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The Design Process of STEM Learning Activities for Problem-Solving on the PM 2.5 Mask: The Case of Primary School in Thailand

Suttikan LAKANUKAN[a], Jirapipat THANYAPHONGPHAT[b*] & Wantana AREEPRAYOLKIJ[b]
[a]*Thawaranukul School, Thailand.*
[b]*College of Arts, Media and Technology, Chiang Mai University, Thailand.*
* jirapipat.than@cmu.ac.th

Abstract: The research purpose of this study is to explain how to develop the competence of problem-solving that integrates comprehensive knowledge and skills in science, mathematics, and technology. The actions were outlined, emphasizing engineering design and the learning process model in the class activities regarding the PM 2.5 protector mask. This study is based on self-study and reflective practices to classroom-based research; particularly, author investigated the subjects through the teaching records and the assessments of problem-solving test form participants. Qualitative data were analyzed by using inductive methods such as grouping, comparison, and conclusion. In this research, learning activities were schemed into six program plans. Each plan represented a step in the engineering design process; additionally, it carried out activities with an inquiry process. The results show that students can solve the problems well within tasks to create PM 2.5 dust masks. Step by step, the applicable practices with the engineering design process that converged existing knowledge and new knowledge, which consists of Science, Mathematics, and Technology Ability, yielded effective results. Significantly, the students, who progressively solved the problems in the class, showed high-potential development of good cooperation and communication skills.

Keywords: STEM learning, inquiry-based learning, engineering design process, primary school.

1. Introduction

In the 21st century, STEM Education is an academic discipline that integrates education majoring in Science, Technology, Engineering, and Mathematics, focusing on learner preparation. With the great benefits of STEM, it fosters learners' development to apply knowledge in various fields. It boosts the capability to utilize tools to solve problems in the present and future worlds (Ostler, 2012). In this study primarily described engineers as problem solvers (Plan & Khandani, 2005). In the problem-based approach, the practical engineering design motivates students to be more curious and active to seek knowledge to eliminate doubts. Students are faced with realistic simulations of problems or situations; consequently, they work together to find alternative ways to solve problems. Learners develop meaningful learning by developing skills, processes, and essential knowledge for livelihood and lifetime learning. Students acquire skills from problem-solving methods and techniques, including observation, data collection, data analysis, interpretation, sequencing, reasoning, collaboration, knowledge summarization, etc. In addition, students develop learning behaviors from different aspects of thinking, which are knowledge, understanding, application, analysis, synthesis, and creativity (Bloom et al., 1956).

As teachers have agreed that STEM teaching is the proficient approach, it can be applied to develop cognitive experience, necessary skills, and most importantly, the appreciation and importance of the knowledge which is highly required in problem-solving. Therefore, researcher researched, designed, and improved learning management methods; especially, researcher employed STEM learning management with attempts to be an effective and up-to-date curriculum. Corresponding to the current situation, researcher brought PM 2.5 as a part of the problem set. In this study, the problem-solving process in the class was designed according to the steps of the engineering design process; then, it was tried and improved until researcher got satisfactory results from the prototype.

2. Stem Learning

A model of STEM learning of the Problem-Solving Method in this research consists of two basic parts in six lesson plans. First comes the inputs to the Engineering Design Process (EDP) in each lesson plan have a one-step of EDP such as Identify a challenge, Explore ideas, Design a solution, Plan and implement solutions, Test and develop, and Presentation. Second, researcher have seen these inputs in the Inquiry-Based Learning (IBL) to driving the learning process in every lesson plan. Integrating EDP and IBL into Problem Solving is a teaching method based on learning psychology: learning occurs when problems arise. This is a method for teaching students to learn how to solve problems systematically. Designing methods of learning enable the application of prior knowledge combined with new knowledge and skills to solve problems. That is a vital part of STEM education in the learning design of the study. Integrated learning management between disciplines links knowledge in the school system to effectively solve problems in daily life. (Ministry of Education, 2017)

In this study, students were assigned to make the PM 2.5 dust mask. The engineering design process was introduced as a guideline instruction for implementation. At the end of the process, students had to explain what they had discovered coupled with principles for problem-solving in the design and improvement of their task. Consequently, the researcher synthesized the answers of students that illustrated a connection in using science, mathematics, technology skills to solve problems as well as other skills that students used from their student work

Figure 1. Conceptual diagram: The design of the learning with the Engineering Design Process and Inquiry-Based learning**.**

3. Research Scope

This qualitative research was conducted with 40 grade 4 students in special science-mathematics classrooms, Anuban-Samutsongkram school, Thailand. In which all selected students were purposive

sampling. The content used in the activity is based on the Thailand and school standard and indicators in grade 3 and grade 4.

4. Methodology

The investigation model was proposed to examine classroom actions comprising 4 main steps: Plan-Act-Observe-Reflect (PAOR) (Zuber-Skerritt & Perry, 2002). The results of the teaching and learning process were interpreted for the phenomena explanation. The research led finding to issues as well as the method was used to develop problem-solving skills of grade 4 students through STEM workshop "PM 2.5 Dust Mask" along with observation, how students adapt to problem-solving skills in the STEM educational activities. The method is clarified in the following steps:

- Plan : The research began with a study of learning management that related to STEM education and the development of problem-solving skills of learners from the research and related documents in order to create a lesson plan that can be developed the problem-solving skills of learners through STEM education activities and aside from studying documents; also, their own teaching experience was considered.
- Act : Implementation of a lesson plan consisted of 6 inquiry lesson plans in each part of the engineering design process. The implementation was in the science hour during 18-28 February 2019, the second semester of the academic year 2018 within 6 lessons, 60 minutes per lesson in total.
- Observe : In the teaching process, students were observed and recorded behavior at the same time. In addition, to answer the 2nd research question, students were asked to write a reflection of the students' thoughts and their post-teaching notes to answer the 1st research question.
- Reflect : The reflection data of the teaching practice was obtained from the teachers' observations. The writing of the reflection from the students is to analyze the guidelines for STEM educational learning. As a result, the reflection review yielded future planning for the learning development of STEM academics.

From the operational process, there were methods for collecting and analyzing data from both research questions as follows:

- Question 1: "How can I improve the problem-solving skills of grade 4 students through STEM education activities the PM 2.5 Dust Mask":

  The utilized tools were post-teaching notes and reports that reflected students' ideas. The inductive analysis was performed by taking the information that had been divided into various issues. Then that information was compiled into integrated issues as the following points: 1) the lesson plan, 2) the strengths and weaknesses of the teaching plan, and 3) ways to improve the teaching plan. In addition, other else issues were be able to observe from the learning period; consequently, they were compared to the consistency with relevant studies.

- Question 2: "How do the students possess problem-solving skills in STEM education activities the PM 2.5 Dust Mask?":

  The utilized tools were post-teaching notes and reports that reflected students' thoughts. The inductive analysis was performed by taking the information from questions in activities. The analysis focused on the answers and behaviors related to the main subjects in the stem, namely science, mathematics, and technology. Then the students were grouped according to the answer conditions and determinants referred to the details in section *6.3 problem-solving skills.*

5. Results and Discussions

5.1 STEM education

According to the engineering design guidelines, STEM educational lesson plan in PM 2.5 dust mask activity was a problem-solving process. There were 6 steps in 6 lesson plans as follows: 1) Problem Identification, 2) Related Information Search, 3) Solution Design, 4) Planning and Development, 5) Testing, Evaluation, and Design Improvement, 6) Presentation. Each plan has an integration of learning, science, mathematics, and technology. The results of the analysis, including standards and indicators in the curriculum, were examined in the tasks of making PM 2.5 masks. It revealed the necessary indicators divided into two groups which are indicators or knowledge. Students' prior knowledge, such as measurement skills from learning mathematics in grade 3, indicates that students did not have enough accomplishment. Students could get information on the integration process of inquiry-based learning in each learning plan that was prior designed.

5.2 Strengths and Weaknesses of STEM education in PM 2.5 dust mask activity

The advantages of STEM education are that students can apply knowledge and integrate related sciences as well as practices in daily life and future careers. This study is an empirical lesson harmonizing with Thailand's education development needs in the 21st century.

5.3 Strengths

1. There was a learning process in which students could create knowledge by themselves by searching for actual experiences and adding new experiences from learning and taking action. This corresponds to the nature of adult learning, meaning a set of conditions suitable for full cognition that might be used as a standard for future learning as adults (Mezirow, 1997).
2. Designing problem-solving solutions throughout the process using group work and a sequence of problem-solving methods using the engineering design process, which was one form of accepted solution. Plan and Khandani (2005) explanation summarised that engineering is the key to solving problems from systematic problem-solving design.
3. Activities designed to enable students to communicate with one another for problem-solving, in which communication and collaboration are important factors for problem-solving skills. For instance, the U.S. Department of Education (2012) considers the abilities of collaborative problem solving as the one dimension of students’21st-century core competencies. In Thailand, communication and collaboration also have been used as essential competencies for students.
4. Students realized the value and benefits of knowledge gained from studying in the classroom by using the knowledge to solve problems in real life.
5. The content/issues studied are modern and are problems with current events.

5.4 Weaknesses and Guidelines for Improvement

1. Development in the academic year 2020 onwards, new indicators for grade 3 levels need to be analyzed because of the improvement of Thailand's curriculum in science, technology, and mathematics.
2. Preserve students’ time to improve the model and the task properly.

5.5 Other observations

For optional observations, It was found that soft skills from the students such as communication skills, searching information, collaborating, and requesting help from teachers or parents; when they could not complete the task by themselves, such as sewing tasks.

5.6 problem-solving skills

The grouping for problem-solving through the STEM education of PM 2.5 dust mask activities was divided into 4 groups which were 1) the group that used specific science/math/technology in problem-solving, 2) the group that used integrated knowledge of science/math/and technology at least two branches of knowledge, and 3) the group that did not use science/math/ and technology knowledge to solve the problem, the detail description is listed in Table 1.

Table 1. *Student problem-solving group through STEM educational Dust mask PM 2.5 activities.*

	Student problem-solving group		
Group	Use specific knowledge	Use integrated knowledge	Do not use any knowledge in Science/Mathematics/Technology
Number of people (percent)	4(10)	36(90)	-
Examples from student reflection	- Our group uses knowledge of measurements obtained from mathematics.	- There is a solution by using measuring tools such as a ruler and a tablet to search for information. - Use the knowledge of dust filters and use the internet to search for a prototype in mask making and measurement equipment. - I (students) use the knowledge they learned from math and sciences subjects	-

Analysis and clustering of students' problem solving found that most of the students are in the group that uses integrated knowledge, science, mathematics, and technology at least two or more, accounting for 90 percent, and no group that does not use knowledge in science, mathematics, and technology to solve problems.

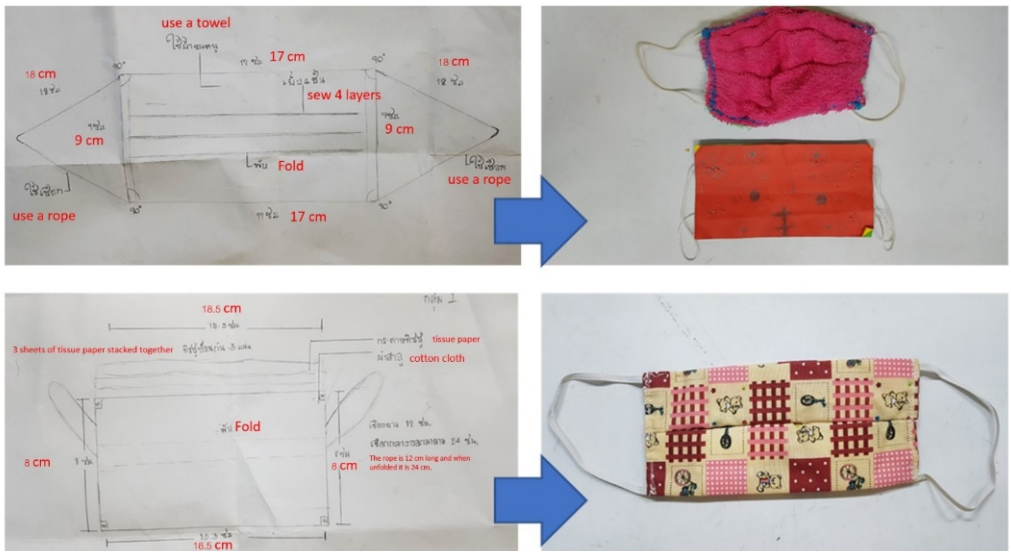

Figure 2. The picture shows the design by creating a draft to model the task and the real task.

To reflect the student's ability of problem identification and problem-solving design, in-class unstructured interviews were conducted. The responses indicated that the major problems after the assignments of the tasks were defined correctly. The students were able to identify the PM 2.5 dust mask defects regarding the mask design and fabrics. Moreover, they suggested different solutions to upgrade the mask quality in several aspects such as fine fabric resolution choices, design of multi-layers, and dust-absorbing with a moistness condition. This after-action review aroused students' desire for additional experiments. Explicitly, students showed proficient problem-solving and critical thinking skills to apply integrated knowledge with aims for the best productivity corresponding with a practical perspective.

The results show that learning management is an effective way for problem-solving by using STEM education as a tool. It helped students learning and practicing to define problems and alternative solutions through knowledge integration. Students succeeded in thought development based on prior experience and improving toward new knowledge creation. Researcher also found that students were capable of various skills for problem-solving, such as communication and presentation skills. Collaboration skills in using technology such as searching are in line with the concept of "knowledge and skills developed include communication of all types, and problem-solving, with application to authentic problems" (Zhou, 2012). The modern learning culture in the 21st century must be learning by practices that require problems or work in the project (Reeve, 2013). The goal of learning is to develop all aspects of learners with integrated learning methods such as STEM. However, this research was to collect data only for students with unique talents in science and mathematics. Therefore, those who study should adjust and apply in proper formation.

6. Benefits from This Research

In this study, the researcher found a way to design learning methods with STEM activities that promote learners' problem-solving. In addition, it also encouraged other competencies of students. This concept is a prototype for designing diverse and suitable activities for learners at different levels and different contexts.

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