. Quite similarly to the above study, in this study we also obtained opinions with the ratio as shown in Table 5.

Table 5: Teaching methods and techniques proposed for STEM education

Teaching methods and techniques	**Number of selectors**	**Rate (%)**
Teaching problem solving	57	28.5
Problem-based learning (PBL)	59	29.5
Teaching discovery and exploration	40	20
Hands-on method	31	15.5
Teaching by angle/station	23	11.5
Method of lecturing to raise problems	21	10.5
Organise group learning	39	19.5
No idea	10	5
Other ideas: - Teaching through games - Use direct context - For students to practice - Teaching based on problems - Using information technology - Integrated teaching - Applying knowledge		

Note: The total number of responses is greater than 200 because there are people who chose multiple options.

Table 5 shows the diversity of the STEM education implementation intentions of the surveyed teachers, in which the two most supported forms are “Problem-solving teaching” and “Problem-based learning”.

The Difficulties that Teachers Face When Implementing STEM Education

The survey results found that raising knowledge outside of our field is the biggest difficulty, with 175 respondents (87.50%). STEM integrated education is now being considered as the mixed teaching and learning of some subjects in 4 areas of science, technology, engineering and maths – even some other subjects such as English and Arts. Meanwhile, in pedagogical schools, basically teachers are trained according to the specific subject. The need to "shift" from single-subject teaching to a new "subject" where the boundary between S-T-E and M becomes blurred makes teachers not only confused about their professional knowledge but also the teaching method. The percentage of teachers worried about teaching methods is also very high, with 160 opinions (80.00%); followed by the difficulties of "Finding ideas for

STEM lessons/topics" (151 opinions - 75.50%); “Assess the learning process of students” (121 opinions – 60.50%) and finally, difficulties in facilities (with 112 opinions – 56%). In addition, the teachers surveyed also raised a number of other difficulties such as: “Schedule student time for deployment” and “Select the appropriate organisation form of activities for students” (Table 6).

Table 6: The difficulties that teachers will face when implementing STEM education

Difficulties	**Number of selectors**	**Rate (%)**
Finding ideas for STEM lessons/topics	151	75,50
Necessary facilities are incomplete	112	56,00
Knowledge beyond major	175	87,50
Teaching methodology updated	160	80,00
Assess students' learning process	121	60,50
No idea	10	5
Other ideas: - Schedule student time for deployment - Select the appropriate form of activity organisation for students		

Based on the difficulties that teachers will face when implementing STEM education in secondary schools, the teachers expressed their wishes, such as: participating in a formal training on STEM education (including interdisciplinary knowledge and methods, teaching organisation form, teaching techniques, checks and assessment); fully invested facilities to implement STEM education most effectively. Another result that is also interesting in our research is that teachers under the age of 45 are very excited and ready to implement STEM education, although there are many difficulties ahead; teachers over 45 are less interested in STEM education.

Conclusion

In general, teachers in secondary schools have a certain interest in STEM education and are eager to apply this educational model to teaching in the future. However, most teachers view STEM education at the level of partial integration (interconnected) rather than at the full integration of STEM (transdisciplinary) components. At the same time, they see the implementation of STEM as positive ways of teaching, aiming to develop learners' capacity in a real-world context, instead of seeing STEM education as educational models requiring too much expensive equipment. Understanding the concepts of secondary school teachers about STEM education is essential for education researchers, managers and policy makers, especially on how to implement STEM in the context of STEM education in Vietnam. In addition, these results can help educators at higher education levels develop training

programs, including towards STEM education, and develop appropriate STEM education training programs for both teachers and students.

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