



11<sup>th</sup> International Academic Conference

"Global Goals, Local Actions: Looking Back and Moving Forward 2020"

---

## A Study of Integrated Vectors into STEM Learning

Chalongrat Khaoloeak, Supotch Chaiyasung

Mathematics Education Program, International College, Suan Sunandha Rajabhat University

Correspondence: Chalongsrat Khaoloeak, E-mail: Chalongsrat.k@ku.th

### Abstract

This study aimed to analyze 'Vector' topic in high school mathematics suitable strategies to engage students learn mathematics by integrating into Science, Technology, Engineering, and Mathematics (STEM). The type of study was synthesis research using information from website resources and related materials. The results of the study found that the applications of vector in mathematics were used in four themes of STEM learning: (1) Definition of vector involves magnitude and direction, (2) Addition and subtraction of vector involves algebraic and geometric calculation, (3) Multiplication of vector or dot vector involves algebraic, geometric, and trigonometric calculation, and (4) Activities for engagement in STEM learning. In addition, the teachers can apply student-centered approach such as experiment in small group, problem-based learning, discussion and others to help students make this connection to achieve in their aims on a regular basis and wants more mathematics in learning science, technology, and engineering.

**Keywords:** vector, STEM

### Introduction

The Institute for the Promotion of Teaching Science and Technology (IPST) has promoted a new method of teaching science, technology, engineering and mathematics to foster students for the 21<sup>st</sup> century by emphasizing knowledge and skills which are suitable to real life and careers. Mathematics is a necessary subject to learn and highly important to develop students to acquire skills in creativity, logic and systematic thinking for planning, making decision, and solve problems accurately and appropriately. Moreover, mathematics



11<sup>th</sup> International Academic Conference

"Global Goals, Local Actions: Looking Back and Moving Forward 2020"

---

serves as a tool for learning science, technology and other disciplines (Ministry of Education, 2008, p. 64).

Today, in Thailand, the topic 'Vectors' in mathematics occupy one topic of the Additional Mathematics Curriculum for grade 11 students. This topic can be taught by using STEM approach which prepares students' background knowledge for further study in science, technology, engineering and mathematics at college or university level.

### **Purpose of the study**

To analyze 'Vector' topic in high school mathematics suitable strategies to engage students learn mathematics by integrating into Science, Technology, Engineering, and Mathematics (STEM).

### **Research Scope**

#### *Sample*

The sample of website and materials related to high school mathematics curriculum in basic education and higher education.

#### *Contents*

The contents related to 'Vector' topic required in the Basic Education Core Curriculum B.E. 2551 (A.D. 2008), Revised B.E. 2560 (A.D. 2017).

### **Methodology**

This paper discusses literature review as a methodology for conducting research and demonstrate an overview of different types of reviews to be some guidelines to how to integrate 'Vector' topic of mathematics into STEM learning.

### **Findings**

According to the 'Vector' topic in the Additional Mathematics Curriculum for grade 11 students, the learning outcomes of this topic are listed in the following (IPST, 2018, p. 134):

1. To define the concept of 'Vector';



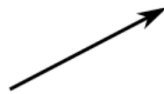
2. To find the vector addition, subtraction, and scalar multiplication;
3. To multiply a vector by a scalar;
4. To multiply a vector by a vector (dot product and cross product).

All of learning outcomes are important for setting up the framework of literature reviews to meet the purpose of this study. The finding was categorized into four themes of STEM learning: (1) Definition of vector involves magnitude and direction, (2) Addition and subtraction of vectors involve algebraic and geometric calculation, (3) Multiplication of vectors or dot vectors involves algebraic, geometric, and trigonometric calculation, and (4) Activities for engagement in STEM learning.

### 1. Definition of vector

#### 1.1 Concepts in Mathematics

A vector has **magnitude** (size) and **direction**.



The **length** of the line shows the magnitude and the **arrow head point** shows the direction.

#### Notation of vector

- 1) The start point is A and the end point is B, the notation of vector is  $\overrightarrow{AB}$  ; or
- 2) Do not indicate start point and end point, the notation of vector is one letter such as  $\vec{u}$  ,  $\vec{v}$  .

#### 1.2 Integrated in STEM

The ideas for integrating the STEM concepts across curricular areas in primary and secondary levels enables the learners to acquire essential skills for systematic problematic problem-solving with scientific knowledge and understanding of nature and man-made technologies that can be applied through critical and creative approaches.

For this article, the specific topic focuses on ‘Vectors’ as stated in the Basic Education Core Curriculum for high school listed the examples in the following.



- Forces and Motion: the nature of electromagnetic, gravitational and nuclear forces; forces acting on objects; motion of objects; frictional forces; moment of motions in daily life (Ministry of Education, 2008, p. 105).

- The motion of an object is the change in the position of an object relative to the reference position with the amount related to movement both **quantity scalar and vector quantities** such as distance, speed, and displacement. Scalar quantity, is a quantity that has dimensions such as distance, speed. Vector quantities are quantities that are both magnitudes / sizes and directions (Ministry of Education, 2017, p. 64).

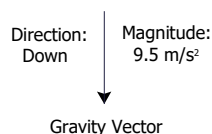
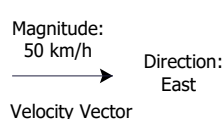
- Draw **diagrams represent vector quantities** with arrows where the arrow length shows the magnitude / size and arrowhead show the direction of that vector (Ministry of Education, 2017, p. 64).

- Force is a vector quantity with both size and direction. In the case of multiple forces acting on an object, find the net force acting on an object using the method of writing tail-to-head vector force parallel to direction of force and **calculation with vector method** (Ministry of Education, 2017, p. 192).

However, in primary level acquires the learner to have the basic knowledge science as shown in Standard Sc 2.2—‘Understand the nature of force in everyday life; Effect of exerted force acting on an object; various types of motion of objects, including the use of knowledge’ (Ministry of Education, 2017, p. 60). The suggestion for effective STEM learning environment the teachers must consider the previous experiences of the students (Glancy & Moore, 2013, p. 10) by preparing the questions for experimentation in small group such as ‘How do gravity and friction affect the balance of force?’, ‘How do mass and distance affect the gravitational pull of an object?’, ‘How are velocity and acceleration related to every life?’

### 1.3 Sample of representation with vectors

- 1) Velocity measures how fast an object is travelling and in which direction.
- 2) The gravitational force is a force that attracts any object with mass



## 2. Addition and subtraction of vectors

### 2.1 Concepts in Mathematics: Horizontal Direction

$$\begin{array}{c} \vec{u} \rightarrow \vec{v} \rightarrow \\ \vec{u} + \vec{v} \end{array}$$

(same direction)

$$\begin{array}{c} \vec{u} \leftarrow \vec{v} \leftarrow \\ \vec{u} - \vec{v} \end{array}$$

(opposite direction)

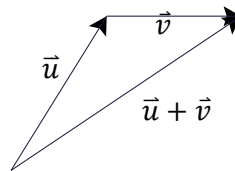
### 2.2 Integrated in STEM: Horizontal Direction

Summations of two force vectors (N = Newton)

$$\begin{array}{c} 5 \text{ N} \rightarrow 3 \text{ N} \rightarrow \\ 5 \text{ N} + 3 \text{ N} = 8 \text{ N} \end{array}$$

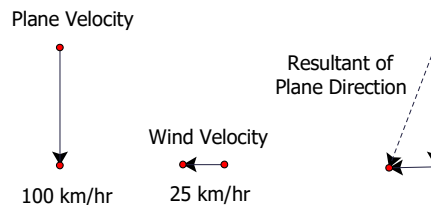
$$\begin{array}{c} 5 \text{ N} \leftarrow 3 \text{ N} \leftarrow \\ 5 \text{ N} - 3 \text{ N} = 2 \text{ N} \end{array}$$

### 2.3 Concepts in Mathematics: Complicated Direction (Head to Tail Method)



### 2.4 Integrated in STEM: Complicated Direction (Head to Tail Method)

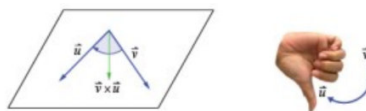
Flying Plane: Find the resultant of plane direction.



## 3. Multiplication of vector

### 3.1 Concepts in Mathematics:

1) Let  $\vec{u}$  and  $\vec{v}$  be two vectors, the product is a vector  $\vec{u} \times \vec{v}$ . The magnitude of  $\vec{u} \times \vec{v}$  is  $|\vec{u} \times \vec{v}| = |\vec{u}||\vec{v}|\sin\theta$ , where  $\theta$  is the angle between them (< 180 degree). The direction is given by the right-hand rule.

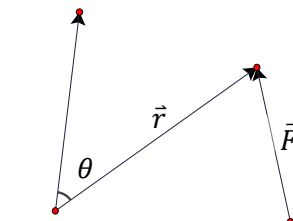


Source: IPST (2018, p. 136)

### 3.2 Integrated in STEM

Calculate the magnitude of the torque ( $\tau$ ).

$$\tau = |\vec{r}| |\vec{F}| \sin\theta$$



Point of rotation

$|\vec{F}|$  = Applied force

$|\vec{r}|$  = Radius from point of rotation to point of applied force

$|\vec{r}| \sin\theta$  = Lever arm

### 4. Activities for engagement in STEM learning

One of the key lessons learned from literature reviews is that supporting STEM learning means supporting the elective instruction actively engages students using a variety student-centered approach for entire school curriculum in science, technology, engineering and mathematics (NRC, 2011). In addition, all students must be a part of the STEM vision, and all teachers must be provided the students' opportunities practice toward acquiring STEM literacy (Kennedy & Odell, 2014).

As indicated earlier, the topic on 'Vector' in mathematics for grade 11 students is typically used as an integrated four separate discipline areas of Science, Technology, Engineering and Mathematics. The Promotion of Teaching Science and Technology (IPST) aligns STEM approach for primary level to high school levels. One way to think about STEM learning is to consider how much of science, technology, engineering and mathematics might be addressed in a particular activity. For example, a robotics activity might be emphasized on engineering and technology with amount of mathematics, but little attention to science. There are six steps for engineering design as the followings: (1) Problem Identification, (2) Related Information Search, (3) Solution Design, (4) Planning and Development, (5) Testing, Evaluation and Design Improvement, and (6) Presentation (STEM Education Thailand, 2014). For mathematics and science, the processes are categorized in the following skills:



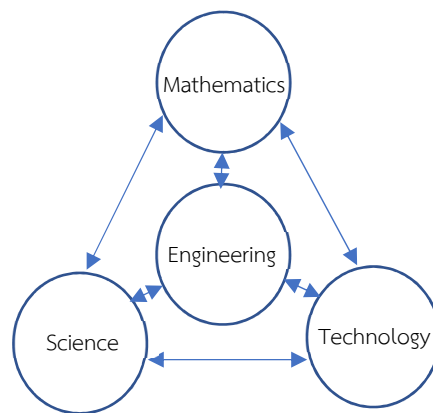
11<sup>th</sup> International Academic Conference

"Global Goals, Local Actions: Looking Back and Moving Forward 2020"

*Mathematical skills* - Problem Solving, Connection, Reasoning and Proof, Communication and Representation;

*Basic science skills* – Observation, Classification, Measurement, Conclusion, Prediction and Communication.

Glancy and Moore (2013) conceptualized STEM thinking and STEM learning as shown in the following figure.



Source: STEM Translation Model (Glancy & Moore, 2013)

## Conclusion

STEM learning approach is an alternative strategy that mathematics teacher can apply in teaching mathematics, especially the topic ‘Vector’ in the Additional Mathematics for grade 11 students. By definition, the vector has magnitude and direction, which is related to topics in science and engineering such as velocity, force, gravity, etc. For the vector operations (addition, subtraction and multiplication), can be applied in science, engineering and technology in order to find the resultants of two or more forces that attract any objects. Within the concept of STEM learning, to teach mathematics in ways that emphasize the relevance of disciplines and engage students’ thinking, reasoning and problem-solving skills can help the students in developing mathematical processes and skills (NTCM, 2014).



11<sup>th</sup> International Academic Conference

"Global Goals, Local Actions: Looking Back and Moving Forward 2020"

---

## References

- Glancy, A.W. & Moore, T.J. (2013). Theoretical Foundations for Effective STEM Learning Environments". *School of Engineering Education Working Papers*. Indiana: Purdue University Press.
- Kennedy, T.J. & Odell, M.R.L. (2014). Engaging Students In STEM Education. *Science Education International*, 25(3), 246-258.
- Ministry of Education. (2008). *The Basic Education Core Curriculum B.E. 2551 (A.D. 2008) Revised B.E. 2560 (A.D. 2017)*. Bangkok: The Agricultural Co-operative Federation of Thailand, Ltd..
- National Council of Teachers of Mathematics [NCTM]. (2014). *Building STEM Education on a Sound Mathematical Foundation*. Retrieved Dec. 10, 2019, from <https://www.nctm.org/Standards-and-Positions/Position-Statements/Building-STEM-Education-on-a-Sound-Mathematical-Foundat>  
<http://www.icasonline.net/sei/september2014/p1.pdfion/>.
- National Research Council. (2011). *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics*. Washington, DC: The National Academies Press.
- National Academy of Engineering & National Research Council. (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*, M. Honey, G. Pearson, & H. Schweingruber (Eds.). Washington, DC: National Academies Press.
- Schwartz, M. (2019). *Using bar models in Singapore math*. Retrieved Nov. 15, 2019, from <https://teacher-blog.education.com/using-bar-models-in-singapore-math-fe7fbfa4a174>.
- STEM Education Thailand. (2014). *Stem education and engineering design*. Retrieved Dec. 21, 2019, from <http://www.stemedthailand.org/?knowstem>.
- The Institute for Teaching Science and Technology [IPST]. (2008). *The Basic Education Core Curriculum B.E. 2551 (A.D. 2008) Mathematics*. Bangkok: IPST.