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STEM Learning through Engineering Design: Impact on Middle Secondary Students' Interest towards STEM

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ABSTRACT
The purpose of this study was to identify students' changes of (i) interest toward STEM subjects and (ii) interest to pursuing STEM career after participating in non-formal integrated STEM education programme. The programme exposed students with integrated STEM education through project based learning involving the application of five phases engineering design process. Two cohorts of middle secondary students participated in 2014 (n=129) and 2015 (n=113) were involved in this study. The study utilized one group quasi-experimental design. The analysis revealed that, overall there is a significant increase in mean scores for interest towards STEM subjects and career after participating in the programme. The findings also indicated that the program was effective at modifying students' interest level as the result revealed positive changes (from moderate to high level) for both 2014 and 2015 groups for interest toward STEM career (42.6% and 69.9% respectively) and interest towards STEM subjects (45% and 82% respectively).
Keywords: STEM Education, interest towards STEM, engineering design, early secondary students, non-formal learning

INTRODUCTION

The primary driver of the future economy and concomitant creation of jobs will be innovation, largely derived from advances in *science, technology, mathematics and engineering* (STEM) (NRC, 2011). The STEM workforce is a powerful component of this innovation pipeline. STEM occupations employ individuals who create ideas and applications that become commercialized and yield additional jobs. STEM fields overwhelmingly dominate other fields

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State of the literature

- STEM integration can occur in multiple ways. One model suggest that integrated STEM education must include engineering design as a basic for creating connections to concepts and practices from mathematics or science (or both).
- However, many research on the impact of engineering design in STEM integration focused on upper secondary grades and college years.
- Thus, there is the need for integrated STEM activities that uses engineering design framework that also takes into account the younger grades to improve students learning especially interest towards STEM.

Contribution of this paper to the literature

- The outcomes of this study provide evidence that exposing early secondary to engineering design process in integrated STEM education has positive impact on their level of interest towards those subjects and related careers.
- Our study has provided an example of how middle secondary school students can engage in processes of engineering design as a context to connect science, mathematics and technology into real world scenario to increase students' interest towards STEM.
- This study does also support previous finding on the positive effect of an integrated STEM learning experiences with active learning environment on students' learning.

in generating new patents, including those that enter the marketplace. The jobs of the future are integrally STEM driven and the foundation of STEM knowledge student receive has been directly linked to the prosperity of the country. It is through proficiency in these STEM fields that our economic and national security will maintain our competitiveness in this global competition.

Thus, to remain competitive in growing global economies that rely on knowledge and innovation-driven industries, it is imperative that we raise students' achievement and enrolment in STEM related subjects. However, recent international assessment on the Malaysian student's performance in science and mathematics shows that student performance is at low. Malaysia's performance in Trends in International Mathematics and Science Study (TIMSS) between1999 to 2011 indicates that student performance has fallen. The results of the 2012 Programme for International Student Assessment (PISA) also showed that Malaysia ranked in the bottom third of 65 participating countries, below the international and Organisation for Economic Co-operation and Development (OECD) average. Parallel to this, according to Martin et al. (2012), a total of 18% of Malaysian children have limited prerequisite knowledge and skills in science classrooms; meanwhile, 55% of them had limited prior knowledge in science.

The number of student who chooses STEM fields also continues to decline in the recent years. In 2011, only 45% of students graduated were from the Science stream, including technical and vocational programmes (Ministry of Education Malaysia (MOE), 2013).

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% (MOE, 2013). 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 (MOE, 2014).

This raises concerns about the education system's ability to produce sufficient STEM graduates for the economy. The National Council for Scientific Research and Development estimates that Malaysia will need 493,830 scientists and engineers by year 2020 (MOE, 2013). At current speed and course, however, the Ministry of Science, Technology and Innovation (MOSTI) (2012) estimate that there will be a shortfall of 236,000 professional in STEM related fields. The current demand for STEM-capable workers surpasses the supply of applicants who have trained for those careers. Given these unmet needs for a STEM-capable workforce, the nation's economic future depends on preparing more students to enter these fields. The declining enrolment in this STEM disciplines is expected to create a shortage of scientists and engineers in the Malaysia workforce in the near future. These figures indicate the need for strong intervention to meet the targeted number of STEM related graduates and to improve future student outcomes.

Previous research showed that students' interest towards STEM related subjects is one of the main factor contributed in the declining in the number of students to choose to enrol in STEM related courses (Subotnik et al., 2010) and has been identified in influencing the decision to choose STEM related fields (Riskowski et al., 2009; Sanders, 2009). Students have lost interest in the domains of science, mathematics, engineering and technology as early as elementary school (before reaching high school) and believe that these areas are not innovative or creative (Marasco & Behjat, 2013). Research do shows that students start to make decisions about their future careers as early as in middle school (Tai et al., 2006), and attitudes and interest changes during middle school have the most long lasting effects than any other time of life (Anderman & Maehr, 1994). Students who indicate that they are interested in pursuing a career in science related field were three times more likely to graduate with a science degree, making career aspirations during middle school an important predictor for STEM professions (Tai et al., 2006). Many researchers have observed the problem of student becoming uninterested in and unmotivated to learn science at a young age (Swarat et al., 2012). Students came into school with strong innate interest in science and the decline of their interest stems from the way science is taught (Krajcik, Czerniak, & Berger, 2003). More alarming, according to MOSTI (2008), only 44.9% of Malaysians are interested in new science inventions or discoveries. These statistics make quite a compelling case that the Malaysian government needs to do more to reach out to those Malaysians who appear to be indifferent to or uninterested in STEM (MOSTI, 2008). As such, there is a great need to spark interest among students in STEM, and to develop and facilitate quality STEM learning experiences among them.

Integrated STEM Education

Curriculum integration was grounded in the tenets of constructivism. Satchwell and Loepp (2002) describe an integrated curriculum as one with an explicit assimilation of concepts from more than one discipline. The idea of curriculum integration is derived from educators' awareness that real world problems are not separated into isolate disciplines that are taught in schools (Beane, 1995; Czerniak et al., 1999; Jacobs, 1989). One of the fundamental problems in schools today is the "separate subjects" or "layer cake" approach to knowledge and skills (Furner and Kumar 2007). Often students cannot solve problems because they do not understand the context in which the problems are embedded (Frykholm & Glasson, 2005). Through curriculum integration, it will provide learning experiences that connect learners' prior knowledge with real world contexts, through integrating meaningful content in real life problem solving setting (Wang et al., 2011).

STEM integration in the classroom is a type of curriculum integration. STEM integration is a curricular approach that combines the concepts of STEM in an interdisciplinary teaching approach (Wang et al., 2011). The goal of integrated STEM education is to be "a holistic approach that links the disciplines so the learning becomes connected, focused, meaningful, and relevant to learners" (Smith & Karr-Kidwell, 2000, p.22). Laboy-Rush (2011) notes that, "integrated STEM education programs apply equal attention to the standards and objectives of two or more of the STEM fields" (p.3). Stohlmann et al. (2012) added that, an effort to combine STEM into one class is based on the connections between the subjects and real world problems. Sanders (2009) argued that the focuses of STEM education should apply knowledge of mathematics, science and engineering, design and conduct experiments, analyze and interpret data, and communicate and corporate with multidisciplinary teams.

STEM integration offers students one of the best opportunities to experience learning in a real-world situation, rather than to learn bits and pieces and then to have to assimilate them at a later time (Tsupros, Kohler & Hallinen, 2009). The separate-subject approach offers little more than a disconnected and incoherent assortment of facts and skills. There is no unity, no real sence to it all. It is as if in real life, when faced with problems or puzzling situations, we stopped to ask which part is science, which part mathematics, which part art, and so on (Beane, 1995). Through STEM integration, it will (1) deepen student understanding of each discipline by contextualizing concepts, (2) broaden student understanding of STEM disciplines through exposure to socially and culturally relevant STEM contexts, and (3) increase interest in STEM disciplines by increasing the pathways for students to enter the STEM fields (Moore, 2008).

Additionally, Morrison (2006) provided the criteria for what an effective STEM instruction should look like in a classroom. She suggested in a STEM integration classroom students should be able to perform as 1) problem solvers, 2) innovators, 3) inventors, 4) logical thinkers, and also be able to understand and develop the skills needed for 5) self-reliance and 6) technological literacy. An analysis of different STEM programs and curricula designs revealed that many researchers and educators agreed on the two major foci of STEM integration: (1) problem solving through developing solutions and (2) inquiry (e.g., Clark & Ernst, 2006; Felix & Harris, 2010; Morrison & Bartlett, 2009; Yasar et al., 2006). Therefore, teaching STEM integration not only needs to focus on content knowledge but also needs to include problem-solving skills and inquiry-based instruction.

Effect of Integrated STEM Education on Students' Learning

Research shows that integrative approaches among science, mathematics, technology and engineering give positive effect on students' learning especially in increasing and improving students' interest and learning in STEM (Becker & Park, 2011). The integration of STEM in the curriculum will increase student achievement in the disciplines (McBride & Silverman, 1991). Besides, teaching STEM disciplines through integrating them would be more in line with the nature of STEM. The nature of the work of most STEM professionals blurs the lines between disciplines, thus integrated STEM education can make learning more relevant and meaningful for students (Stohlmann et al., 2013). It can improve students' attitudes toward STEM subjects, improve higher level thinking skills, and increase achievement (Stohlmann et al., 2013). STEM learning experiences prepare students for the global economy of the 21st century (Hynes & Santos, 2007).

Previous research has found that traditional didactic lecture may lead to memorization of factual information, but often fail to elicit comprehension of meaningful learning (Loverude, Kautz & Heron, 2002; Wright et al., 1998). Meaningful learning occurs when learners make connections between prior knowledge and new experiences and skills within real world contexts (Brooks & Brooks, 1993). Hirst (1974) pointed out that separated subject areas restricted learning by making learners alienated from real world experiences. Curriculum integration give students more meaningful learning experiences by connecting disciplinary knowledge with personal and real world experiences (Beane, 1995; Capraro & Slough, 2008; Childress, 1996; Jacobs, 1989; Sweller, 1989). Students stated that lesson content that they perceived as personally "meaningful" and interesting are topics that were important in or related to their daily lives (Mitchel, 1993; Palmer, 2009). The form of activities (i.e., the use of group work, computers, puzzles) through which learning took place also played an important role in influencing student interest (Palmer, 2009).

CONCEPTUAL FRAMEWORK

STEM integration can occur in multiple ways. It may include different combinations of the STEM disciplines, emphasize one discipline more than other, be presented in a formal, non-formal or informal setting, and involve a range of pedagogical strategies (NAS, 2014). Additionally, the integration can be such that all content areas are emphasized or one is the focus and the others are used as context to learn disciplinary content. One model suggests that "integrative" STEM education must include technological or engineering design as a basic for creating connections to concepts and practices from mathematics or science (or both) (Sanders, 2009). Engineering design is the process that engineers use to solve engineering problems and to develop product. It also encapsulates the essence of the engineering profession. Engineering can act as a connector for meaningfully learning the content of mathematics and science (Moore et al., 2013). Bryan et al. (2016) stated that, one of the core characteristic of integrated STEM learning experiences include instruction in which the integrator is the engineering practices and engineering design of technologies as the context and/or an intentional component of the content to be learned. They added that the engineering design or engineering practices related to relevant technologies requires the use of scientific and mathematical concepts through design justification.

Engineering design has been treated as a pedagogical strategy to bridge science and mathematics concepts in use of solving ill-defined (open-ended) problems, developing creative thinking, formulating solutions and making decisions, and considering alternative solutions to meet a variety of constrains (Samsudin et al., 2007; Wang et al., 2011; Yasin et al., 2012). Engineering requires the use of scientific and mathematical concepts to address the types of ill-structured and open-ended problems that occur in the real world (Sheppard et al., 2009). Using engineering design as a context for these problems is a natural way for students to learn through STEM integration. Using engineering contexts as spaces for students to develop real-world representations can be the catalyst for developing related scientific and mathematical concepts through using multiple representations (concrete models, pictures, language, and symbols) and facilitating translations between and among them (Moore et al., 2013).

Engineering design activities in classrooms support an interdisciplinary approach that incorporates knowledge of science, mathematics, and technology (Brophy et al., 2008; Thornburg, 2009), as well as problem solving, creative thinking, and communication skills (NRC, 2009; Lewis, 2006; Roth, 2001; Thornburg, 2009). Engineering design activities can motivate students learning of the mathematics and science concepts that make technology possible (Moore et al. 2013). Research also provides evidence that integrating engineering design activities into mathematics and science courses benefits students' learning of the content of mathematics and science (Cantrell et al., 2006; NRC, 2009). Therefore, giving the importance of teaching engineering design in school, given the need to increase the pathways into engineering and the evidence that bridging the STEM disciplines is beneficial for students, it is imperative that students be given the opportunities in school to learn about engineering and participate in engineering design either in their formal, informal or non-formal education.

However, many research on the impact of engineering design in STEM integration focused on upper secondary grades and college years, those for the younger grades appear limited (English & King, 2015). This could be due partly to the view that design processes are too complex for the younger grades. Thus, given that the bulk of the research has targeted older learners, there is the need for an integrated STEM activities that uses engineering design framework that also takes into account the younger grades to improve students learning especially interest towards STEM, as research has shown that as interest changes during middle school have the most long lasting effects on interest than any other time of life. These

Table 1. Engineering Design Cycle (Museum of Science-Boston, 2009)

Design process	Description
Ask	What is the problem? How have others approached it? What are your constraints?
Imagine	What are some solutions? Brainstorm ideas. Choose the best one
Plan	Draw a diagram. Make lists of materials you will need.
Create	Follow your plan and create something. Test it out!
Improve	What works? What doesn't? What could work better? Modify your designs to make it better. Test it out!

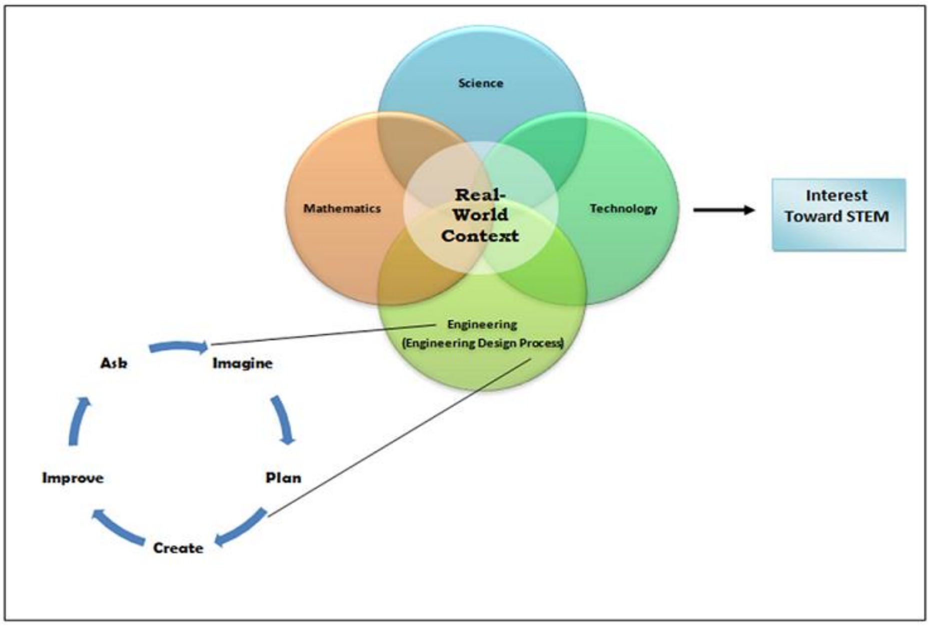


Figure 1. Conceptual framework of Bitara-STEM: Science of Smart Communities

years are when students consider future career and academic pathways (Singh, Granville & Dika, 2002). Students with more confidence in STEM subject are more likely to pursue careers in math and science (Herbert & Stipek, 2005).

One of the most important characteristics of effective science curriculum is early timing and interventions. Interventions should occur prior to high school in order to be effective (Subrahmanyan & Bozonie, 1996). Thus, for the purpose of this research we use engineering design framework proposed by Museum of Science-Boston (2009) that take into account the younger grades. The application of engineering design process in the module is based on the five cycle as; (1) *ask,* (2) *imagine,* (3) *create,* (4) *test*, and (5) *improve* (**Table 1**). The application of STEM content knowledge during the design processes will be the key component of students' learning in solving engineering-based problem. The context of instruction requires solving the real-world problem or task through teamwork.

Bitara-STEM: Science of Smart Communities is an STEM integrated program that use engineering design process as bridge to connect STEM subjects together. The conceptual

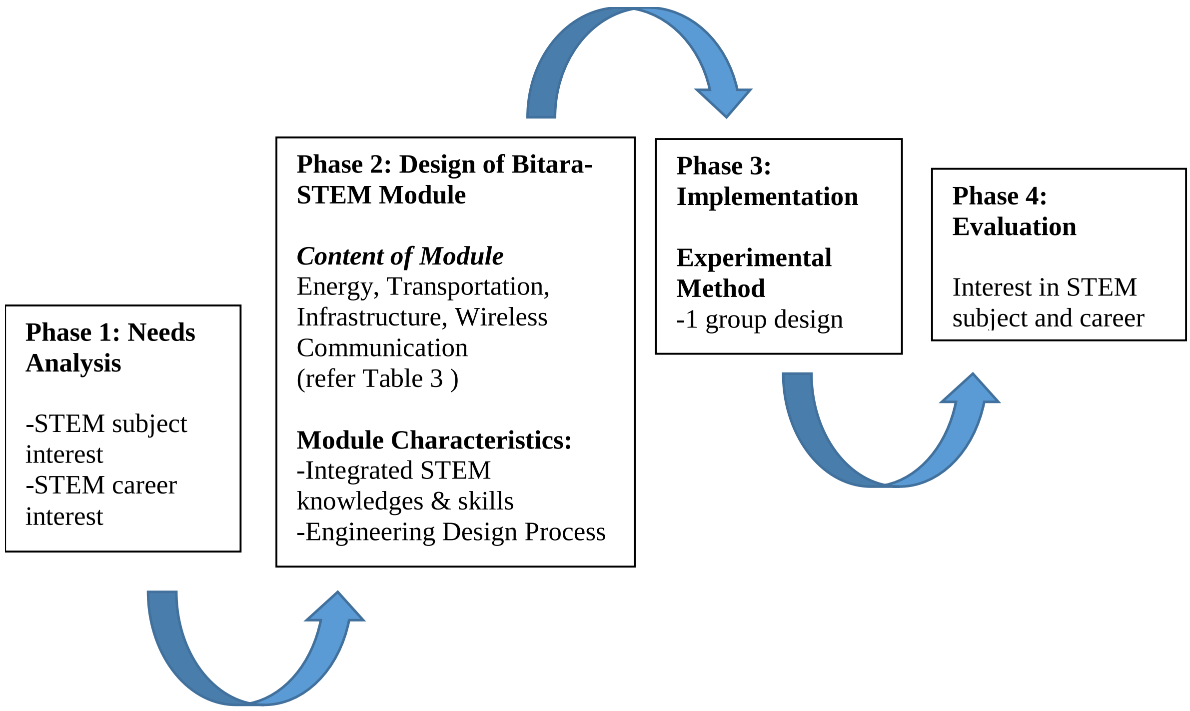


Figure 2. Bitara-STEM: Science of Smart Community Module Development Process Conceptual Framework

framework of *Bitara-STEM* has several steps and phases (refer **Figure 2**). The first phase is the needs analysis that is to identify problems related to the STEM education aspects. Identification and assessment of STEM integration content created and confirmed by several experts before proceeding to the second phase. The second phase of the *Bitara-STEM* Module construction is the design phase. Features of the *Bitara-STEM* Modules were developed involving the application of engineering design process through solving real-world problem where STEM content knowledge was applied. Phase third phase is the implementation of the programme. The study utilized experimental method with one group design. Finally, on the fourth phases, the effectiveness of the programme on students' interest towards STEM subjects and careers were measured.

Research Questions

The aim of this study was to assess the impact of the *Bitara-STEM: Science of Smart Communities* program on participants' interest towards STEM by using a one group quasi-experimental design. The participants were pre- and post-tested on their interest towards STEM subjects and careers and examine the outcomes for significant changes. This study was guided by the following research questions:

RQ1. Were there significant changes in the participants' interest towards STEM subjects?

Table 2. Students activities in Bitara-STEM: Science of Smart Communities

Day	Activities
Day 1 to 3	Participants were divided into four groups and were given the different module of *Bitara-STEM: Science of Smart Communities*. Each group will complete all the activities in the modules in separated room. A group of facilitators will be assigned to facilitate students in completing the activities.
Day 4	On day 4, all student from each group will be divided to form 10 groups consist of members from each modules. Each group will be assigned to build a replica of *Smart-cities*. They will collaborate and use the knowledge and skills gained during previous session to complete the task
Day 5	Showcase the '*Smart-Cities Model*'. Students' communicate their replica of smart cities to the visitors Guest speaker (several professors form the local university) provided workshops in STEM related topics (eg; geology, forensic science, sustainable energy, solar panels, just to name a few) to expose participants in STEM related careers.

RQ2. Were there significant changes in the participants' interest towards STEM related careers?

RQ3. What were the participants' response categories on interest towards STEM subjects and interest towards STEM related careers.

METHODOLOGY

Bitara-STEM: Science of Smart Communities

Bitara-STEM; Science of Smart Communities is an integrated STEM education programme in non-formal settings conducted by Faculty of Education, National University of Malaysia (UKM) to spark interest towards STEM and provide fun learning experience among middle secondary school students. The programme measures student levels of interest towards STEM to determine whether project activities have a positive impact on students. The first pilot programme was held during June, 2013, serving 65 students. *Bitara-STEM* programme used project-based activities divided into four separated modules namely Energy, Urban Infrastructure, Transportation, and Wireless Communication. The activities in the modules use engineering design process as a bridge to connect STEM subjects together. Through these activities, engineering design process can act as a catalyst to improve student learning and achievement in science and mathematics by providing a gateway to turn the abstract science and mathematics concepts into concrete real-life applications. At the same time, building an engineering project will also serve as a pedagogical strategy that combines problem solving, creative thinking skills and presentation skills in other STEM subjects. This overall module is given a 5 days (**Table 2**). 35 facilitator (post graduate students) in the fields related to STEM were involved to facilitate students' learning during the programme (17 of them were science and mathematics teachers, 80% of the facilitators hold degrees in science related fields while the remaining was in engineering). All facilitators involved were received professional development programme (called *The Bitara-STEM Training of Trainer programme*) that provided

Table 3. Units of intervention and activities

Modules	Units	Example of Activities
Energy	Introduction of Newton's Law & Electrical Basics Worldly environment Power generation Power storage Biomimicry	Solar Car
Transportation	Modes of transport Smart transportation Smart highways Intelligent transportation systems. Traffic engineering	Smart Transportation (Anti Collision Line Follower)
Wireless Communication	Smart electronics basics Real time communication Space based wireless communication Internet and communication network. Smart wireless communication	Home Automation
Urban Infrastructure	Environmental engineering Soil and land development Building towards to the future Recycling and waste management Natural disasters	Earthquake Town

integrated STEM teaching and learning experiences for STEM facilitators prior to the implementations of *Bitara-STEM* activities to the secondary students.

Bitara-STEM Module

Bitara-STEM modules consist of four different module named *Energy Module*, *Urban Infrastructure Module*, *Transportation Module* and *Wireless Communication Module*. The curriculum includes a variety of STEM activities from Earth science, physical science, and life science, with daily themes overlapping these three content areas. These topic was selected as it reflect the elements in a model of smart cities and can exposed students on multiple role of STEM professional (especially engineers and scientist) in various fields. **Table 3** shows units involved in each module and the example of the activity. Each module consists of a few different project-based activities that involve the integration of STEM knowledge and skills in the context of instruction require solving a real-world problem. The modules were adapted from previous module (*Science of Smart Cities*) developed by New York University Polytechnic School of Engineering (NYU-Poly). The content of the module were then modified to infuse engineering design process and to suit it contents to the Malaysian context by a group of researcher from various fields related to STEM and STEM Education from National University of Malaysia (Faculty of Education, Faculty of Engineering and Faculty of Science & Technology). **Figure 3** provide example of the content or skills of STEM in one of the activity in the module.

Module: Energy Activity: Solar Car			
Science	**Mathematics**	**Engineering**	**Technology**
Solar panel : Electricity generation principal, lever principal	Illuminating angle	Engineering design process: **Ask**: Can the solar car move? **Imagine**: Design the shape of the solar car **Create**: According to the results of discussion, select appropriate body of trolley and materials for tires and decide where to place motor, solar panel and gears **Test**: Test the solar car performance **Improve**: Make changes to improve the solar car performance	Assembling, fixing, sticking technology
Electromotive force (EMF): Fleming's left hand rules	Voltage, power, force, current, magnetics field		
Velocity: Physical strength, drag, gear ratio	Ratio		
Stability: Friction force, normal force, external force	Gravity, weight		

Figure 3. Example of the activity from Energy Module

Participants

Participants of the programme were lower secondary students (13-14 years old) from selected secondary school in Malaysia. This study involved participants form *Bitara-STEM* programme held on 2014 and 2015. The number of participant for the 2014 programme was 205, however only 129 (59.5% female, 40.5% male) completed both pre and post-survey. While the number of participant for the 2015 programme were 141, however only 113 (60.3% female, 39.7% male) completed both pre and post-survey. 94.1% of participants in 2014 and 100% participants in 2015 were students in the high achiever categories (scored A in Science and Mathematics subjects in national level examination called UPSR). The 2014 *Bitara-STEM* cohort were held in Maktab Rendah Sains Mara, Trolak, Perak on 31st May to 6 Jun 2014, while the 2015 programme were held on Faculty of Education, National University of Malaysia on 1st to 4 Jun 2015.

The Survey Instrument

To measure the interest towards STEM related careers, *STEM Career Interest Survey (STEM-CIS)* (Kier et al., 2013) was modified. The *STEM-CIS* was developed based on *Social Cognitive Career Theory* (Lent et al. 2008) to measure STEM Career interest and the effects of STEM programs on changes in middle school student interest in STEM subjects and careers. *STEM-CIS* has been reported in previous study (e.g. Gardere et al. 2015; Unlu et al. 2016; Vaino et al. 2015) as being valid and reliable to measure changes in student interest in STEM subjects and potential careers as a function of the intervention. For the purpose of this study, items related to student interest in STEM career only were used (N=28). Examples of items are '*I am interested in careers that use science*', '*I am interested in careers that use engineering*' and '*I plan to use technology in my future career*'. Items from the *STEM-CIS* that did not directly measured students interest towards STEM career instead measure students interest in STEM were removed (e.g. *I like my science class; I am able to complete my math homework; I am able to learn new technologies; I like activities that involve engineering*). While, to assess the impact of the programme activities on student interest toward STEM related subjects, some of the items were modified from the scale measuring Enjoyment of Science Lesson and Leisure Interest in Science in *Test of Science-Related Attitudes* (Fraser, 1981) and some were developed by the researcher. Example of items are, *'I like mathematics', 'Science lessons are fun', 'Mathematics lessons are fun' & 'I look forward to science lesson'.* The total number of items to measure interest towards STEM subjects was 16 items. Both the questionnaire included 44 items to which students responded by selecting one of five options ranging from "1" representing "Strongly Disagree" to "5" representing "Strongly Agree". Items were translated into Malay language by the authors. Back translation was then performed on the Malay items ie. from Malay to English by English and Malay Language experts to ensure validity. Both surveys were piloted using the pre-test scores on 2014 programme. The Cronbach's alpha for both the measure of interest towards STEM subjects was found to be 0.85 and for measure of interest towards STEM careers was 0.86, indicating a high level of reliability.

Research Design, Procedures & Data Analysis

This study used one group experimental method. Pre-survey were administered at the beginning of the programme by the facilitators in order to determine students pre-existing interest toward STEM subjects and careers. At the end of the programme, post-survey were administered to the students. Pre- and post-survey were matched by using students' identification number. Researchers used content analysis to sort pre- and post-surveys according to student response pattern. The primary analysis allowed researchers to sort surveys into nine broad groups: 1) remained high; 2) remain moderate; 3) remain low; 4) high to moderate; 5) high to low; 6) moderate to high; 7) moderate to low; 8) low to high and 9) low to moderate. Frequency counts were conducted on the nine categories. The range of mean score for high level of interest was (3.67-5.00); moderate (2.34-3.66); and low (1.00-2.33). This study involved students' group from 2014 and 2015 cohort to see the consistency of the impact of the programme on students' interest towards STEM.

RESULTS

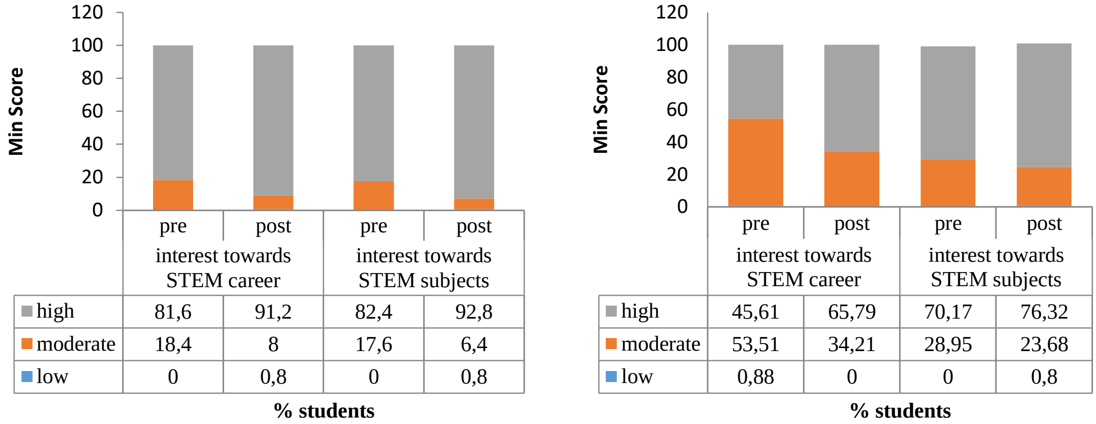
RQ1 & RQ2: Level of Interest toward STEM Subjects and Careers

The means, standard deviations, t-test scores, and p-values are shown in **Table 4**. To conduct this analysis, the data matching all pre-test scores to post-test scores were conditioned. A series of pair sample t-test were conducted using pre and post-test scores. The analysis

Table 4. Means, standard deviations, t-test, and level of significance for the student' interest toward STEM subject and interest toward STEM career

Aspect		2014 (N=129) Mean	S.D	Level	Paired Sample t-test t	p	2015 (N=113) Mean	S.D	Level	Paired Sample t-test t	p
Interest toward STEM career	Pre	4.24	0.56	High	2.50	.014*	3.59	0.45	Mdrt	6.62	.000*
	Post	4.36	0.63	High			3.82	0.43	High		
Interest toward STEM subject	Pre	4.11	0.77	High	2.40	.018*	3.98	0.39	High	2.57	.011*
	Post	4.27	0.79	High			4.05	0.43	High		

**significant at 0.05*



2014	interest towards STEM career pre	post	interest towards STEM subjects pre	post
high	81,6	91,2	82,4	92,8
moderate	18,4	8	17,6	6,4
low	0	0,8	0	0,8

2015	interest towards STEM career pre	post	interest towards STEM subjects pre	post
high	45,61	65,79	70,17	76,32
moderate	53,51	34,21	28,95	23,68
low	0,88	0	0	0,8

Figure 4. Level of students' interest towards STEM

revealed that the mean scores for students' interest towards STEM subjects and career increases in value for both 2014 and 2015 cohorts after participating in the programme, this increase is significant for interest towards STEM career and interest towards STEM subjects ($p<0.05$) for both cohorts of students. Finding shows that students' level of interest on pre and post-test were at high level for both interests towards STEM subjects (for both 2014 and 2015 cohorts). While for interest towards STEM careers, interest level for 2014 were remain at high level, but for 2015, the level of interest has changed from moderate to high level.

Figure 4 shows the percentages of students according to the level of interest towards STEM subjects and careers on pre and post-test. As described in Figure 4, both the 2014 and 2015 cohorts of students reported that the percent of students with high level of interest towards STEM career (91.2% and 65.79%, respectively) and subjects (92.8% and 76.32%, respectively) increase after the programme.

Table 5. Student response categories

	2015 (N=113)		2014 (N=129)	
	Interest towards STEM Subjects	**Interest towards STEM Careers**	**Interest towards STEM Subjects**	**Interest towards STEM Careers**
Response Categories	n (%)	n (%)	n (%)	n (%)
Remained High	71 (88.75)	48(92.31)	98(90.74)	102(96.23)
High to Moderate	9 (11.25)	4(7.69)	5(4.63)	4(3.77)
High to Low	0	0	5(4.63)	0
Total	80 (100)	52 (100)	108 (100)	106 (100)
Remained Moderate	18 (54.54)	35(57.38)	3(14.29)	6(26.09)
Moderate to High	**15 (45.46)**	**26(42.62)**	**18(85.71)**	**16(69.56)**
Moderate to Low	0	0	0	1(4.35)
Total	33 (100)	61 (100)	21 (100)	23 (100)
Remained Low	0	0	0	0
Low to Moderate	0	0	0	0
Low to High	0	0	0	0

RQ3: Student Response Categories

Table 5 shows student response categories for interest towards STEM subjects and STEM careers. It is encouraging to note that both the 2014 and 2015 cohorts of students indicated a positive interest change (from moderate to high) for interest towards STEM subjects (13.27 and 14.4%, respectively) and careers (23.01 and 12.8%, respectively). Further analysis has been made for these positive changes (moderate to high) to identify the percentage of participants' interest level that shift from moderate to high level (as shown in Figure 5). For interest towards STEM subjects, the table shows that the total number of student with moderate levels of interest for both 2014 and 2015 cohorts before the intervention (pre) was 21 students and 33 students respectively. However, after the program (post), the percentage of student that shifts to high level was 85.71% (n=18) and 45.46% (n=15) respectively (Figure 5C & 5A). While for the interest towards STEM careers, the total number of students with moderate level of interest for both 2014 and 2015 cohorts before the intervention was 23 and 61 students respectively. After the intervention, the percentage of students that shift to high level was 69.56% (n=16) and 42.62% (n=26) respectively (Figure 5D & 5B).

DISCUSSION

While the impact of integrated STEM education program to increase students' interest towards STEM are acknowledged in the literature, however the impact of engineering design in STEM integration learning environments especially in non-formal setting for the younger

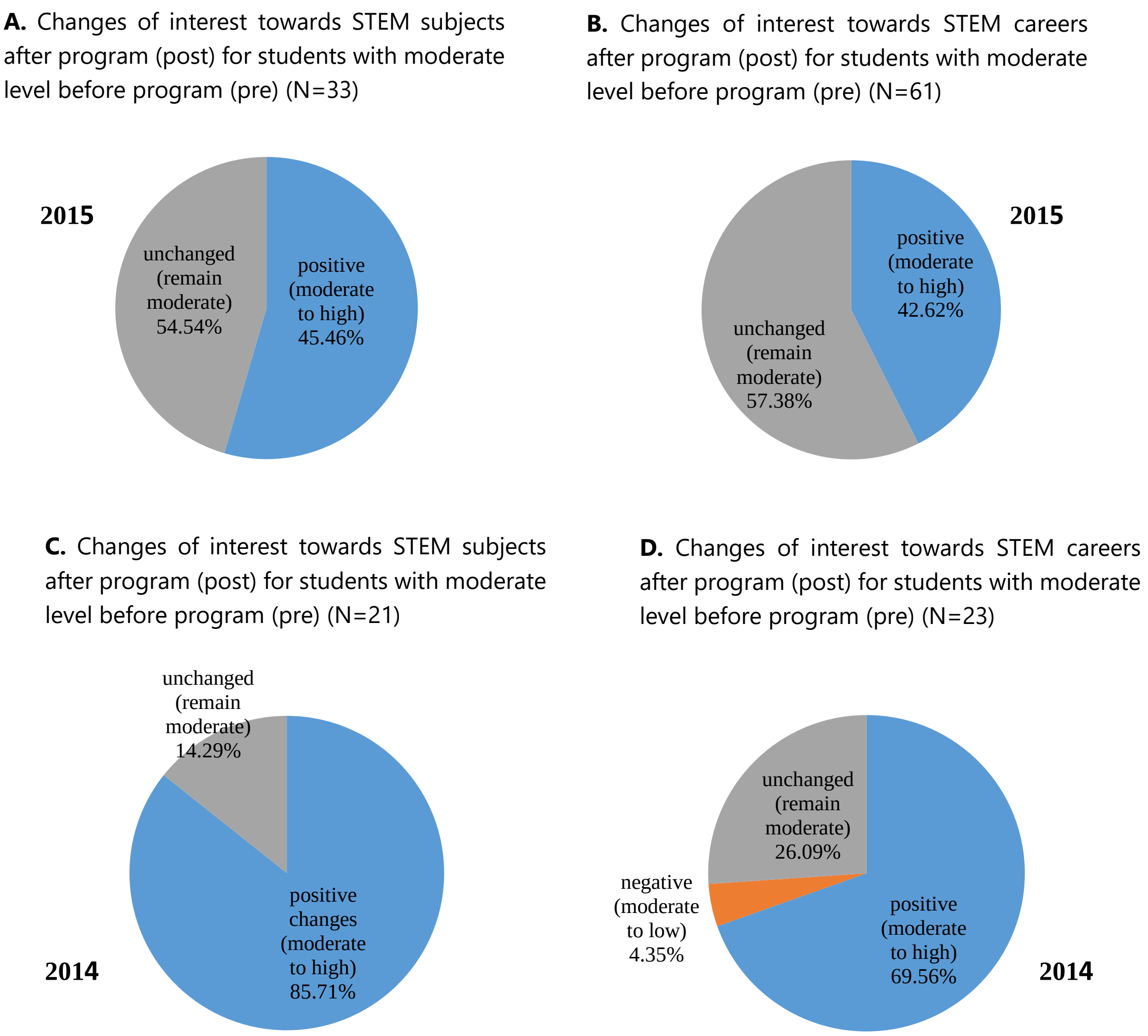


Figure 5. Changes of interest towards STEM after intervention (post-test) for student with moderate level of interest towards STEM before intervention (pre-test)

grades appear limited. Our study has provided an example of how middle secondary school students can engage in processes of engineering design as a context to connect science, mathematics and technology into real world scenario to increase students' interest towards STEM. Overall, the findings of this study have revealed that our participants' interest towards STEM related careers and subjects' increases significantly after participating in the program. Percentages of students with high level of interest towards STEM subjects and STEM careers also increase after participating in the program for both cohorts (Figure 4). The findings from two different cohorts show that the ability of the *Bitara-STEM: Science of Smart Communities* programme to increase the participants' interest towards STEM related subjects and careers were consistence.

It is also encouraging to note that, further analysis on students' response categories for both cohorts of students (**Table 5**, **Figure 5**) indicate that our STEM integration intervention was effective at modifying our participants' level of interest towards STEM related subjects and careers. More than 40% of students from 2014 cohort and 60% of students from 2015 cohort that were at moderate level of interest prior to the program (pre) has shift to high level after the intervention program (post) for both interest towards STEM subjects and careers. The outcomes of this study provide evidence that exposing early secondary to engineering design process in integrated STEM education has positive impact on modifying students with moderate level of interest towards those STEM subjects and related careers. The demography of the participants participates in this programme were student with high achievement in Science and Mathematics subjects in school (Score A in national level assessments - 92% (2015) & 97% (2014) in Science and 97% (2015) & 96% (2014) in Mathematics). Thus, it can be concluded that the programme were effective on modifying the high achiever students that have moderate level to shift to high level of interest in STEM related subjects and careers. As reported by Ministry of Educations, 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% (MOE, 2013). Our finding provides offer one of the possible solutions in overcoming this scenario.

The ability of this intervention to significantly influence students' interest towards STEM related subjects and careers may also be attributed to the integrated structure module, which was designed to attend to a wide range of educational needs and student learning. These intervention programmes utilized several promising practices for encouraging student STEM interest. Students participated in *hands-on* learning activities with clear applications for the real world. They used professional scientific tools, and interacted with STEM professionals (facilitators with degree in engineering and science related background). Students' learning experiences included small group work and collaborative problem solving. Parent involvement was encouraged: parents were invited to attend their child's presentation on a smart city model community as an audience. As the programme was five days long, students' engagement with these "promising practices" was more in-depth than that offered by a one-day workshop. Thus, it can be concluded that the experiential features of our programme that provide participants with experience in conducting the integrated STEM activities by themselves appears to be having positive effect on students' affective variables especially in their interest towards STEM related subjects and careers.

In general, conducting *hands-on* activities in STEM related classes is widely recommended by educational authorities. Many *hands-on* activities offer the potential to positively influence students' interests in the activities (Holstermann et al., 2010). Practical work, or so-called *hands-on* experience, is one situational factor that is often assumed to evoke students' interest and to motivate them to learn science (Bergin, 1999). Most empirical studies provide evidence for the assumption that conducting *hands-on* activities leads to positive motivational outcomes (Holstermann et al., 2010). Prior studies indicate that students who participate in *hands-on* research report improvement in GPA, successful completion of science course, and increased desire to pursue STEM degrees (VanMeter-Adams et al., 2015). Activities that were "*hands-on*" in nature and those that involved the use of scientific instrument or technology elicited higher interest (Swarat et al., 2012). A study by Palmer (2009) also found out that student interest was much higher during the experiment and demonstration phase than during the proposal and report phases. Palmer (2009) found that three main sources of interest which are novelty, autonomy, and social involvement. Thus, having students actively participate in authentic activities similar to those in which professionals participate holds great potential for promoting student interest and engagement (Blumenfeld, Kempler, & Krajcik, 2006). Our study supported this finding, and suggested that this effect is most likely due to the active nature of these integrated STEM instruction as described above. We conclude from this study that well-structured engineering experiences where students were provided with opportunities to engage in the design processes connected to a real-world problem through applying integrated STEM knowledge and skills were effective at increasing their interest towards STEM.

Even though majority of students that were at high level before the intervention remain at this level after completing the programme, there were also students with high level of interest at the beginning that shift to moderate level after completing the program. This could be due to the experiences that they gain were unable to motivate their learning. As stated by Krapp (2005), the quality of experience during task completion is also an important factor for the development of students' intrinsic motivation. Interest development will occur if a person experiences his or her actual engagement on the basis of cognitive-rational and emotional evaluations in a positive way (Krapp, 2005). Therefore, interest will be strengthened when a person experiences a learning activity as enjoyable, pleasant, stimulating and important. Positive emotions such as enjoyment correlated positively with students' interest and intrinsic motivation (Pekrun et al., 2002; Schiefele, 1991). Experiences that promote positive attitudes could have very beneficial effects on students' interest and their learning (Hofstein & Lunetta, 2003). Thus, the shift of interest towards STEM to positive or negative could be due to the difference experiences that the students' gain from the programme. Students engaged in challenging academic work, such as project-based learning may categorize into two different patterns. As stated by Meyer et al. (1997), there were two patterns of student self-perceptions and behaviours in project-based instruction –"challenge seekers" and "challenge avoiders". Challenge seekers self-reported a tolerance for failure, a learning goal orientation, and a higher than average self-efficacy in math. Challenge avoiders self-reported a higher negative affect after failure, a more performance-focused goal orientation, a lower self-efficacy in math, and greater use of surface strategies (i.e., strategies requiring minimal processing of information). Thus, the differences in the program on changing students interest could also possibly be due to this experiences pattern that students gain from the programme as described by Meyer et al. (1997).

LIMITATIONS

However, this study has some limitations. The first limitation was, that the study only involved one group and with small number of participants. Since the design did not include a control or comparison group, it is not possible to attribute the results of this study to the programme alone, nor is the results generalizable. Interpretation of the findings should take into account that the control group does not exist and we are reporting the responders' perceptions. Therefore, this finding suggests that future study could do a two group design with large number of participants. The second limitation was the configuration of our study population. The participants in our study were students with high achiever (students who have strong talent in STEM), and therefore may not be representative of the larger student population. Additional research with a broad selection of student with a wide range of achievement level may be needed to fully substantiate our findings. The limitations of our study provide excellent contexts and directions for future investigation in this line of STEM education research.

CONCLUSION

The *Bitara-STEM: Science of Smart Communities*, an integrated STEM Education programme was developed to increase students' interest towards STEM subjects and STEM related careers. The participants of this programme were revealed to have significant increases in their interest in relation to the interest towards STEM subjects and STEM related career. The major conclusion of this study is that these findings indicate that our short-term non-formal integrated STEM intervention was effective at modifying our participants' interest towards STEM. The increase of mean score of interest and ability to modify students interest has provided an example of how early secondary can engage in processes of engineering design and apply disciplinary knowledge in solving a meaningful an appealing problem. The outcomes of this study provide evidence that exposing early secondary to engineering design process in integrated STEM education has positive impact on their level of interest towards those subjects and related careers. The program was also effective at increasing the student with moderate level of interest to high level of interest towards STEM.

These data provide insight that can be influences initiatives for STEM education. Because STEM learning through engineering design in non-formal integrated STEM settings is highly influential as the initial attractors for students with a potential talent in STEM, community-based programs that create awareness and provide opportunities for those 'magical' encounters with STEM for children and their family members should be strongly encouraged. The ability of a four-day intensive intervention to bring about change in these variables provides the justification for offering these opportunities to students, for our data suggests the experience can be transformative in multiple ways. Students at this age may lack exposure to the career possibilities in the STEM fields and therefore may be making decisions about career choices without accurate information. This study does also support previous finding on the effect of an integrated STEM learning experiences with active learning environment on students' learning.

Further research should be studied to explore the reason for those changes. Understanding the factors involved will help further researchers improve and design programs that produce large positive changes on the variables being studied. The long-term effects of this study are also not known. How long the interest in pursuing a STEM careers may remain could be a further investigation. Thus, follow up studies will be done to identify the long-effect of this study in STEM interest. Future studies should also include other sources of data to triangulate the data and strengthen findings.

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