Journal of Engineering Science and Technology
Special Issue on i-CITE 2018, November (2018) 80 - 89

IMPACT OF INTEGRATED STEM SMART COMMUNITIES PROGRAM ON STUDENTS SCIENTIFIC CREATIVITY

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Abstract

Scientific creativity is such a complex skill and is often ignored by teachers during teaching activities. The purpose of this study was to identify students' changes of scientific creativity in an integrated STEM of Smart Communities programme. The programme exposed students with integrated STEM education through project-based learning involving the application of the engineering design process. The elements of scientific creativity are divided into three aspects, which are scientific processes, inquiry skills, and creative thinking. The study was conducted experimentally on two groups of students, i.e., the control group that did not receive the STEM of Smart Communities modules and the treatment group, i.e., students who had received the modules. This study was conducted in six schools, with three schools with an intervention and three schools without any intervention. Data were collected through a questionnaire given to 330 students. The findings showed a significant difference and have a positive impact on the element of scientific processes, inquiry skills and creative thinking among students with interventions rather than students without intervention.

Keywords: Integrated STEM, Scientific creativity, Smart communities, STEM.

1. Introduction

The term STEM is still uncertain among some students and society. According to Sanders [1], STEM education was originally derived from Science, Mathematics, Engineering and Technology (SMET), which was an initiative created by the National Science Foundation (NSF) in the United States. This initiative is an educational program to provide students with critical thinking, creative problem-solving skills and eventually, these students can be marketed in a global job world. The study by Brown et al. [2], found that students participating in the STEM program will have the advantages and tendency to further their studies in STEM field at a higher level. They are also more creative, scientific and confident in doing hands-on activities compared to students who are not involved in the STEM field during secondary school.

The number of students who choose STEM fields also continues to decline in recent years. In 2011, only 45% of students graduated were from the Science stream, including technical and vocational programmes. Additionally, the percentage of secondary school students who met the requirement to study Science after national level examination (named Lower Secondary Assessment) but chose not to do so increased to approximately 15%. The enrolments in STEM in upper secondary school level in 2013 were only 35% (29.2% in the pure science stream, 1.3% in the technical stream and 4.5% in the vocational stream [3]. The STEM intervention program known as Bitara STEM is carried out by experts from Universiti Kebangsaan Malaysia (UKM). This program has had a big impact on education, especially in preserving STEM education in Malaysia. The aim of the program is to increase the interest and performance of students in science in the STEM integration approach and to make students more creative, innovative and competitive [4].

2. Theoritical Framework

2.1. Scientific creativity

Thinking technique in a scientific manner is the best strategy to learn science and technology. Scientific thinking techniques need to exist among students nowadays to allow them to make problem statements, analyse problems, identify the impacts and be confident in solving problems. Scientific and creative thinking by combining elements of science and technology can solve the problem in the design process, especially when designing a valuable commercial product [5].

The education culture of the 21st century makes scientific creativity an important element in the teaching and learning process systematically (formulation, implementation, proving, and explanation). Individuals with scientific creativity skills are able to generate new ideas beyond others thinking [6]. They have defined this scientific creativity into several elements. Among the elements, they state that scientific creativity is a creative thinking ability that involves the intelligence of an individual mind, in which, one’s intelligence is connected with scientific knowledge and skills, which is divergent thinking, convergent thinking and associative thinking in processing idea scientifically.

An individual is said to be scientifically minded when he or she identifies and solves the problem by experimenting or processes scientifically. Liang [7] explained that scientific creativity is about inquiry skills, which related to the seeking evidence, making hypothesize and inference. In solving science-related problems, an individual need to use a variety of ways and resources in designing experiments to explore and investigate using theory and concept in science. This exploration and investigation need to go through various scientific processes such as formulation, implementation, proving an explanation.

2.2. Integrated STEM

STEM education is defined as a teaching and learning approach that is closely related to any subject or component within STEM, according to a particular discipline [8]. In a study conducted by Wai et al. [9], the activities in which, students practice using integrated skills to learn science and technology to solve problems enable students to enhance their understanding and the learning process are more meaningful.

Sanders [10], defines STEM education as a process of integrating technology and engineering design concepts into teaching and learning of science and mathematics. While Kelley et al. [11] and Fitzgerald and Smith [12], mentioned that the teaching integration by incorporating various elements of teaching methods, including STEM elements, encouraging creative and innovative thinking among students and increasing the debate session between students on science and technology is a good step in developing dynamic students in this century.

One important part of STEM integration is to use a systematic approach to solve problems. The theory behind a systematic approach is that students will be better prepared to use the engineering process when trying to solve problems in a situation or course. Students learn and use skills that can be used in various situations. Rockland et al. [13] and Tsupros et al. [14], explains that science can be visualized as suggesting an explanation of the natural world, while engineering proposes solutions to problems in human adjustment to real-world based on findings inquiry, problem-solving, and learning in STEM. Usually, students prefer cooperative learning such as working in groups to research, completing assigned tasks, testing theories, planning and implementing the completion process.

STEM integration offers students one of the best opportunities to experience learning in real-world situations [15]. Through the integration of STEM, it will deepen students' understanding of each discipline through contextual concepts, broadening student understanding of STEM discipline through exposure to social and cultural STEM contexts, and increasing interest in STEM disciplines by increasing the path for students entering the STEM field [16]. In addition, Morrison [17] provides criteria for what is appropriate with the proper STEM instruction in the classroom. He suggested that STEM integration students be able to implement them as 1) problem solvers, 2) innovators, 3) inventors, 4) logical thinkers, and also to understand and develop the skills required for 5) survival and 6) technology literacy.

3. Problem Statement

The future of the nation as embodied in TN50 (2050 National Transformation) aspiration requires Malaysian youth to have the aspirations for a sustainable, high-income and technology-driven economy, and provide many job opportunities and entrepreneurship. Malaysian youths also have the aspirations for an effective life-long education and learning system to equip Malaysian to face challenges and economic demands. All this starts with the system and the content of education that leads to STEM education. By 2050, it is illustrated that students will find the teachers either in each other's presence or virtually and discuss STEM syllabus related to space science and Malaysia can produce Malaysia STEM Experts. In the National Transformation Plan Report 2050, this will not be achieved if the country is unable to provide a stable STEM education integration plan earlier. This system is said to be the main contributor to the low unemployment rate of youth in the country. This is because the focus on STEM field and skills is needed to develop the economy and socio-economy of a country. Among the causes of graduates not being able to be employed and cannot survive in the working environment is because they cannot think creatively to adapt to the challenging working environment today [18].

Recent studies show that Malaysia needs 60% of students from schools and universities to continue their studies in STEM fields to strengthen socio-economic development [15] As a developing country, rich in biodiversity and resources, STEM plays an important role in ensuring sustainable solutions to global challenges. STEM should be one of the important remedies for changing Malaysian economy that leads to many solutions to the water problem, energy, food security, healthcare, biodiversity and climate change. One of the fundamental problems in school today is the "separate subject" approach to knowledge and skills [19]. In most of the time, students cannot solve the problem because they do not understand the context in which, the problem [20] while with this integration will provide a learning experience that links previous knowledge with the real world context, by integrating meaningful content in a real-life problem-solving environment [21, 22].

4. Methodology

The Science of Smart Communities (SoSC) emphasizes the four integrated areas of energy, transportation, wireless communications and urban infrastructure. It is implemented through Bitara STEM initiative on based on Project Based Learning. However, all of these need to be mastered by creative and scientific thinking. The conceptual of the SoSC intervention has several phases (refer to Fig. 1). SoSC modules were first adopted from New York Polytechnic-School of Engineering (NYU-Poly).

The first phase of the intervention is knowledge building stage is to build students awareness and content knowledge of the four modules towards building smart communities for sustainable development. The second phase of the intervention is to design and develop projects based on the first phase. In this phase, students also need to complete and displayed their projects and artefacts as well as involved in STEM speed challenge. All these intervention process and activities are meant to develop the students' scientific creativity, inquiry skills and creative thinking, which will be evaluated in the third phases. Next, the third and fourth phase is the implementation and evaluation phases. In the implementation phase, the experimental research design is used. Two groups were formed, which are the control group and two treatment groups. The treatment groups were given modules with and without intervention to compare the outcome. The outcome evaluated is divided into three aspects, which is scientific process, inquiry skills and creative thinking, which is as a set of scientific creativity [23, 24]. Curriculum integration is based on the principle of constructivism. The idea of curriculum integration is derived from real-world problems linked to certain disciplines taught at school [25].

The sample was randomly selected where the Form 1 to 3 (13-15 years old) students were chosen because they had received several STEM subjects such as science, mathematics, life skills, computer literacy and design. Table 1 shows respondents' distribution by type of school.

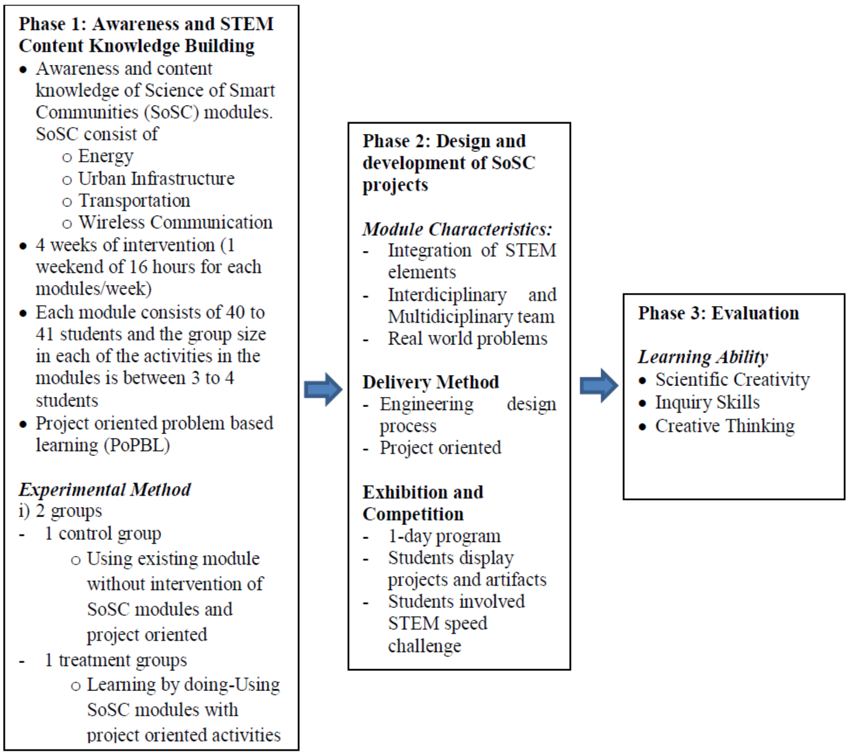

Fig. 1. STEM intervention process.

Table 1. Respondents distribution by type of school.

Schools without STEM intervention project.										
		Gender		**Race**				**Form**		
	Total	**Male**	**Female**	**Malay**	**Chinese**	**Indian**	**Others**	**2**	**3**	**4**
SMK *A*	56	29	27	32	17	7		14	20	22
SMK *B*	56	20	36	39	10	7		14	20	22
SMK *C*	57	19	38	39	8	10		16	26	15
Schools with STEM intervention project.										
		Gender		**Race**				**Form**		
	Total	**Male**	**Female**	**Malay**	**Chinese**	**Indian**	**Others**	**2**	**3**	**4**
SMT *D*	53	33	20	53						53
SMK *E*	54	21	33	54					31	23
SMK *F*	54	25	29	54				14	12	28

The answer to this questionnaire uses the Likert Scale for ordinal data by selecting either 1 - very disagreeable to 5 - strongly agrees. The questionnaire is divided into several sub-constructs as shown in Table 2.

Table 2. Instrument specifications for scientific creativity skill level construct.

Sub-constructs	Element
Scientific process	*A*1. Formulation
	*A*2. Implementation
	*A*3. Proving
	*A*4. Explanation
Inquiry skills	*B*1. Seek evidence
	*B*2. Hypotheses making
	*B*3. Inference making
Creative thinking	*C*1. Divergent thinking
	*C*2. Convergent thinking
	*C*3. Associative thinking

5. Results and Discussion

Based on Table 3, the t-test showed that there were three elements in the scientific creativity skills that are significantly different to each other ($p < 0.05$). With p-value = 0.035 ($p < 0.05$), there was a significant difference in Formulation element between a school with intervention compared to school without intervention. For Explanatory element, there was a significant difference of $p = 0.030$ ($p < 0.05$) after school was given STEM intervention. The most significant difference is that the element makes an explanation in the construct of the inquiry skills with p-value of 0.022. The value less than the 0.05 resolution explains the very significant difference occurring after a school undergoing the STEM intervention program. Overall, significant differences in these three elements indicate that the STEM integration program at school has a positive impact.

Students in school without STEM intervention are better in Implementation element in the construction of the scientific process. Mean value of 3.80 (*s.p.* = 0.76) was recorded by school students without intervention, compared to 3.79 (*s.p.* = 0.80) by students in schools with intervention. In implementing STEM teaching in schools without intervention, students are more likely to take steps, processes and evaluate before implementing the project.

The most dominant element mastered by the student after STEM intervention is the element of Associative Thinking (mean = 4.03, *s.d.* = 0.65). It is included in the construct of creative thinking. This element explains the attitude of the student who always thinks of various disciplines every time he finds a solution. For example, students are always thinking about safety, stability, endurance, cost, science, technology and decoration aspects of each project or product. The element that is least mastered by the student after STEM intervention is the convergent thinking element (min = 3.42, *s.p.* = 0.93). It is also contained in the construct of creative thinking. Convergent thinking refers to the ability to concentrate in one direction to find the right answers based on existing data. This process reduces the variety of answers to only one answer to a clear problem and only has a fixed answer. In this STEM integration situation, students are more likely to follow the design given by teachers rather than doing modification and innovation.

Table 3. Mean, standard deviation, *t*-test and a significant level of scientific creativity skills.

N = 330						Paired sample *t*-test	
Construct	**Element**	**Types of school**	**Mean**	**S.D.**	**Level**	***t***	***p***
Scientific process	Formulation	Without intervention	3.67	0.85	High	2.72	0.035*
		With intervention	3.91	0.77	High		
	Implementation	Without intervention	3.80	0.76	High	0.15	0.508
		With intervention	3.79	0.80	High		
	Proof	Without intervention	3.72	0.76	High	1.84	0.650
		With intervention	3.87	0.72	High		
	Explanation	Without intervention	3.70	0.88	High	1.52	0.030*
		With intervention	3.83	0.75	High		
Inquiry skills	Seek evidence	Without intervention	3.25	0.82	Average	1.95	0.890
		With intervention	3.43	0.87	Average		
	Hypotheses making	Without intervention	3.71	0.72	High	1.63	0.371
		With intervention	3.83	0.68	High		
	Inference making	Without intervention	3.86	0.75	High	2.00	0.022*
		With intervention	4.02	0.67	High		
Creative thinking	Divergent thinking	Without intervention	3.67	0.87	High	1.83	0.221
		With intervention	3.84	0.79	High		
	Convergent thinking	Without intervention	3.20	0.89	Average	2.15	0.554
		With intervention	3.42	0.93	Average		
	Associative thinking	Without intervention	3.76	0.76	High	3.42	0.063
		With intervention	4.03	0.65	High		

*significant at $p < 0.05$

Overall, the achievement of the level of scientific creativity of students in schools undergoing STEM interventions has increased. Two elements of the construct of the scientific process indicate a significant change between school and intervention of schools without intervention. Explanatory Skills (p = 0.030, p <

0.05) and make Formulation (p = 0.035, $p < 0.05$) have a great impact on the scientific creativity skills of STEM integration results.

The impact of this STEM integration can also create students who are confident in explaining, investigating, evaluating, giving ideas and communicating. This is proved by the significant findings of p = 0.022 ($p < 0.05$) on the making explanations element contained in the Inquiry Skills constructs. The integration of the STEM on the trained schools has clearly impacted the inquiry skills. This finding as supported by Bao et al. [26] stating that inquiry skills involve active learning in a series of learning processes, providing immediate feedback, contributing new ideas and thinking, and evaluating evidence and hypotheses through discussions with friends and teachers.

6. Conclusion

Basically, the STEM integration program or Bitara STEM UKM proves the mastery and enhancement of scientific creativity skills. There are five types of scientific creativity used by Rasul et al. [23], five scientific processes by Liang [7] and the "Three-Dimensional Scientific Creativity Model", which are mastered constructs and elements of scientific creativity skills that are included and supported in the research findings and theories. Therefore, the integration of STEM in schools needs to be continued to increase the capacity of scientific creativity and produce expertise in the STEM field. The intervention to build knowledge and students awareness integrated with STEM content knowledge through project orientation is crucial to building scientific creativity. It is proven, the findings show students, which go through these process having higher scientific process skills, higher inquiry skill, and higher creative thinking skills. Next, in the implementation by adopting the principle of constructivism theory, which derived from real-world problems is also contributes to scientific creativity skills. Constructionism advocates student-centered, discovery learning where students use the information they already know to acquire more knowledge. Students learn through participation in project-based learning where they make connections between different ideas and areas of knowledge. Further, constructionism holds that learning can happen most effectively when people are active in making tangible objects in the real world. In this sense, constructionism is connected with experiential learning and builds on Jean Piaget's epistemological theory of constructivism [27].

Acknowledgement

This study is part of a grant project titled " Bitara STEM: Science of Smart Communities " under Research University Grant (grant reference number GG-2017-017).

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