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Developing Critical Thinking Skills of Grade 11 Students by STEM Education: A Focus on Electrostatic in Physics

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Abstract
This action research aimed to develop critical thinking skills of secondary school students by STEM Education in Physics using the topic of *electrostatic*. The subjects were 47 Grade 11 students in a large-sized secondary school in Pathum Thani, Thailand in Semester 2, Academic Year 2016. Three types of research instruments were (1) experimental tools: five STEM Education lesson plans on electrostatic; (2) reflective tools: student learning behavior observation form, teaching behavior observation form and field record form; and (3) evaluation tools: worksheets. The research was divided into three phases. The first phase focused on construction of STEM Education lesson plans and worksheets to develop critical thinking skills and validation of the constructed lesson plans and worksheets. The second phase tried the constructed lesson plans and worksheets with the subjects under study. The third phase evaluated the subjects' critical thinking skills from the reflective data. The qualitative results from reflective data showed that 38 students (81%) performed well, while 9 students (19%) did not. In terms of students' critical thinking skills development detected by the researchers and the teacher mentor, the averaged increase of critical thinking skills development was 49 percent, and the averaged decrease was 44 percent.

Keywords: *Critical thinking skills, STEM Education, Physics teaching, secondary school students*

1. Introduction

Thinking is a human's high potential of brain activity. It distinguishes humans from other animals. A person with high thinking skills solves problems quickly and develops himself or herself continually. An intelligent thinker is always praised by others and becomes a leader in an organization. Therefore, educational development has placed great emphasis on thinking skills development. As known, there are various factors that determine thinking skills in learning, and thinking is categorized into many forms (Khammani, 2011). In this article, thinking is presented in two categorizes; basic and advanced thinking. Basic thinking encompasses observation, survey, categorization, comparison, grouping, connecting, sequencing, reasoning, and summarizing. Advanced thinking covers critical thinking, problem solving and creative thinking (Sakon Nakhon Rajabhat University, 2006). In today's world, people access large amount of information rapidly. They therefore need advanced thinking skills to categorize information as true and untrue for work or decision-making.

Phonchaiya (2014:7) relevantly put it: “organizing learning activities through STEM Education helps learners to develop problem-solving skills, creative thinking skills and critical thinking skill.”

Nowadays, STEM Education is a concept widely applied in Thai Education. STEM Education stands for Science, Technology, Engineering, and Mathematics; it integrates teaching and learning by using knowledge in science, technology, engineering, mathematics as a core, and focusing on systematic problem solving that enables learners to utilize knowledge for daily life and careers. The engineering process is the same process as technological process developed by Thailand’s Institute for Promotion of Teaching Science and Technology (IPST). The process consists of seven steps: (1) Identifying the problem, (2) Information gathering, (3) Selection, (4) Design and making, (5) Testing, (6) Modification and improvement, and (7) Assessment. *As mentioned above, the researchers were interested in developing students’ critical thinking skills through STEM Education so that they can apply these skills in their daily life.*

2. Research Methodology

This research aimed to develop critical thinking skills of secondary school students by STEM Education in Physics using the topic of *electrostatic*. The research methodology was described below:

2.1 Research Design

The design was of an action research applying the concept of Kemmis and McTaggart (2000) comprising four steps: Planning, Action, Observing and Reflecting.

2.2 The Subjects

The subjects were 47 grade 11 students in the Science-Math Program selected by the school mentors to participate in the study as a pilot project. They were studying Physics on the topic of *electrostatic* in Semester 2, Academic Year 2016.

2.3 Research Instruments

There were three types of research instruments.

2.3.1 Experimental tools were five STEM Education lesson plans on electrostatic, covering 15 fifty-minute periods. These five STEM Education lesson plans on electrostatic carried the following components in implementation:

1. Introduction
    1.1 The teacher presented a video about teaching and learning.
    1.2 Students grouped themselves and received worksheets.
2. Teaching and learning
    2.1 The teacher taught S-Science so that students gained knowledge to solve problems in the provided worksheets.
    2.2 Each lesson/worksheet content covered calculation relating to M-Mathematics. Students did additional calculation exercises.

2.3 Interactive animation and T-Technology were utilized to facilitate students' understanding. The teacher also provided free online simulation for students who were interested.

2.4 In the provided worksheets, the teacher set simulation situations with questions for students to practice. The questions were related to E-Engineering, which emphasized technological processing prescribed by Thailand's Institute for the Promotion of Teaching Science and Technology (IPST).

2.5 The teacher applied critical thinking assessment criteria to assess students.

2.3.2 Reflective tools were in three:

- Learning behavior form
- Teaching behavior form
- Field record form

2.3.3 Evaluation forms were in five:

- Worksheet 1 "Coulomb Ship"
- Worksheet 2 "Art of Electric Field"
- Worksheet 3 "Illuminated by the Nature"
- Worksheet 4 "DIY Capacitor Challenge"
- Worksheet 5 "Electrostatic Applied"

3. Data Collection

The researchers collected data by using five STEM Education lesson plans with 47 students. The steps of data collection were as follows:

1. The researchers studied background of the school and the students.

2. The researchers gave descriptions of roles, responsibilities, learning objectives and STEM Education learning activities to students.

3. The researchers as the teacher taught the students with five STEM Education lesson plans for 15 periods, 50 minutes each. Details are shown in Table 1.

Table 1: Data Collection for Five STEM Education Lesson Plans

No.	Topic	Time (periods)
1	Subtopic 1: Coulomb's Law	3
2	Subtopic 2: Electric Field and Electric Poles	3
3	Subtopic 3 : Electric Potential and Electric Potential Differences	3
4	Subtopic4 : Capacitors and Capacitances (1) - Capacitances - Dielectric constant	3

5	Subtopic5 : Capacitors and Capacitances (2) - Capacitor connections - Power of capacitors - Electrostatic application	3

4. The first researcher as the teacher collected data from all lesson plans and reflected upon her actions through reflective tools including student learning behavior evaluation form, teaching behavior evaluation form and field record form.

5 . After teaching all lesson plans, the first researcher as the teacher collected all evaluation forms and worksheets for data analysis and summary, followed by data interpretation.

4. Data Analysis

The researchers and a teacher mentor collected data from the records of each lesson plan, student learning behavior evaluation form, teaching behavior form and worksheets to evaluate suitability of STEM Education for the group under study. Content analysis of qualitative data showed the results in brief descriptions of exemplified responses or comments. All obtained qualitative and reflective data were analyzed by the researchers and the teacher mentor to detect whether the target group developed critical thinking skills after being taught by STEM Education.

5. Results

Development of critical thinking skills of the students under study was detected by the researchers and the teacher mentor from the qualitative and reflective data, and shown by slopes of individual graphs. Of 47 students, there were 38 students (81%) whose development increased. The average increase of development was 49 percent. There were 9 students (19%) whose development decreased. The averaged decrease of development was 44 percent.

6. Discussion

The results indicated that STEM Education had a good potential to develop students' critical thinking skills. This finding was consistent with the previous work of Phonchaiya (2014) who asserted that organizing learning activities through STEM Education helped learners to develop problem-solving skills, creative thinking skills and critical thinking skill. Similarly, Jindanurak (2016) stated that STEM education did not only integrate four branches of knowledge, but also gave relevancy to activities in daily life. This definitely gave a meaningful learning experience to students for their interest and application to their daily lives. Moreover, STEM Education was to support a trend in developing the twenty-first-century skills that students were to take what they learned at school to the real world as their possible future work or career. In addition, Meyrick (2011) pinpointed that STEM education in teaching should provide for learners daily-educational experiences regardless of gender differences and gaps of success. Such application should enable learners to develop critical thinking skills comprehensively.

As for the results on the averaged decrease of development at 44 percent, the researchers observed that it could perhaps come from the students' mindset on the tests and their varied learning abilities. Some students were concerned that they had to take the tests and therefore did not pay much attention to the learning activities on critical thinking skills development. Besides, students with different learning abilities felt uncomfortable with group work and thus paid less attention to the given activities. It was possible that some students were not in favor of specific learning activities, due to individual learning preferences, as stated in Howard Gardner's multiple intelligences theory. Gardner explained that learners differ in their brain-based abilities to solve problems in single or multiple society; some are intelligent in one particular field but some are not (Gardner, 1983 cited in Jantarak, 2013). The researchers also noted time limitation as causing some students' decrease in critical thinking skills development in that some students might need more learning time to handle the activities effectively. This observation point was in accordance with the work of Sineharun (2012) who stated that learning process varied in time for learners to do, think and practice through printing or concrete media by themselves. The time factor basically determined how learners could process direct experience to reach actual practice, and how they could retain their long-term memory for self-learning creation and knowledge linkage.

7. Conclusion

The study explored how teachers could help develop critical thinking skills in secondary students via STEM education with the use of *electrostatic* as a physics topic. The researchers described the constructed lesson plans in STEM education to integrate learning tasks that prompted critical thinking skills in learners. The researchers emphasized that situations should be created relevantly to the students' interest and challenge their thinking individually as well as in groups. The created situations should inspire students to do follow up on their own outside the classroom and in their daily lives. The researchers also noted that STEM Education can be applied to science teaching in other branches like biology, chemistry, mathematics, product studies, and the like.

8. The Authors

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