Nourishing Students' Creative Thinking through Exemplar STEM Lesson Embedded During Extracurricular Activities

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Abstract

Education, research, and innovation have an impact on economic development in the world today. In a highly competitive economy, the government needs to concentrate on technologies to increase the value of production by concentrating on using innovative thinking to solve the problem. This study aimed to improve the creative thinking of students through extracurricular activities focused on the STEM Learning Based Project on the topic of density. The study used a one-group pre-test, post-test, and delayed post-test design. Quantitative results were used to see the effect of project-based learning as a model STEM lesson that was incorporated into extracurricular activities through 6E Teaching Learning Modeling as an intervention. There were 44 secondary school students in attendance. The tools used included photo analyzes and questionnaires on creative thinking with two subscales curiosity and flexibility, along with photo interpretation. The data was analyzed using MANOVA. The mean score for curiosity pre-test score was (M=2.65, SD=0.26), then increased to (M=3.42, SD= 0.59) for post-test and continued to increase to (M=4.25, SD=.27) for delayed post-test. In addition, the mean score of flexibility also indicates progress from pre-test (M= 2.60, SD=0.40), then increased to (M=3.48, SD=0.53) for post-test and continued to increase to (M= 4.13, SD=0.28) for delayed post-test. The study found that a STEM teaching-based learning project embedded in extracurricular activities through 6E Teaching Learning Modeling project-based learning that is incorporated into extracurricular activities could enhance students' creative thinking; curiosity, and flexible thinking.

Introduction

Creativity is the desire to put something new into being, to do something unique that could not be accomplished simply by following laws, or by meeting general requirements. Economic and geopolitical developments can occur and impact the workforce, which may disrupt the conventional workforce and generate new demands (Shafie *et al*., 2019). As educators, students should be prepared to be innovative in dealing with uncertain potential demands. There are three elements of creative thinking: (1) curiosity, (2) flexibility, and (3) originality. Nonetheless, the creative thinking skills of students can't develop properly if the learning activities offered by teachers do not actively engage and involve students in understanding the development of concepts, apart from the learning strategies used in teaching and learning activities that are less innovative and yet based on teacher-centered. Use an area other than the classroom, by introducing them to real-world issues in project-based learning, would improve their innovation in solving the problem.

In this study, project-based learning has been introduced to students throughout extracurricular activities. Students need to create the water level warning prototypes using the density definition that they studied during the formal class. This project-based learning integrated with Science, Technology, Engineering, and Mathematics know as STEM, using 6E Instructional Teaching Learning Modelling which compromise with (1) engage, (2) explore, (3) explain, (4) engineering, (5) enrich and (6) evaluate.

Theoretical Framework

The theory of creative cognition and Kolb's theory has been chosen for this study. The theory of creative cognition presents processes engaged in the stages of generation and exploration (Finke *et al.,* 1992).

Conceptual Framework

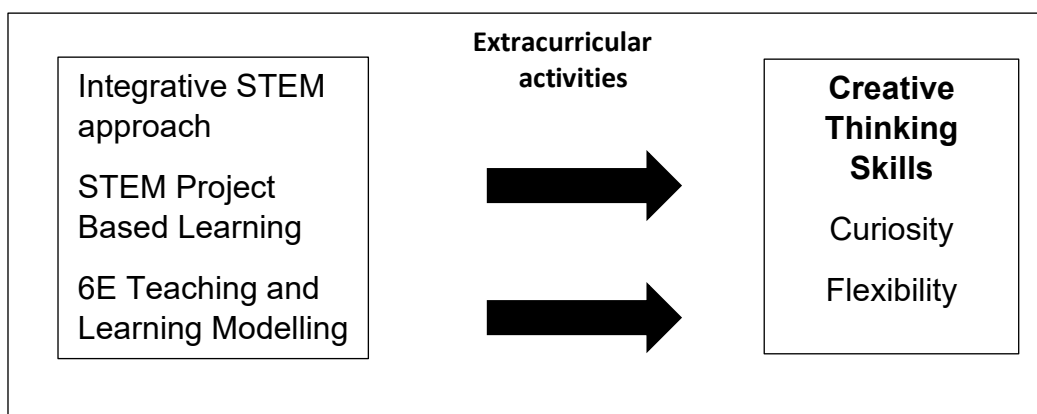The diagram below shows the conceptual framework of the study.

Figure 1: Conceptual Framework of the study

Rapid science and technology advances now require educational institutions to not only train people prepared with knowledge but also to train people who know how to access knowledge and generate new information through the use of their knowledge (Kanadli, 2019). In order to stimulate them to STEM, a project-oriented curriculum has been used as a strategy, offering students an opportunity to consider real-world concerns focused on interdisciplinary topics (Dugger, 2010). Furthermore, STEM has been described as working in the context of complex phenomena or situations on tasks that require students to use knowledge and skills for multiple disciplines Honey *et al.,* (2014). In project-based learning, 6E Teaching Learning Modelling has been integrated. In this project-based learning, students need to create their water level alarm as their prototypes. In constructing their prototypes, students need to be creative.

Creativity is one of the 21st-century skills that are requested for their future career (Hanif *et al*., 2019) and should be fostered by students (Dawes & Wegerif, 2004). Fluency, flexibility, originality, and elaboration are four elements of creative behaviors that can be encouraged to inculcate students(Tsai, 2014). Creativity is not only required when constructing the prototype and develop for innovation, but it is also required in solving the problem. Table 1 shows those of four elements, which are taken from Torrance Framework for Creative Thinking's creativity characteristics (1979).

Table 1: Four Elements of Creative Thinking's creativity

Elements	Explanation
Fluency	Fluency refers to the capability to generate many ideas. This capability to generate many ideas to a problem enhances understanding of the problem.
Flexibility	Flexibility refers to the ability to produce multiple ideas from various aspects. Mingling with people from different disciples with different knowledge will contribute to various views.
Elaboration	Elaboration refers to the ability to extend and enhance existing ideas.
Originality	Originality refers to the ability to produce unique and novel ideas.

Resources: Shafie *et al.,* (2017)

Sternberg (1996) has argued that creativity is three dimensional; synthesizing, analyzing, and contextualizing. Apart from that Treffinger *et al.,* (2002) have grouped creativity into four broad categories; generating ideas, digging deeper into ideas, openness, and courage to explore ideas, and listening to one's inner voice. Taken definition from a few prominent researcher such Arasteh (1968) who describes

curiosity as a phenomenon related to creativity while Torrance (1963) who has viewed that curiosity and thirst for knowledge motivate the creative achievements of even young children. Meanwhile Maw & Maw (1970) argued that curiosity to be an aspect of creativity and problem-solving. However, in this study for novice thinkers, only two elements of creative thinking have been light up; curiosity and flexibility.

STEM Project-Based Learning through 6E Instructional Teaching Learning Modelling. Recently, the importance of providing students with a strong background in Science, Technology, Engineering, and Mathematics (STEM) has been stressed. In secondary school, the main purpose is to develop needed skills by students such as creativity in facing the advance of technology and preparing for their future career. STEM project-based learning is one of learning model that can be used to satisfy the needs of STEM because the integration of Science, Technology, Engineering and Mathematics Lou *et al.,* (2011) and prepare students in facing the advance in technology education (Hanif *et al.*, 2019). There are six phases involved in STEM project-based learning in this studied as shown in Table 2.

Table 2: Six phases involved in STEM Project-Based Learning

Phase	Activities
Engage	Students have been purposed with Social Scientific Issue (SSI). Visit the fieldwork, the flooded area. Given the situation: As an engineer, you need to overcome the problem of how to alert the people surrounding you when river levels rise.
Explore	Students need to use any resources to find out information. Students can get information from their parents, magazine, website, teachers, you-tube, etc.
Explain	In their group, they discuss what they have found out about the project. Changing idea. They may sketch this phase, and present it to their friend for sharing.
Engineering	This is the stage of implementation, which required students to produce a product according to their design drawings and conduct the test.
Enrich	Students may conduct the actual test on their prototypes. Present their project for comment.
Evaluate	The phase of the evaluation required the teacher to gives the evaluation or suggestion regarding the students' project. The stage of correction was encouraged students to correct according to the evaluation.

Methodology
Materials & Methods
This research uses quantitative research methods in the form of a single group design, with repeated measures, pre-test, post-test and delayed post-test.

Participants
Form one students (44 persons) with the same criteria were selected for this study. None of these students ever had experience with STEM project-based learning prior to this study. Table 3 shows number of students involved in this study.

Table 3: Number of students involved in this study

	Male	Female	Total
Frequency	19	25	44
Percent (%)	43.2	56.8	100

Research Instrument
The research instrument used to collect the data needed in this study is questionnaire, which have been adopted and adapted for Malaysian secondary school students.

Research Question
1. Is there any difference between creativity skills in doing STEM project-based learning with the subscale curiosity and flexibility at pre-test, post-test, and delayed post-test?
2. To what extend STEM project-based learning play important role in enhancing students' creative skills?

Results and Discussion
From the study conducted, it shows that STEM project-based learning increases students' creative thinking. This was based on:

Descriptive analysis of mean score pre-test, post-test, and delayed post-test for creative thinking skills
Table 4 below shows the mean scores of pre-test, post-test, and delayed post-test for creative thinking skills.

Table 4: Descriptive Statistics pre-test, post-test, and delayed post-test for creative thinking skills.

	N	Pre-Test	Post-test	Delayed Post-test
Creative thinking skills	44	2.64 (0.30)	3.46 (0.53)	4.20 (0.19)

Table 5 below shows the mean scores pre-test, post-test, and delayed post-test for sub-scale creative thinking skills which consist of curiosity and flexibility after application of informal STEM activities in enhancing students' entrepreneurial mind among lower secondary students during extracurricular activities.

Table 5: Descriptive Statistics pre-test, Post-test, and delayed Post-test for curiosity and flexibility

	N	Pre-Test	Post-test	Delayed Post-test
Curiosity	44	2.65 (0.26)	3.42 (0.59)	4.25 (0.27)
Flexibility	44	2.63 (0.40)	3.48 (00.53)	4.14 (0.28)

( ) : Standard Deviation

The mean score pre-test for curiosity was (M=2.65, SD=0.26), then increased to (M=3.43, SD= 0.59) for Post-test and continued to increase to (M=4.25, SD=0.27) for delayed Post-test. Furthermore, mean score of flexibility also show an improvement from (M=2.64, SD =0.40), then increased to (M=3.48, SD=0.53) for Post-test and continued increased to (M= 4.14, SD =0.28) for delayed Post-test.

Overall, the mean score for creative thinking skills which consists of curiosity and flexibility has shown an increase after the application of informal STEM activities among lower secondary students during extracurricular activities.The discussion on the study will be based on the two research questions proposed in the following subheading. There are two sub-scales of creative thinking are curiosity and flexibility.

Creative thinking skills in doing STEM project-based learning.
Curiosity and flexibility are two facets of creative thought. Creative thinking is not only about innovative product development or invention but also about creative thinking to solve the problem. Creativity is one of the 21st-century skills needed by students in facing a future career (Hanif *et al.*, 2019) and it should be fostered by students (Dawes & Wegerif, 2004). STEM-based learning is a model of learning that incorporates science, technology, engineering, and mathematics into the curricular design *(Lou et al.,* 2011) and pragmatic platform to satisfy the needs in preparing students facing the advance of technology (Hanif *et al.,* 2019).

In this study, creativity refers to creating or solving an open-ended task. Results showed that creativity mean score increase from pre-test to post-test and delayed post-test. Two dimensions of creativity; curiosity and flexibility regarding to the concept of density have been investigated. The mean score of each dimension's creativity increased following the implementation of the STEM-based learning project as displayed in Table 5. Grossnickle (2016) defines curiosity as the desire for new knowledge, information, experiences, or stimulation to resolve gaps or experience the unknown. For this reason, curiosity is particularly valued in young learners, as it is a

key component that drives both their exploration and their refinement of perception as they gather information and learn from their surroundings (Banning & Sullivan, 2011).

| **Figure 1: Side visit to Dabong to see the real area that flooded in 2014.** | **Figure 2: Exposure to real social-scientific issues.** |

During the STEM-based learning project, students have gone through six phases; engage, explore, explain, engineer, enrich, and evaluate. In the engage phase, students were exposed to social scientific issues before they doing their project. In engage phase students were given newspaper cutting about flood in Kelantan. After plan arrangement, the students decided to visit the flooded area, and find out the solution themselves (Figure 1 & Figure 2).

Figure 3: Sketch prototypes after discussion, explanation, and exploration the real flooded area.

During the exploration phase, students were also given a free opportunity to explore the problem and gather some information from any resources. At this stage, students were encouraged to explain and discuss with their peers to improve their ideas (Figure 3). In the explain phase, students have the opportunity to discuss the project with their group based on information obtained from the internet. Contribution of ideas were encouraged during this phase. Ideas will be combined and expanded.

Figure 4: Construct prototypes by referred to the you-tube, or website in engineering phase.

Figure 5: Students test their prototypes and make enrichment to improve.

In the engineering phase, students began to construct their prototypes by refering to the youtube channel and websites (Figure 4). While during the enrich phase, students test and make improvement to their prototypes (Figure 5). At this stage, students were the main keyperson to strengthen their hands-on ability and problem-solving competency. They find out from various resources such as youtube and websites to improve their prototypes. This stage emphasized in helping the students to clearly understand their design conceptions and reason. Students were encouraged to make corrections according to the feedback and suggestions thus improving their abilities in engineering.
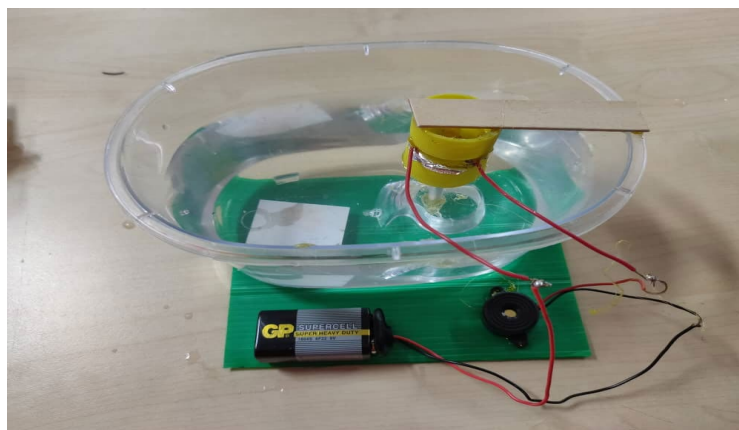

Figure 6: Complete prototypes of water level alarm.

The last stage is completion of prototypes that have been evaluated and comments by their peers and also external experts (Figure 6). The above activities reveals the connections between the student groups' actual performance in all learning stages and their creativity (Figure 1 to Figure 6). As mentioned by Munandar (1999), creative thinking can be developed through experiments and discussion activity between students. The spiral process in project-based learning involved the students were greatly beneficial to improve students' ability in design and production as well as the cultivation of their creativity. In constructing their prototypes, students used materials that they can found in their daily life, which could arouse students' curiosity. Discussion conducted during the explanation phase will also lead to new ideas for improvement. Students were encouraged to look for comments from different perspectives. Flexibility is one of the elements of creativity, students who can think flexibly from a different perspective on a question or topic will create a range of ideas. Therefore, limiting one's point of view to a sole perspective limits possibilities. Flexible thinkers discover whole new areas of possibility, including different interpretations of scientific data. Flexibility also promotes interpersonal and cross-cultural understanding. Flexibility can also lead to originality, which is the most elusive aspect of creativity. Students were encouraged to be more flexible in the discussion group hence they can gain more ideas and knowledge.

As shown in Figure 4, students used media to find out the best method and design to construct their prototypes, water level alarm. Students use technology and media to help them produce high-quality work in a sense of creativity (Loveless, 2002). Creative thinking is novel thinking that produces ideas of values (Lubart & Sternberg, 1995) and became the outcome in this study. It compromises curiosity and flexibility. The results suggest that project-based learning during extracurricular activities has value beyond promoting student creativity. Besides students also were guided to detect problems from practice and learn from mistakes. The results showed a positive influence of project-based learning on the affective development of creativity. The project-based learning was also designed to be based on objects in daily life. In short, project-based learning aims to improve the deficiencies of traditional teaching. In traditional classrooms, teaching and learning are dominated by teachers, where students have minimal opportunities to express their opinions and ideas (Tytler & Aranda, 2015) thus will minimize the interaction of students and limit them from expressing their view Chua *et al.,* (2017). Apart from that, the rigid classroom slows down the conceptual activities among the students and this leads to low performance of students in science.

Conclusion
In conclusion, project-based learning allows students to accumulate practical experience and enables them to integrate and apply the related knowledge of science, technology, engineering, and mathematics in meaningful learning thus enhancing students' creativity.

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