Application level of STEM education in teaching school mathematics in Vietnam

Bui Thi Hanh Lam¹, Nguyen Danh Nam²
¹ Thai Nguyen University of Education, Vietnam
² Thai Nguyen University of Education, Vietnam
the corresponding author’s e-mail: danhnam.nguyen@dhsptn.edu.vn

Abstract. The article presents the potentials of STEM education and the level of application STEM education in teaching mathematics at schools in Vietnam. Based on general education curriculum, mathematics education curriculum, teaching facilities at schools, we conducted a survey to investigate the real situation of STEM education in some schools and suggested some solutions for teaching mathematics in the classroom which connected to STEM education. The research results have shown three levels of teaching mathematics in STEM classroom. We have offered the procedure of teaching mathematics in the classroom and designed some STEM activities that integrated science, technology, engineering and mathematics knowledge. We have realized that our approach could be implemented in teaching mathematics at schools in the context of renovating general education curriculum in Vietnam.

1. Introduction
The fourth industrial revolution and the global integration context have presented many countries in the world with many opportunities and challenges. One of the biggest challenges is the strong competition for intellectual property rights. Vietnam has built policies to create a breakthrough in the current development, which requires strong human resources in science and technology [4], [6]. Vietnam’s need for human resources requires education to identify the appropriate personality model that needs to be formed in the society. However, the reality of teaching in high schools shows that students are tending to choose and more interested in social science subjects.

According to the Ministry of Education and Training’s statistics, in 2019 the number of candidates registering universities for the social science field accounted for 53%, the natural science field accounted for 34%, the remaining candidates registered both combination. In 2018, the number of candidates registering for the social science field accounted for 48%, natural science accounted for 37%. In 2017, the number of candidates registering for social science field accounted for 43%, natural science accounted for 48%. As such, the percentage of students choosing natural sciences courses has dropped significantly in the past three years [7-9]. It is this that will likely hinder the potential for future development of science and technology in Vietnam.

In order to avoid these obstacles in human resource training in Vietnam in the future, the new general education program has focused on developing capacity and quality for student’s learning, developing student’s problem-solving ability, creativity, collaboration and especially enhancing STEM education in schools. STEM education is a form of teaching that integrates science, technology, engineering and mathematics subjects. STEM education, strengthening students with STEM skills, also plays a great role in developing students’ competence, especially real world problem solving skills. To sum up, teaching mathematics according to STEM education orientation is appropriate, necessary and meaningful to Vietnamese schools. Therefore, in this paper, we focus on the study of
STEM education-oriented mathematics teaching and the extent of STEM education application in teaching mathematics in schools in Vietnam.

2. The concept of STEM education

STEM is the abbreviation for the words Science, Technology, Engineering and Mathematics [1-3]. STEM is the abbreviated term used when discussing American development policies on science, technology, engineering and mathematics. This term was first introduced by the American Science Foundation in 2001. Currently the term STEM is used in two different contexts: the educational and professional contexts [12], [13].

In the context of education, STEM is meant to emphasize the interest of education in the subjects of science, technology, engineering and mathematics. In our research, we are interested in integrating these subjects into practice to improve the capacity of learners. Currently, STEM education is interested in many organizations and educators. Therefore, the concept of STEM education is also defined based on different interpretations. According to [4], there are three ways of understanding STEM education:

Firstly, STEM education is understood in terms of interest in the subjects of science, technology, engineering and mathematics. STEM education is a program that aims to provide students with support, reinforcement, and education in science, technology, engineering and mathematics in schools. This is a broad sense when it comes to STEM education.

Secondly, STEM education is understood in the sense of integration of four fields of science, technology, engineering and mathematics. This is an interdisciplinary approach to learning in which academic knowledge is closely associated with practical lessons by applying the knowledge of science, technology, engineering and mathematics into specific contexts. This approach links schools, communities and businesses and allows learners to develop STEM skills and increase competitiveness in a new economy.

Thirdly, STEM education is understood in the sense of integrating from two fields of science, technology, engineering and mathematics or more. In other words, STEM education is an approach, discovery in teaching and learning between two or more STEM subjects, or between one STEM subject and one or more different subjects in schools.

In this study, STEM education is understood in the third meaning and defined as follows: STEM education is a teaching perspective based on interdisciplinary approach from two or more fields of science, technology, engineering and mathematics. In which, learning content is linked to practice in reality and teaching methods based on discovery strategies.

3. Teaching STEM-oriented mathematics

3.1. The relationship between teaching mathematics and STEM education

Mathematics plays an important role in general education program. Mathematics is considered a tool subject, providing knowledge and thinking skills so that learners can study other subjects. Mathematics is of practical origin and universal [6]. Its universality is reflected in the extensive application of mathematical knowledge in other subjects as well as in practice. Therefore, in teaching mathematics, teachers can motivate students from practical situations, interdisciplinary situations and after students have knowledge and skills teachers can help students use and consolidate knowledge through solving such interdisciplinary or practical situations. Thus, through teaching mathematical knowledge at schools, teachers can strengthen their interdisciplinary knowledge and develop students’ problem solving skills as well as critical thinking. With this characteristic, mathematics plays an important role and has close relationship with other subjects such as physics, chemistry, biology, informatics and geography [8]. Therefore, teachers can choose mathematical topics, select subjects, content to design and organize STEM-based mathematical teaching topics. STEM education through teaching mathematics is often approached from the perspective of exploiting practical elements through teaching a number of topics in mathematics or experience activities of mathematics.

Mathematics is one of the four important components of STEM education, the instrumental field of the remaining scientific fields in STEM education. The limitation of students’ mathematical skills is a
major barrier to the implementation of STEM education in mathematics. Therefore, to implement STEM education effectively, it is necessary to develop students’ mathematics competency. This is an important condition for successful implementation of STEM education at schools. In contrast, STEM education also contributes to the development of students’ ability of applying mathematics and practical problem solving [9].

With STEM-oriented approach, teaching is emphasized on students’ experience learning, integrated learning, interdisciplinary learning and problem-based learning. A number of studies show that STEM-oriented learning method based on discovery and product-oriented learning. This method has great potential to promote students’ love of mathematics. Moreover, enhancing STEM education is a way to motivate young people to be more interested in science, engineering, technology and mathematics.

3.2 What is teaching STEM-oriented mathematics?

Many research have shown the significance of integrated teaching of mathematics and science subjects, models of integrated mathematics and science subjects, STEM education concepts, STEM educational principles and processes, STEM-oriented mathematics teaching, etc [7-8]. In this study, we defined as follows: “Teaching STEM-oriented mathematics is a teaching strategy that integrated with STEM subjects in the context of education. Students can apply the combined knowledge and skills of those subjects to effectively solve problems that arising in these subjects or in real life”.

We have determined some features of STEM-oriented mathematics teaching like: Teaching objectives are often described in detail, clearly observable and assessable, with a focus on STEM educational goals; Students consolidate and expand their knowledge and skills in the areas of science, technology, engineering and mathematics; Students would be better understand the instrumental role of mathematics in other and practical subjects; Teaching is based on activities and students’ products; Teaching ideas integrate interdisciplinary and applied orientation to solve practical problems; Assessment in STEM-oriented teaching focus on formative assessment and product evaluation.

3.3 The potential of teaching STEM-oriented mathematics in Vietnam

In order to investigate the potential of STEM-oriented mathematics teaching, we conducted a small survey of 67 high school mathematics teachers representing the downtown areas and suburbs cities, rural and mountainous areas with questionnaires and semi-structured interviews. Through the survey, we found that 74.5% of teachers agree or strongly agree with the concept of STEM in the third interpretation. As such, most teachers have understood STEM education as our concept.

Regarding the meaning of teaching STEM-oriented mathematics, the results are shown as follows:

| Role of STEM education | Completely disagree | Disagree | Agree | Completely agree |
|------------------------|---------------------|----------|-------|-----------------|
| Students understand the instrumental role of mathematics | - | 3.6% | 78.2% | 18.2% |
| Engage students in STEM education | - | 5% | 60% | 34.5% |
| Forming and developing capacity and quality for students | - | 1.8% | 74.5% | 23.6% |
| Students understand the application of STEM knowledge and skills to solving practical problems | 1.8% | - | 70.9% | 27.3% |
| Connecting schools with the community | - | 20% | 60% | 20% |
| Career guidance, student diversion | - | 14.5% | 58.2% | 27.3% |

Table 1 shows that most teachers are aware of the significance of teaching STEM-oriented mathematics with 70.6% of teacher said that it is very necessary to teach STEM-oriented mathematics.
Therefore, the teachers’ initial understanding of STEM education, the meaning and necessity of teaching STEM-oriented mathematics is a favorable condition for deploying STEM-oriented mathematics teaching at schools. Furthermore, we have asked about the factors affecting STEM-oriented mathematics teaching, the results are shown as follows:

| Factors                                                                 | Completely disagree | Disagree | Agree  | Completely agree |
|------------------------------------------------------------------------|---------------------|----------|--------|------------------|
| The school’s interest in the fields of science, technology, engineering, mathematics and informatics | -                   | 10.7%    | 67.3%  | 18.4%            |
| Perceptions about the role of STEM education and STEM education in teaching mathematics of administrators and teachers | -                   | 3.6%     | 81.8%  | 15.1%            |
| STEM-oriented mathematics teaching competence of teachers              | -                   | 3.1%     | 66.4%  | 29.4%            |
| Facilities for STEM educational activities                             | -                   | 22%      | 50.5%  | 19.0%            |
| Basic mathematical knowledge of students                               | -                   | 9.1%     | 80%    | 10.3%            |
| Knowledge of STEM subjects: physics, chemistry, biology, geography, informatics, engineering, technology, etc | -                   | 9.0%     | 65.3%  | 15.1%            |
| Existing STEM skills of students                                       | -                   | 20%      | 55.3%  | 14.2%            |

Table 2 has shown that the majority of teachers agreed with the factors affecting STEM-oriented mathematics teaching as mentioned above, especially the teachers appreciated the influence of school interest and awareness of STEM education teachers, STEM-oriented mathematics teachers, students’ basic mathematical knowledge, STEM facilities and students mathematical skills. When interviewing further, the teachers said that the students’ existing STEM facilities and skills are important and not the deciding factor. Teachers and students can take advantage of used materials (paper cans, plastic bottles for drinking water, beverage cans, etc.) to design STEM graphics. Students’ STEM skills could be gradually developed through the lessons.

Regarding teachers’ experience in teaching STEM-oriented mathematics, 88.3% of teachers have never / infrequently, 7.6% of teachers are regular / very regular. This shows that STEM-oriented mathematics teaching has not really been paid attention to by schools and teachers. To find out the reason, we conducted in-depth interviews with teachers, teachers said that the main reason was due to the pressure on the amount of knowledge of a lesson, the ability to design mathematics lessons according to the plan. STEM education orientation of teachers is limited, the school has not encouraged teachers to teach that direction. Learn more about the conditions of schools serving STEM education, we obtained the results in the following table:

| Factors                                                                 | Very bad | Not good | Good  | Very good |
|------------------------------------------------------------------------|----------|----------|-------|-----------|
| Computer room                                                          | -        | 50.9%    | 41.6% | 4.5%      |
| Internet                                                               | -        | 18.2%    | 70.1% | 7.3%      |
| 3D printer                                                             | 43.6%    | 30.3%    | 5.9%  | -         |
| STEM practice room                                                     | 40%      | 50.2%    | 4.0%  | -         |
| STEM team / group                                                      | 39.1%    | 43.6%    | 13.6% | -         |
| Organize annual science and technology competitions                    | -        | 38%      | 50.4% | 9.1%      |
| School policy for STEM education                                       | 14.8%    | 55.5%    | 12.7% | 1.8%      |
Thus, the conditions of the schools about the internet, the organization of science and technology examinations are good, the conditions for equipment, human resources, and policies to encourage STEM education are still limited. In the program of mathematics in general education curriculum 2018 in Vietnam, there have been many changes in the goals, content, organizational structure of teaching, assessment and evaluation, especially the content of STEM education has been introduced in mathematics program from primary to high school. Understanding the feasibility of implementing STEM-oriented mathematics teaching in the general education program 2018, the results showed that 65.6% of teachers thought it was appropriate / very appropriate, 32.1% of teachers gave that does not fit / is less suitable.

Thus, through the survey, we found that the organization of teaching STEM-oriented mathematics in the new general education program 2018 is entirely possible. Schools need to have policies to develop and invest in STEM education in terms of facilities, training and capacity building for teachers. However, in the context of Vietnam, there are still many difficulties in facilities, the number of students is too crowded in the classes, the amount of knowledge is still large, teachers need to be supported to get STEM-oriented mathematics teaching forms suitable for high schools in Vietnam. Therefore, in this paper we propose the process of teaching mathematics in Vietnam with three levels of STEM integration.

3.4 Levels of STEM integration in teaching mathematics

In this study, we proposed the STEM-oriented mathematics teaching process consists of the following steps:

**Step 1: Design lesson plan**
Lesson objectives: Teachers need to identify lesson objectives, in addition to the goals of knowledge and skills mathematics need to clearly define the goal of developing STEM skills for students.
Identify appropriate mathematics, science, engineering and technology content that can be integrated into a lesson.
Design a chain of activities to achieve goals.

**Step 2: Implementation**
Teachers and students prepare materials and equipment for the lesson.
Teachers study the organization plan, application level of STEM learning activities to appropriate for students, the content of the lesson, teaching time, class size, class space, facilities, etc.

*Level 1: Proposal of STEM ideas*
Through learning activities, students discover STEM ideas, which means they can apply mathematical knowledge with one of the scientific and technological fields or techniques for proposing solutions to practical situations. Students propose blueprints and make models according to the ideas and proposed designs using salvaged materials at home. Then after class, students explain the models, teachers and other students evaluate and comment on the models.

*Level 2: Proposing the design for STEM ideas*
Through the learning activities, students discover STEM ideas, which can use their mathematical knowledge with one of the sciences, technology or techniques to propose solutions to practical situations, then propose designs for that STEM idea. Students make models with materials at home that take advantage of the ideas and designs proposed. Then, teachers explain the models, teachers and other students to evaluate and comment on the models.

*Level 3: Design of STEM models*
Through the learning activities, students discover STEM ideas, which means they can apply mathematical knowledge with one of the scientific, technological or technical knowledge to propose solutions to solve real-life situations, then propose designs for STEM ideas. Students use the materials used to model in class, teacher are demonstrating for models, teachers and students assessing and commenting on models.

**Step 3: Assess teaching and learning experiences**
At this stage, teachers after finishing teaching will compare the results of the lesson with the identified target to know the level of achieving the objective of the lesson. The causes of successful or
unsuccessful lessons should be identified. On that basis, teachers will draw experience for colleagues or individual teachers to learn from experience to make adjustments so that the following lessons are more effective.

In this study, we illustrate the teaching of “Cylinder Volume (Geometry 12)” in the STEM-oriented mathematics teaching as follows:

**Step 1: Design lesson plan**

+ Knowledge: Develop a formula to calculate the surrounding area, the total area, the volume of the prism and related knowledge; State the condition of an object’s equilibrium.

+ Skills: Assembling model of clothes-drying wardrobe upon request; Draw the spatial geometry of the model of clothes-dryer; apply mathematics knowledge to calculate and evaluate required quantities; Presentation on the model of drying oven, especially cases with different shapes and heat sources; Teamwork, complete academic tasks.

Identify the integrated contents:

+ Science (S): Applying the knowledge of the soleplate, the equilibrium conditions of the soleplate to determine the soleplate, determining the most stable drying model, the best heat, in accordance with user conditions.
+ Technology (T): The ability to use, manage, understand and access data sources, software supporting the design of models, measurement and calculation on models.
+ Technique (E): Read the instructions for assembling the model of the oven, assemble the model of the oven from available materials, draw the spatial geometry of the model of the oven.
+ Mathematics (M): Applying knowledge of spatial geometry to determine the parameters of the oven model in many different cases. Applying mathematical knowledge such as inequality, functions to evaluate the parameter values.

Construction activities:

**Activity 1: Identify a problem or practical need**

Students propose ideas from practical situations “Upland people in fog-covered areas do not have dry clothes to wear”. Students turn the practical problem into a mathematics exercise (modeled into a mathematics exercise): The volume of a rectangle will be the largest when the area of a rectangle has the largest cross-section. Set a goal to find the size of the rectangle so that it has the largest volume.

**Activity 2: Equipping mathematical knowledge and skills**

Component activity 1: Learning engagement

| Students’ activities | Teacher’s activities | Content |
|----------------------|----------------------|---------|
| Students: Observe, discuss and predict. | Teacher: Have students observe a quadrilateral prism model which is inscribed in cylindrical form. Then replace the prism with the base is octagon. | Activity 1: Identify a problem or practical need |
| - The height of the prisms is equal to the height of the cylinder. | Ask students to answer the question: | Question 1: Comment on the height of the cylinder and the height of the prism. |
| - When the area of the bottom increases from 4 sides to 8 sides, the area of the base of the prism gradually increases to the bottom area of the cylinder. | Question 2: Comment on the relationship between the bottom area of the prism and the bottom area of the cylinder when increasing the number of triangular bases of the prism. | Teacher: Comment on the relationship between the volume of the prism and the volume of the cylinder. |
| - As the number of base polygon edges increases from 4 to 8, the volume of the prism gradually | | |
increases to the volume of the cylinder.

| Component activity 2: Forming knowledge |
|------------------------------------------|
| **Students’ activities** | **Teacher’s activities** | **Content** |
| Student: Observe and notice that as \( n \) increases, the image of the prism is closer to the image of the cylinder. | Teacher: Let students predict the test through observation on the projection screen when the teacher uses the software to increase the number of edges of the bottom polygon, 6, 8, 30 respectively. | Volume of cylinders: \( V = Sh = \pi r^2 h \) |
| Student: Circle. | Teacher: What is the shape of the cylindrical bottom polygon? | where: |
| Student: Cylindrical volume. | Teacher: The volume of the prism will gradually come to the volume of which shape? | \( S \): bottom area. |
| Student: Discuss and give results. | Teacher: Based on the formula for calculating the volume of the prismatic cube, deduce the volume of the cylinder. | \( r \): is the radius of the base circle. |

Component activity 3: Consolidation

| Students’ activities | Teacher’s activities | Content |
|----------------------|----------------------|---------|
| Students: Thinking and answer. | Teacher: Calculate the volume of coca cans. | To determine the volume of a cylinder we need to determine the radius of the base and the height of the cylinder. |
| Students: Measure and apply formula to calculate cylinder | Teacher: Comment on the difference in actual volume of the can and the volume of the can compared to the difference in Students measure and calculate | |

To determine the volume of a cylinder we need to determine the radius of the base and the height of the cylinder.
Students: Discuss and speak according to their own understanding.

Teachers help students discover carbonated substances to make the difference more. This difference is due to the fact that milk and coca have different thermal expansion.

---

**Step 2: Implementation**

- Teachers and students prepare covers, tape, bamboo sticks to model the oven, teachers prepare projectors, students bring personal computers, measuring devices for lengths, angles.
- Teachers determine options and level of integrated applications:
  * Level 1: Proposal of STEM ideas
    + In class: Students come up with solutions to solve the problem of designing a rectangular, cylinder with the largest volume, using heat from wood, coal or electricity.
      Since the total area is constant (the area of the board), the problem is about finding the dimensions of the oven so that the volume of storage is the largest.
    + At home: Students propose a design (calculate the data to design a model of the oven based on the area of the board and the prepared materials, which can show the design with different heat sources, calculation software can be used) and make models according to proposed ideas and designs.
    + In class (after class): Teacher gives students to explain the models, teachers and other students evaluate and comment on the models.
  * Level 2: Proposing the design for STEM ideas
    + In class: Students come up with solutions to solve the problem of designing a rectangular, cylinder with the largest volume, using heat from wood, coal or electricity.
      Students propose a design (calculate data to design the oven model based on the area of the board and the prepared materials, which can show the design with heat sources). Different softwares may be used to support calculation.
    + At home: Students make models according to the proposed ideas and designs.
    + In class (after class): Teacher for students to explain the models, teachers and other students to evaluate and comment on the models.
  * Level 3: Design of STEM models
    + In class: Students come up with solutions to solve the problem of designing a rectangular, cylinder with the largest volume, using heat from wood, coal or electricity.
      Students propose a design (calculate data to design the oven model based on the area of the board and the prepared materials, which can show the design with heat sources). Different softwares that can be used to calculate and make models according to proposed ideas and designs.
      Students use the materials used to model in class and demonstrate for models, teachers and students evaluate and comment on the models.
    + At home: Students improve the model based on suggestions of the teachers and students.

**Step 3: Assess teaching and learning experiences**

Teaching STEM-oriented mathematics is essentially understood through teaching mathematics to train students with STEM skills. These knowledge and skills must be integrated and complementary in a lesson, helping students not only deeply understand the knowledge and skills of STEM subjects, but also be able to practice and create products for students’ daily life. STEM education will close the gap between academia and reality, building highly creative environment for students to develop problem solving competence. Depending on the specific teaching context of high schools in Vietnam, teachers can be creative in applying the process and applying STEM integration levels in teaching mathematics to not only increase the mathematics passion for students through which they develop other mathematical competencies.
4. Conclusion

STEM-oriented mathematics teaching approach in high schools would still meet many difficulties in facilities, teachers’ STEM skills and students’ life experiences. Vietnam has changed general education curriculum that meet the requirements of radical and comprehensive education renovation where STEM education is one of the new thing. For that reason, Ministry of Education and Training has encouraged high schools to develop their own curriculum that integrated STEM activities or STEM lessons in the classroom. Especially, it should be developed cooperative relationships between schools and inter-agency organizations regarding STEM education. The results of the research have shown that Vietnam should invest in facilities to build subject-oriented classrooms STEM as well as fostering the capacity of STEM education for teachers. Finally, it should be integrated STEM curriculum in pre-service teacher training programs and in-service professional continuous development programs so that we could prepare for implementing STEM curriculum in high schools at all levels.

References

[1] Gil Taran (2016), STEM education in general education programs of some countries and apply to conditions of Vietnam, Carnegie Mellon University, USA.
[2] Gillian H. Roehrig (2017), Teacher Conceptions of Integrated STEM Education and How They Are Reflected in Integrated STEM Curriculum Writing and Classroom Implementation, Elizabeth A. Ring.
[3] JeongSuk Pang and Ron Good, A Review of the Integration of Science and Mathematics: Implications for Further Research, School Science and Mathematics, Volume 100(2), February 2000.
[4] Nguyen Thanh Nga (2017), Design and organize STEM educational themes for middle and high school students, Ho Chi Minh City Pedagogical University Publishing House
[5] N Milaturrahmah et al (2017), J. Phys.: Conf. Ser. 895 012030, Mathematics Learning Process with Science, Technology, Engineering, Mathematics (STEM) Approach in Indonesia.
[6] Nguyen Thanh Hai (2019), STEM/STEAM education: From practical experiences to creative thinking, Tre Publishing House.
[7] Nguyen Thanh Nga, Phung Viet Hai, Nguyen Quang Linh, Hoang Phuoc Muoi (2017), Design and organize STEM education topics for middle and high school students, Ho Chi Minh City University of Education Publishing House
[8] Nguyen Thanh Nga, Hoang Phuoc Muoi, Phung Viet Hai, Nguyen Quang Linh, Nguyen Anh Dung, Ngo Trong Tue, (2017), Teaching STEM topics for middle and high school students, Ho Chi Minh City University of Education Publishing House
[9] Le Xuan Quang, Le Huy Hoang, Vu Dinh Chuan, Nguyen Hoai Nam, Nguyen Thi Tu Anh, Vu Thi Hong Nhung (2015), Integrated science, technology, engineering and mathematics (STEM) education through active experience of designing technical toys in the Vietnam schools, British Journal of Education, Society and Behavioural Science, 11(2).
[10] Capraro R. M., Capraro M. M., and Morgan J. R. (2013), STEM project-based learning: An integrated science, technology, engineering, and mathematics (STEM) approach, Springer Science & Business Media.
[11] Oztelli D., Corlu M., Corlu M., and Capraro R. (2014), Introducing STEM education: Implications for educating our teachers in the age of innovation, Education and Science, 39(171), pp.74-85.
[12] Sutaphan, S. Yuenyong, C. 2019. STEM Education Teaching approach: Inquiry from the Context Based. Journal of Physics: Conference Series, 1340 (1), 012003
[13] Chompuphra P, Chaipidech P, Yuenyong C 2019. Trends and Research Issues of STEM Education: A Review of Academic Publications from 2007 to 2017. Journal of Physics: Conference Series, 1340 (1), 012069