Learning Activities to Promote the Concept of Engineering Design Process for Grade 10 Students’ Ideas about Force and Motion through Predict-Observe-Explain (POE)

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Abstract. The purpose of this study was to learning activities for promoted the concept of engineering design Grade 10 students’ ideas of engineering design process on the problem based about force and motion. The force and motion unit provided the problem based activities through predict-observe-explain (POE). Participants included 60 Grade 10 students who were studying in Khon Kaen University Demonstration Secondary School (suksasart). Methodology regarded interpretive paradigm. The Hynes et.al. (2011) framework of engineering design process (EPD) was applied as reference of students’ existing ideas of engineering design process. The Hynes et.al. (2011) EPD consists of 9 steps including (1) identify need or problem, (2) research need or problem, (3) develop possible solutions, (4) select the best possible solution, (5) construct a prototype, (6) test and evaluate solution, (7) communicate the solution, (8) redesign, and (9) completion decision. The force and motion POE problem based was provided in order to allow students to design the possible solutions of inclined plane problem based. The 13 students’ tasks of solutions were interpreted to clarify students’ existing ideas of EPD. The findings revealed that all group could be interpreted that they held 9 steps of Hynes et.al. (2011) EPD to design their solutions. The paper will discuss the details of students’ existing ideas of engineering design process. The paper may have implication for STEM education teaching and learning.

1. Introduction

Education in the 21st century society endures the responsibility for preparing young people to realize their potential amidst rapid social and economic change. Schools are tasked with having to prepare students for jobs that over expectations, technologies that have not yet been invented and problems that we don’t yet know will arise [13]. While this is a noble sentiment there are a number of obvious challenges when trying to meet objectives that are shrouded in uncertainty. Globally, the focus of meeting these objectives has led to the promotion of STEM education, where the STEM acronym stands for Science, Technology, Engineering, and Mathematics. The evolution of the STEM acronym can be traced back to the 1990s when the National Science Foundation in the United States invested heavily in science, mathematics, engineering and technology (SMET), stating that the “quality of our future technological achievements depends heavily on the education in science, mathematics, engineering and technology (SMET)” (National Science Foundation, 1998). ‘SMET’, as an acronym, failed to catch on and was replaced with STEM in year 2001 [11]. STEM became a more widely known acronym because the popularity of books like “The World is Flat” [6] which highlighted how
traditional emerging economies like India and China were catching up on the US economy, and could potentially surpass it, due to their investment in STEM education. As a result, the US government invested heavily and the STEM acronym quickly became ubiquitous with western education [12].

The availability of funding for STEM initiatives in the European Union also saw the acronym proliferate among European countries. Horizon 2020 is the research and innovation funding programme of the European Commission and has posed a series of ‘Societal Challenges’ that will rely on STEM research over the next seven years to help tackle the economic and social challenges facing European society [4]. These challenges range from topics such as health, food, energy, transport, climate, equality and freedom and will receive almost €30 billion in funding — more than 35% of the entire budget for Horizon 2020. This funding is expected to be utilised by researchers in STEM education, particularly in higher education, as noted by Cortese [2] : “If higher education does not lead the sustainability effort in society, who will?”. Despite the availability of funding, implementing a coherent approach to supporting STEM education has proven difficult. Attempts to incorporate each of the core subjects into a consistent curriculum have been met with constraints and challenges which has seen the STEM acronym struggle to cement itself in the educational environment. Failures to consider STEM as a true curriculum concept and an overemphasis on science and mathematics to the detriment of technology and engineering are among the chief concerns [7].

What the conceptions of STEM education should be provided for teachers? It found that descriptions of what comprises STEM content and practices and what STEM conceptions look like range in the literature, especially conceptions of STEM education [1]. However, there are three consensus issues of discussion about STEM education including (a) instructionally (b) as a set of integrated or interconnected disciplines, or (c) as more dependent on the stakeholders or context in which it is viewed or conceptualized. For this study, we will hold Moore et.al. [5] definition of STEM education for enhancing teachers. They define it as “the teaching and learning of the content and practices of disciplinary knowledge which include science and/or mathematics through the integration of the practices of engineering and engineering design of relevant technologies.” To them, five characteristics distinguish integrated STEM instruction from other teacher pedagogy: (a) the content and practices of one or more anchor science and mathematics disciplines define some of the primary learning goals; (b) the integrator is the engineering practices and engineering design of technologies as the context; (c) the engineering design or engineering practices related to relevant technologies requires the use of scientific and mathematical concepts through design justification; (d) the development of 21st century skills is emphasized; and (e) the context of instruction requires solving a real-world problem or task through teamwork. This conceptualization of STEM is grounded in learning research.

STEM education in Thailand has been strongly driven. The government organizations have pushed the projects to prepare STEM teachers across the nation. The STEM professional development projects have been provided for in-service teachers by many organizations such as the institute for the promotion of teaching science and technology (IPST), the office of basic education commission (OBEC), the office of higher education commission (OHEC), the ministry of energy, the Electricity Generating Authority of Thailand (EGAT), the chevron enjoy science project, and the schools and universities STEM education projects. These projects could provide approximately 5,000 teachers (in the year of 2017) who could generate the learning activities through integrating knowledge, concepts and skills systematically as STEM education.

Thailand Office of Basic Education Commission (OBEC) has pushed in-service teachers to develop his or her competence of organizing STEM education instruction. The OBEC STEM in-service teacher professional development project called STEM smart trainer team organized the workshop across the nation in order to enhance teachers to understand the concept of STEM education and fundamental ideas of utilizing STEM instructional approaches in their classroom. The STEM smart trainer team project enhanced teachers to provide STEM learning activities through engineering design process (EDP).
The EDP of OBEC STEM consists of 9 steps including (1) Identify the problem, (2) analyzing five capitals, (3) explore information, (4) knowledge sharing, (5) model solution, (6) planning and development, (7) testing and evaluating the solution, (8) present the solution, and (9) reflection and revise.

2. Methodology
This research uses interpretation. And the interviews of the student's motivational and motivational activities by learning POE, which is the main problem, to organize the learning activities. To promote the concept of student-centered engineering in the framework of Hynes (2011) [8].

2.1. Target group
The participants were 60 Grade 11 students of Demonstration School, Khon Kaen University Khon Kaen, and Thailand, Organized into 15 groups.

3. Research Findings

3.1 Stem Education and Engineering Design
The combination of the concept of engineering design and learning of Science, Technology and Mathematics is unique to STEM learning organization. As students attempt to learn, understand and practice skills in Science, Technology and Mathematics, they have an opportunity to apply the knowledge gained to design a product or a method to meet their daily life problem solving needs [10].

The Engineering Design Process (EDP) refers to organizing ideas to improve decision making in order to develop high quality solutions and/or products to problems. The main objectives EDP are 1) students become engineers, meaning that teachers need to listen to students, and 2) classroom environments need to change properly to enable learning through the EDP.

Specifically, skills and abilities associated with engineering design for high school student consist of nine stages according to including (1) identify need or problem, (2) research the need or problem, (3) develop possible solution(s), (4) select the best possible solution, (5) construct a prototype, (6) test and evaluate the solution(s), (7) communicate the solution(s), (8) redesign, (9) completion decision (see Figure 1)[8].

Throughout this process, students repetitively assess and challenge their ideas by repeating steps every now and then, even restarting from the beginning. Frequently, the imaginative ideas emerged from overlooking the flaws, or a different approach may become apparent through work on the challenge [8]; [14].

![Figure 1. Engineering Design Process [3]](image)
3.2. Predict–Observe–Explain (POE)
White and Gunstone (1992) have promoted the predict-observe-explain (POE) procedure as an efficient strategy for eliciting and promoting discussion of students’ science conceptions. This strategy involves students predicting the outcome of a demonstration, committing themselves to a possible reason for their prediction, observing the demonstration, and finally explaining any discrepancies between their prediction and observation. Whether used individually or in collaboration with other students, POE tasks can help students explore and justify their own individual ideas, especially in the prediction and reasoning stage. If the observation phase of the POE task provides some conflict with the students’ earlier prediction, reconstructions and revision of initial ideas are possible (Searle & Gunstone, 1990; Tao & Gunstone, 1997).

3.3. Data Collection and Analysis

3.3.1. Observation of students’ behavior in each activity. Observation with the following.
  • Predict: What students have done and are consistent with the EDP.
  • Observe: What did the students do and was consistent with the EDP.
  • Explain: What students do and how they are aligned with the engineering process.

3.3.2. Interviewing students’ ideas during activities.

3.3.3. Interpretation of the protocol from the activity sheet.

4. Results
To start, the teacher opens a video about the bowling competition for students to watch. And ask students: Do students know about bowling? How did you play? Then define the problem and conditions for the students.

Teacher had question before activity, How student designed a plate to hit bottles fall as much as they can? By the way we prepared materials for them. The second, They predicted and explained their concepts about solutions and problems when they let bottle fell form inclined floor.

![Figure 2. Bowling competition.](image1)

![Figure 3. materials](image2)

The result of learning activities to promote the concept of engineering design process for students’ Ideas about force and motion through predict-observe-explain (POE) are as follows.
All student could identify solutions and situations and create a part of the material. So relationship with step 1 The Identify problem of engineer design process (EDP) following figure 3
4.1. Predict
It is a step for students to predict phenomena and the expected results. Students must give reasons for their predictions.
- Students groups have searched scientific concept to design work piece be consistent with step 2 Research of engineer design process (EDP)
- Students have brainstorming and discuss each other in groups to find the best possible materials and have teacher supervision be consistent with step 3 possible solutions of engineer design process (EDP) Example: student interviews
  Group 1: They think, should be designed with circular wheels for work to roll away.
  Group 2: They think, should be designed to have a cylindrical shape to be able to roll far.

4.2. Observing
It is a step that students must take to experiment with what is predicted.
- Each group as created a piece of work From the model designed. Be consistent with step 5 construct a prototype of engineer design process (EDP).
  All students will be able to create three main types of work:
  Model 1: make the plate a cylindrical shape and use sticks piece to roll.
  Model 2: make the work piece by sticks piece a cylindrical shape and use plate to roll.
  Model 3: make the plate a cylindrical shape is embedded sticks piece in the core.
Example: design and prototype

- Group 1
  กลุ่มนี้นักเรียนใช้แผ่นฟิวเจอร์บอร์ดม้วนเป็นเกลียวทรงกระบอก และใช้แท่งไม้ไอติมทำเป็นสามเหลี่ยมเพื่อทำเป็นล้อให้กลิ้งไปได้

- Group 2
  กลุ่มนี้นักเรียนใช้แผ่นฟิวเจอร์บอร์ดตัดเป็นแผ่นกลม 4 ชิ้น จากนั้นใช้แท่งไม้ไอติมเชื่อมติดระหว่างแผ่นฟิวเจอร์บอร์ดให้มีลักษณะเป็นล้อกลม จากนั้นใช้แท่งไม้ไอติมที่เหลือทำเป็นเกลียวที่ชี้มั่นคงตลอดที่ให้กลิ้งไปได้

- Group 3
  กลุ่มนี้นักเรียนใช้แท่งไม้ไอติมมัดรวมกันเป็นเกลียวกลางและใช้แผ่นฟิวเจอร์บอร์ดม้วนให้เป็นทรงกระบอกที่ให้กลิ้งไปได้

*Figure 7. design*

*Figure 8. prototype of each group*

- Each group created a work piece to experiment on the sloping ground to roll against a bottle of water with step 6 test and evaluate solution of engineer design process (EDP).
4.3. Explain
Students have committed their explanations to paper, discuss their ideas together.

- Students present ideas. And the process of creating a piece of work rational or scientific principles that bring solutions and the integration of STEM, which corresponds to step 7 communicate the solution.

Example: Students present ideas scientific principles and analyze to guide the create of work, have three main types. Following:

| Group 1 | Main concept of group 1: they were using the principle of moment of inertia to make the workpiece has a cylindrical shape with less radius for moving parts faster. |
|---------|-------------------------------------------------------------------------------------------------|
| Group 2 | Main concept of group 2: make the work piece a cylindrical shape. |
| Group 3 | Main concept of group 3: should reduce the contact between the material and the floor to reduce friction, causing the work piece to roll further. And they were make roll in circle to make rolling easier and reduce friction. |

Figure 10. scientific principles of students
Students found a problem. Then modify the workpiece and then try again, which corresponds to step 8 redesign.

Example: how to improve student work are optimize into 4 main ideas:
- Method 1: adjusting the wheel size
- Method 2: adjusting the shape of the workpiece to the most appropriate target.
- Method 3: improve the workpiece to be more balanced.
- Method 4: improves wheel alignment.

Each group decided and chose the workpiece, which corresponds to step 9 completion decision.

It is seen that students have nine engineering processes that appear in this activity.

5. Conclusion
The results show Engineering Design Process Skills that Hynes (2011)'s nine engineering design processes were relation the planning of learning activities, such as predictive observation (POE). It also encourages students to integrate science, technology, engineering and mathematics (STEM) in solving problems or situations under specified conditions.

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