Design Steps for Physic STEM Education Learning in Secondary School

C. Teevasuthonsakul\textsuperscript{1,*}, V Yuvanatheeme\textsuperscript{2}, V Sripit\textsuperscript{2}, S Suwandecha\textsuperscript{2}

\textsuperscript{1}Assistant professor, Burapha University Chanthaburi Campus, Thailand
\textsuperscript{2}Instructor, Burapha University Chanthaburi Campus, Thailand
\textsuperscript{*}E-mail: chai1962@yahoo.com

Abstract. This study aimed to develop the process of STEM Education activity design used in Physics subjects in the Thai secondary schools. The researchers have conducted the study by reviewing the literature and related works, interviewing Physics experts, designing and revising the process accordingly, and experimenting the designed process in actual classrooms. This brought about the five-step process of STEM Education activity design which Physics teachers applied to their actual teaching context. The results from the after-class evaluation revealed that the students’ satisfaction level toward Physics subject and critical thinking skill was found higher statistically significant at $p < .05$. Moreover, teachers were advised to integrate the principles of science, mathematics, technology, and engineering design process as the foundation when creating case study of problems and solutions.

1. Introduction
The Program for International Student Assessment in 2015 showed that Thai students have been underperforming their peers from several Asian countries as their scores were below the international average for years.[1] Since then, STEM Education has been integrated into learning activities to enhance the quality of teaching and learning system in Basic Education Level.[2] However, each individual school has its own context which obstructed the application of STEM Education, so the activities should be well-designed to be congruent with each teaching and learning context. This study therefore focused on assisting teachers to design appropriate STEM activities to match with their own context. It is found that there have been a few research studies over this matter.

2. Objectives
The objectives of the study were to develop the process of STEM Education activities for Physics taught in the Thai secondary schools, to evaluate the quality of STEM Education activities which are created by the teachers and to investigate the level of satisfaction after the experiment. The students’ learning outcomes were also evaluated to compare their critical thinking skill and attitude toward Physics subject using pre-test and post-test assessment.

3. Research methodology
The researchers have conducted the study by reviewing the literature and related works and interviewing nine experts who specialized in Physics teaching and STEM Education. The process of STEM activity was then designed and revised by the experts. After that seven Physics teachers applied the suggested process and constructed their own teaching activities to their actual classrooms.
The activities used were then revised for quality again by the experts. Three Physics teachers were also asked to experiment such a process with small groups of 9-11 students over the weekends to avoid any external interference that may occur. One of the teachers constructed STEM Education activity and applied to his actual class of 37 students during the week. Students’ critical thinking skill, [3] their attitude toward Physics and satisfaction toward the activities used were eventually evaluated.

4. Result

4.1. The process of STEM education activity design in Physics subject

The results showed that in the situation where Thai teachers always have a large number of heavy workloads, STEM Education activities designed should be based on problem-based situations with conditions and limitations provided. These would enable students to apply their scientific, mathematics and technological knowledge with their own experience and creativity on the basis of engineering design process in order to get the most possible solutions. The problem-based situation can be applied to several classes at one time and the students would not be able to copy their work. In the meanwhile, the teachers’ preparation task would be decreased and they would consequently gain more expertise over the subject.

The process of Physics STEM Education design was as follows:

Step 1: Study the concept, definition and objectives of STEM Education. The objectives and concept should be emphasized to motivate the students to learn and realize the importance of science, mathematics and technology.

Step 2: Study the engineering process design as well as its application to STEM Education. [4,5]

Step 3: Investigate the characteristics of STEM Education activity as well as various examples of Physics STEM Education activity.

Step 4: Design the STEM Education activity as follows:

Step 4.1: “Project”, which was an assignment based on problem-based situation with conditions and limitations provided. It should also be based on real-life situation which was suitable for all ranges of students’ ages and consumed the appropriate period of time. This project has to be challenging and competitive enough. It should not be solved by using only students’ own experience or their trial-and-error skills. Take “Bungee Jumping” design as an example. The situation was the students had to design their own “Bungee Jumping” with one rope from any materials with the condition that when the \( m_M \) kilogram of sand bag (a substitute for a human body) was released at the height of \( H \) meters, the lowest falling level of sand bag had to be at \( x \) centimetres above the ground.

Step 4.2: The objectives of the STEM activity should be clearly identified. Those objectives should emphasize on motivating the students to learn and increasing their awareness to the knowledge of science, mathematics and technology.

Step 4.3: A set of related knowledge, which the students would use to solve the problem, should be well-provided and integrate the principles of science, mathematics and technology. The level of difficulty should be suitable for students’ learning potential. The unnecessarily-complicated situation could cause negative attitude toward STEM Education. In case that the students failed to integrate the related knowledge to solve the problem themselves, the teacher had to provide them. This was due to the fact that the Basic Education Level curriculum sharply separated each discipline into different subjects. If such knowledge could come into mathematics equation with appropriate difficulty level, it would assist in applying the engineering process design in the following step. However, the teachers should bear in mind that there could be other principles used to explain the problem or to generate the solution, hence
they should be open-minded to other alternatives. Then the teacher may have to select the appropriate
learning strategy for the students, either teacher’s explanation or students’ self-study under the teacher’s
supervision. For example: “Bungee Jumping” design with one rope in figure 1, the students had to
apply the following information: the high point jump \((H)\), rope length \((l)\), weight of rope \((m_l)\), stretched
constant \((k)\), jumper’s height \((y)\), jumper’s weight \((m_M)\), long rope stretched \((d)\), Physics knowledge(S)
and Mathematics Knowledge (M) to form an equation 1. Furthermore, technological knowledge (T)
and Computer skills can be applied to calculate long rope stretched value \((d)\) and other values in order
to calculate the accuracy of the design.

\[
(m_y + m_M)gh = \left(\frac{1}{2}kd^2\right) + m_l g \left(h - \left(\frac{d}{2}\right)\right) + m_M g \left(h - \left(l + d + \frac{y}{2}\right)\right)
\]  

(1)

Step 4.4: Other key factors that could affect the solution based on individual knowledge, experience and
ing engineering sense were analysed. In this “Bungee Jumping” project design, the important factors
included rope length \((l)\), weight of rope \((m_l)\), stretched constant \((k)\), long rope stretched \((d)\), jumper’s
weight \((m_M)\), jumper’s height \((y)\), rope material, rope toughness etc. The relationship between these
factors was also analysed. This could be direct impacts (positive-positive or negative-negative) and
contrastive impact (positive-negative). The researcher, then, illustrated the diagram explaining the logic
of cause and effect among the factors by pointing the arrow from the cause factor to the affected factors
(Causal Diagram). [4,5] In this case, each cause factor might impact on several affected factors as can
be seen from the “Bungee Jumping” Figure 2.

Figure 1. Bungee Jump design with one rope.

![Figure 1](image1.png)

Figure 2. Diagram of Impact Factors of Bungee Jumping Design.

Step 4.5: The possible design methods had to be analysed. (There should be a variety.) Each design
method has its own advantages and disadvantages in terms of level of difficulty. The teacher had to look
into the design method whether it maintained the limitations and conditions given or not. For instance,
the design method for “Bungee Jumping” started from finding material of the rope, Rope toughness, and
rope length before jump \((l)\) which was tough and safe for the jumper \(\rightarrow\) calculating the stretched constant
\((k)\) \(\rightarrow\) measuring the height of the jumping point from the ground \((H)\) \(\rightarrow\) getting information of jumper’s
height ($y$) and weight ($m_M$) → getting possible result of the length of the rope ($d$) computed by the computer → calculating the lowest falling point above the ground ($H - (l + d + y)$) → calculating repetitive length of the rope ($l$) that allowed the lowest falling point at x centimetres above the ground.

**Step 4.6:** The teacher, then, had to analyse the appropriate method for the students as suggested from step 4.3 - step 4.5 either teacher’s explanation or students’ self-study under the teacher’s supervision. The selected method had to be suitable with the student’s learning potential to avoid complication or boredom.

**Step 4.7:** The teacher gathered the information from step 1 to 4 and designed the lesson plan considering the students’ capability and the appropriateness with the teaching and learning context at a certain time.

**Step 5:** This activity might be revised by the experts and then tried out in the actual classroom. Meanwhile, the teacher evaluated the outcome from the students, improved such activity and experimented again. After repeated evaluation and improvement, this activity would be improved while the teacher got acquainted and gained more experience. By repeating the activities, the preparation time would be shortened and the teacher could perform better teaching.

**4.2 Result from the Effectiveness Evaluation of STEM Education Design**

All the experts agreed that the STEM Education activity designed by the seven Physics teachers were well-qualified and congruent to the concept of STEM Education. They would be more qualified if they were able to get some advice from engineering or innovation experts. The students’ satisfaction level toward Physics subject and critical thinking skill was found higher statistically significant at $p < .05$. The student’s satisfaction level toward the activity used was at a “good” level. ($\bar{x} = 4.24; sd. = 0.47$)

**5. Conclusion**

This research study not only proposed the process of STEM Education activity design in Physics subject that can be applied to match with any learning context, but it also found that some of the teachers lack of knowledge and experience of applying STEM Education as well as integrating the principles of science, mathematics and technology to generate problem-solving situation that match with their own teaching and learning context. Some of the teachers failed to understand the engineering design process which obstructed the development of STEM Education in Thailand.

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