DEVELOPMENT AND EVALUATION OF AN INTEGRATED STEM THROUGH ENGINEERING DESIGN MODULE TOWARDS STUDENTS' ACHIEVEMENT, CRITICAL THINKING SKILL AND STEM CAREER INTEREST

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by

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ABSTRAK

Pelaksanaan STEM di Malaysia perlu mengenal pasti bahan pembelajaraan yang efektif yang dapat mempengaruhi pencapaian pelajar, kemahiran berfikir secara kritis dan minat kerjaya STEM. Selaras dengan itu, kajian ini telah dijalankan dengan membangunkan dan menilai keberkesanaan modul bersepadu sains, teknologi, kejuruteraan dan matematik melalui proses reka bentuk kejuruteraan (iSTEM-EDP) untuk topik Nutrisi bagi pelajar tingkatan empat sekolah menengah. Modul ini telah dibangunkan berdasarkan teori Konstruktivisme, Teori Kognitif Situasi dan Teori Kerjaya Kognitif Sosial dengan menggunakan Model ADDIE. Amalan sains dan kejuruteraan dan konsep merentas STEM dari NGSS telah diintegrasi dalam Kurikulum Bersepadu Sekolah Menengah bagi subjek Biologi Tingkatan Empat untuk membentuk pembelajaran berasaskan pendekatan STEM-EDP. Setelah dibangunkan dan dinilai, modul iSTEM-EDP dilaksanakan di salah sebuah sekolah yang terletak di Wilayah Utara Malaysia untuk mengenal pasti keberkesananya. Kajian ini berbentuk penyelidikan kuasi eksperimen. Kumpulan eksperimen telah mengikuti Modul iSTEM-EDP manakala kumpulan kawalan menggunakan kaedah konvensional untuk mempelajari topik Nutrisi. Ujian pra-ujian, pos ujian dan ujian pos lanjutan diberikan kepada kedua-dua kumpulan menggunakan tiga instrumen iaitu Ujian Pencapaian Topik Nutrisi, Penilaian Pemikiran Kritikal Watson-Glaser dan Soal Selidik Minat Kerjaya STEM. Analisis statistik menggunakan ANCOVA mendedahkan bahawa nilai min

untuk pencapaian [F (1,79) = 58.85, p <0.05, η^2=0.43] dan pemikiran kritikal [F (1, 79) = 34.16, p < .05, η^2 = 0.31] adalah lebih tinggi untuk kumpulan eksperimen berbanding dengan kumpulan kawalan dalam ujian pasca selepas pengaruh ujian pra telah dikawal. Begitu juga, ujian statistik *repeated measure ANCOVA* yang menunjukkan bahawa nilai skor min untuk pencapaian [F (1, 77) = 72.40, p < 0.05, η^2 = 0.54] dan pemikiran kritikal [F (1, 77) = 33.20, p < 0.00, η^2 = 0.26] adalah lebih tinggi untuk kumpulan eksperimen berbanding dengan kumpulan kawalan dalam ujian pasca tertunda apabila pengaruh ujian pra adalah kawalan. Dapatan kajian menunjukkan bahawa Modul iSTEM-EDP adalah berkesan dan mampu mengekalkan pencapaian dan kemahiran berfikir kritis pelajar dalam kumpulan eksperimen ketika membandingkan dengan kumpulan kawalan. Walau bagaimanapun, corak ini tidak dapat diperhatikan untuk pemboleh ubah bersandar ketiga yang merupakan minat kerjaya STEM. Analisis statistik yang menggunakan ANCOVA mendedahkan bahawa nilai min untuk minat kerjaya STEM adalah lebih tinggi untuk kumpulan eksperimen berbanding dengan kumpulan kawalan dalam ujian pasca setelah pengaruh pra-ujian dikawal [F (1, 79) = 1062.99, p < 0.05, η^2 = 0.93]. Namun, analisis *repeated measure ANCOVA* menunjukkan nilai min skor bagi minat kerjaya STEM adalah lebih rendah untuk kumpulan eksperimen berbanding dengan kumpulan kawalan [F (1, 77) = 388.92, p < 0.05, η^2 = 0.53]. Ini menunjukkan bahawa modul ini berkesan dalam meningkatkan minat kerjaya STEM tetapi tidak mampu mengekalkannya di kalangan kumpulan eksperimen. Analisis lanjut mengenai minat kerjaya STEM sahaja menggunakan MANOVA dan *repeated measure ANOVA* menunjukkan bahawa minat dalam sains dan matematik tidak berubah dengan ketara di mana minat dalam kerjaya teknologi meningkat dengan ketara dan dikekalkan juga semasa ujian pasca tertunda. Minat karier kejuruteraan pula menunjukkan peningkatan signifikan dalam ujian pasca dan penurunan signifikan dalam ujian pasca tertunda.

Suatu temu bual yang dijalankan dengan empat orang profesional dari bidang sains, teknologi, kejuruteraan dan matematik menjelaskan secara lebih lanjut mengenai corak data yang diperoleh dan cara untuk memperbaiki modul tersebut. Implikasi kajian seperti penumpuan terhadap teori minat kerjaya bersama dengan teori berkenaan dengan pengajaran dan pembelajaran, pengunaan modul interdisiplinari untuk menigkatkan mutu proses pengajaran dan pembelajaran STEM dan memberi kesedaran terhadap kerjaya STEM sebagai suatu bidang interdisiplin kepada pelajar telah dibuat.

DEVELOPMENT AND EVALUATION OF AN INTEGRATED STEM THROUGH ENGINEERING DESIGN MODULE TOWARDS STUDENTS' ACHIEVEMENT, CRITICAL THINKING SKILL AND STEM CAREER INTEREST

ABSTRACT

Current initiation of implementing STEM in Malaysia required effective instructional material that able to effect students' achievement, critical thinking skill and STEM career interest. In line with that, this study had developed and evaluated an integrated science, technology, engineering and mathematic through engineering design process (iSTEM-EDP) module for the topic Nutrition that was intended for Form Four secondary school students. This module was developed based on Constructivism Theory, Situated Learning Theory and Social Cognitive Career Theory using ADDIE Model. The science and engineering practice and crosscutting concepts from NGSS fused into Malaysia's National Curriculum for Form Four Biology to form an interdisciplinary learning using STEM through engineering design process. Upon developing and validating, the module was implemented in one of the school in Northern Region of Malaysia. The quasi experimental research design was used to conduct this study. The experimental group followed the iSTEM-EDP Module whereby the control group used conventional method to learn the topic Nutrition. The pre-test, post-test and delayed post-test was administered upon both groups using three instruments namely the Nutrition Test, Watson-Glaser Critical Thinking Appraisal and STEM Career Interest Survey. The statistical anlysis using ANCOVA revealed that the mean value for achievement [F (1,79) = 58.85, $p < 0.05$, $\eta^2 = 0.43$] and critical thinking

[F (1, 79) = 34.16, $p < .05$, $\eta^2 = 0.31$] is higher for experimental group compare to the control group in the post-test when the influence of the pre-test was control. Similarly, the repeated measure ANCOVA showed that the mean score value for achievement [F (1, 77) = 72.40, $p < 0.05$, $\eta^2 = 0.54$] and critical thinking [F (1, 77) = 33.20, $p < 0.00$, $\eta^2 = 0.26$] is higher for experimental group compare to the control group in the delayed post-test when the influence of the pre-test was control. The finding revealed that the iSTEM-EDP Module was effective and also able to retain achievement and critical thinking skill of learners in experimental group while comparing to the control group. However, this pattern was not observed for the third dependent variable which is STEM career interest. The statistical analysis using ANCOVA revealed that the mean value for STEM career interest is higher for experimental group compare to the control group in the post-test when the influence of the pre-test was control [F (1, 79) = 1062.99, $p < 0.05$, $\eta^2 = 0.93$]. But, the repeated measure ANCOVA revealed the mean score value of STEM career interest in delayed post was lower for experimental group compared to control group [F (1, 77) = 388.92, $p < 0.05$, $\eta^2 = 0.53$]. This shows that the module was effective in enhancing STEM career interest but unable to retain it among the experimental group. Further analysis on STEM career interest alone using MANOVA and repeated measure ANOVA showed that the interest in science and mathematics did not change significantly whereby the interest in technology career increase significantly and was retained as well during delayed post-test. Engineering career interest on the other hand showed significant increase in post-test and significant decrease in delayed post-test. An interview that was conducted with four professionals from the field of science, technology, engineering and math further explained the possible reasons for such data and ways to improve the module. Implications such as focusing on the career interest related theory along with theories on teaching and learning, the use of

interdisciplinary modules to enhance the quality of STEM teaching and learning and to provide awareness of STEM career as an interdisciplinary field for students have been made.

CHAPTER 1

INDRODUCTION

1.1 Introduction

STEM was first introduced at the United State of America. At first, "STEM" was introduced as "SMET," abbreviating for Science, Mathematics, Engineering and Technology. The new acronym was coined by the National Science Foundation (NSF) in 1990s to emphasize the importance of these four distinct disciplines (Sanders, 2009). At the beginning, STEM education was devoted on improving science and mathematics as isolated disciplines (Breiner, Harkness Johnson & Koehler, 2012). Minimal integration and attention were given to technology or engineering during those period (Bybee, 2010). Unfortunately, students are often disinterested in science and math when they learn in an isolated and disjoined manner, missing connections to crosscutting concepts in these four disciplines and real-world applications (Kelly & Knowles, 2016).

Therefore, many researchers in USA turned their attention to integrated STEM approach. Researchers found that the integrated STEM approach able to improve the learning process by making learning more relevant, less fragmented, and more stimulating experience for students (National Research Council [NRC], 2012; Kelley & Knowles, 2016). This is considered an important factor because learning process determines a learner's academic achievement, interest in furthering one's education in the field of their liking and continue to be in the field of interest through the field related career (Marginson, Tytler, Freeman & Roberts, 2013). It is also found that the student centred nature of this approach, empower students to explore their capabilities in different roles such as problem solvers, self-reliant, critical thinkers, innovators and

inventors (Morrison, 2006). Stohlmann et al mentioned that in this process of exploring their capabilities students instinctively use of their critical thinking skill such as problem solving ability, innovative thinking and etc. (Stohlmann, Moore & Roehrig, 2012). Apart from this, learning STEM in an integrated manner also carries long term benefits. It prepares students for the age of synthesis where more and more critical challenges await such global warming, food security and etc as they enter career field (Stohlmann et al., 2012). This is possible because lessons learned through integrated STEM approach connects the content of learning to real life applications that are not only relevant to daily life, school or community around them but also expose the students to how STEM professionals work in real life. This purvey students an in depth understanding of STEM career pathways that can smoothen the process of students' transition from STEM learning to STEM career. This eventually aids in producing the STEM workforce in a nation (Hyslop, 2010).

Hence, integrated STEM can be a solution for issues that currently found among Malaysian secondary school students. According to the literature review, it was found that more and more students find science subjects such as Biology, Physic and Chemistry irrelevant, difficult and boring (Saleh, 2012). Therefore, they choose art stream as their choice over pure science stream. Students also have developed a wrong perception that they have limited STEM related career choice in Malaysia that it is no point to pursue in science stream (Badlilshah, 2016). Some students who have chosen science stream in their high school, drop out from the STEM pipeline as they move towards pre-university programs or first degree program due to lack of cognitive skills and science skills that are crucial for scoring good grades in public examinations and to secure a good job in STEM field (Kamisah, Zainaton & Lilia,2007; Badlilshah, 2016;

Saleh, 2012; Sulaiman, Muniyan, Madhvan, Hasan, Syrene & Rahim 2017; Zainudin, 2015).

Although Malaysia's Ministry of Education recognises STEM approach to be a possible solution to the above mentioned problems (Ministry of Education [MOE], 2016), there are still gaps in terms of knowledge on how to integrate STEM subjects especially engineering in science subjects such biology. Apart from this, there is also lack of integrated STEM approach based instructional materials that can be used in teaching and learning in Malaysia (Jayarajah, Saat, Rauf & Amnah, 2014). Hence, in this study, an integrated STEM approach through engineering design process (iSTEM-EDP) Module was developed and evaluated for the topic Nutrition which is taught in form four biology subject. STEM as an interdisciplinary approach has been connected with step in engineering design process to effect student's achievement in the topic Nutrition, critical thinking skill and interest towards STEM career.

1.2 Background of Studies

The National Council for Scientific Research and Development predicts that Malaysia will require 493,830 scientist and engineers by year 2020. However, what worries the nation is the forecast of Ministry of Science, Technology, and Innovation (MOSTI) that there will be a shortage of 236,000 professionals in STEM fields. The current demand for STEM-capable workers exceeds the supply of applicants who have trained for those job (Shahali, Halim, Rasul, Osman & Zulkifeli 2017). This closely related to the unmet two important policies in Malaysia which are the 60:40 ratio policy and Vision 2020. In the year 1970, Malaysia introduced 60:40 ratio policy in order to achieve 60 % science stream students and 40% of arts stream students. When this is

done, more science stream students are expected to enter STEM related courses in their tertiary education. It is inevitable that Malaysia still trying to achieve this ratio as not much students enrol in science stream after their lower secondary examination. Another policy that haven't been met is Vision 2020. This policy was launched in 1991 with the aim to develop an advance society that not merely uses technology but contributes to scientific civilization and future technology (MOE, 2016).

The paradigm shifts of global economy from industrial age to knowledge based economy (Djeflat, 2009), have challenged countries like Malaysia due to the above mentioned reasons. Malaysia is ranked as the 35th country in the world for Global Innovation index 2016. When innovative skills among workforce depletes in the country, it is going to be hard to compete in knowledge based economy. This condition is reflected in Global Competitiveness Report 2016 when Malaysia slide to 25th rank from its 18th rank in the year 2015 (Malaysia Science and Technology Information Centre [MASTIC], 2016). Innovative and competitive human resource of a nation closely related to quality education of one nation could provide especially science education (Dutta, Lanvin, & Wunsch-Vincent, 2015).

Margison et al (2013) further supports Dutta et al.'s notion by finding the close fit between the nations with leading and dynamic economies, and the nations with the strongest performing education and/or research in science. This was apparent in the in the Organisation for Economic Co-operation and Developments (OECD's) Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS). The nations with the largest group of learners at the top three prowess levels were China, Singapore, and Taiwan. Interestingly, this are the nations that has exceptionally strong research and development in various science field.

At the same time, they have all experienced two decades of extraordinary economic performance. From here, it is clear that the three factors which are science, universal learning and economic prosperity forms a single interdependent system (Marginson et al.,2013).

PISA examines reading, scientific and mathematical literacy, focusing on knowledge and skills gained through education whereby it is applicable to everyday choices and the solving of real-world problems. On the other hand, TIMSS assesses student's performance in different mathematics and science domains (algebra, geometry, biology, chemistry, etc.) and their problem-solving skills in each of these contexts. Malaysian participants performed below average in both 2011's TIMSS and 2009's and 2012's PISA. In the year 2015, students performed at an average level in PISA. Malaysia has targeted to improve its placement by 2025 (Ismail, Salleh, & Aris, 2017). Malaysian students were outperformed by many other Asian countries such as Singapore in PISA due to the fact that they were unable apply their science knowledge to real world situation. Furthermore, a microanalysis in a cognitive level of questions in TIMSS 2011 unveiled that Malaysian students were weak in thinking skill which requires a display of critical thinking (Jayarajah *et al.,* 2014).

Every advancing nation knows that the way to economic triumph and global prowess starts with implementing STEM in education system (Putra, 2012; Dutta *et al.,* 2015). This calls for Malaysia to look into this issue and implement STEM for the need of students. Batterson (2010) mentioned that policy makers often cry out for innovation as the foundation for economic redemption and this situation made more emphasis in STEM education which is often tailed by a move to have students take another math or science course. By strongly rejecting this concept, Batterson (2010) instead pointed out

innovation being the child of engineering- the “E” of STEM. Engineering design process is an approach to learning which provides a systematic pathway in solving a problem. It ranges from having 5 step up to 9 step depending on the user and the complexity of the process model (Mangold & Robinson, 2013). It gives structural bone on how an engineer thinks and finds solution in real world. Therefore, it can be said engineering design provides both skill and mental model of an engineer (Mangold & Robinson, 2013). Bringing in engineering design process in an integrated STEM approach able to increase student’s cognitive synthesis towards the co-dependent nature of science and mathematics in order to have advancement in engineering and technology. When this four discipline co-exist jointly in an integrated approach, it gives rise to problems solving, innovation, and design, the three themes with high priorities on each nation’s agenda for economic prosperity (Batterson, 2010; Hernandez et al.,2014).

Besides, STEM through engineering design process is identified to often go well along with learning STEM in an integrated manner. It imparts a contextual learning platform for students to critically think into different aspects of design problems using various STEM concepts which leads to an engineering design solution. This learning approach often contextualised using real world problem that are relevant to the learners (Rose, 2016; Shahali *et al.*, 2017; Siew, Goh & Sulaiman, 2016; Silk, Schunn & Cary 2009). Adding engineering process along with science concept can be an added value as any engineering challenge can be highly motivating for all age groups of student (Bybee, 2011). Engineering experiences becomes an eye opener to students on how it can shape a society by problem solving (Cunningham & Carlsen, 2014).

On top of this, students were situated in roles of STEM professionals such as engineers and scientist while learning using the integrated STEM through engineering design process approach in order to give them the opportunity to mimic how scientist and engineers work into order to find a solution to a real world problem. This learning leads to students exploring their interest in various STEM career. When students able to see that they can operate and find solutions like actual STEM professionals, they want to learn about the vast opportunity that are available in STEM career. This shows that, integrated STEM through engineering design process holds promising outcomes that can pave pathway towards tackling both global and local issues faced by Malaysia.

However, although there are many promising outcomes based on the studies conducted in oversea, Malaysia still in its infancy stage in implementing STEM at schools. Currently, Malaysia still teachers STEM subjects in silo that too the focus are only given to science, mathematics and technology for high school students. Engineering is not being taught in high school. Moreover, the lessons are taught using conventional method where teachers use "chalk and talk" method to teach which is very didactic. Focus were given to memorize the facts that enable students to re-call during exams. This exam oriented teaching and learning in school definitely caused a lot of attention that need to be given in STEM implementation in school (Suhaila, Mohd Yusof & Faridah, 2019).

Therefore, research on implementing STEM became crucial when Ministry of education mentioned about strengthening STEM in Malaysian education system in Malaysian Education Blueprint 2013-2025 (MOE, 2013). As such, one of the crucial issue faced by Malaysia was to identify an effective way to integrate STEM in its mainstream education and to have instructional material for its teaching and learning

(Bunyamin & Finley, 2016; Jayarajah et al., 2014; Mustafa, Ismail, Tasir, Said, & Haruzuan, 2016). Speaking about integrated approach, STEM integration can be viewed from different perspective. According to Vasquez et al. (2013) the perspective on how discipline integration can be achieved varies with reference to multidisciplinary, interdisciplinary and transdisciplinary approaches. This adds to the debates on effective implementation of STEM (Mustafa et al., 2016; Vasquez, Sneider & Comer, 2013).

Nevertheless, the recent findings showed that STEM as an interdisciplinary approach is being more popular in western countries (Mustafa et al, 2016; NRC, 2012). Tsupros et al., defined STEM as an interdisciplinary approach to learning where rigorous academic concepts are coupled with real world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy (Tsupros, Kohler & Hallinen, 2009).

From this definition it can be seen that, integrated STEM as an interdisciplinary approach provides a platform to bridge academic concepts to real world application for both individual academic progress and a nation's economic progress. Identifying an appropriate integration of STEM leads to the next step which is having instructional material for learning using this approach which is why this study will focus on developing and evaluating the iSTEM-EDP Module. Research and development in this area will be regarded as a contribution to upcoming generation to excel in STEM field.

1.3 Problem Statement

Research showed that many Malaysian students displayed lack of career interest in STEM field (Fadzilah et al., 2017; Lau et al., 2011). This is due to lack of awareness upon this field (Fadzilah et al., 2017; Ing et al., 2014). Rashid (2011) have found that students from technical and vocational schools are more exposed to career awareness, pathways and guidance compared to national schools. This tremendously increases the students' knowledge, skill and career readiness compare to a student from national school (Rashid, 2011). Fadzilah mentioned that STEM intervention or implementation in Malaysia needs to include career awareness as part of teaching and learning. This provides an early experience upon career interest with some level of adult guidance. This is even more crucial in Malaysia as students tend to make career decision relying on parents' opinion yet many parent still doesn't possess the awareness on STEM career field (Fadzilah et al., 2017; Ing et al., 2014; Lau et al., 2011).

A serious consideration need to be given in forming STEM career interest among students through teaching and learning as the number of students' enrolment in science stream and retaining them in the pathway that leads to a career in the same this field is keep reducing that makes Malaysia to face a depleting human resource in the STEM field (Badlilshah, 2016). Badlilshah further adds that these phenomena are caused by the perception that the Malaysian secondary school students have upon science and math subjects. They assume that what they are learning in science subjects such as Biology, Physics and Chemistry is not relevant to real life. This decreases the ability of the students to integrate the learning from science subjects with daily life which leads to creating static students who shows no progress in learning. Static students often lacks integrated knowledge. This is alarming because integrated

knowledge is considered very important for intuitive learning. This impacts the students' achievement in science subjects and also the interest to pursue further in STEM field (Badlilshah, 2016). Along with this, rote learning approaches have been identified as another causing factor for lacking conceptual understanding and interest towards the science subjects among learners which impacts their achievement in science subjects (Badlilshah., 2016; Kamisah *et al.*, 2007; Saleh, 2012; Shaharuddin, 2002).

This is especially evident in the topic, Nutrition. The topic Nutrition that is being taught as the sixth chapter in Form Four Biology curriculum is considered as one of the largest topic which contains fifteen subtopics compare to other topics in this curriculum (Mazni, 2017). It contains many biological concepts that covers various living organisms and frequently tested in Biology Paper 2 in Malaysian Certificate of Education (*Sijil Pelajaran Malaysia, SPM*) (Malaysian Examination Board [MEB], 2003; 2008; 2010). According to the analysis (*Kupasan Mutu Jawapan)* done by the Malaysian Examination Board on the past year students' answer in Malaysian Certificate of Education, it was revealed that many students unable to answer the questions that are asked related to the subtopics of the chapter such as applying concepts of balanced diet, eating habits and more (MEB, 2003;2008;2010). These questions are often asked in a manner that requires students to relate the concepts to real world applications and this has been one of the main reason why many unable to answer these questions compare to the direct questions asked in Paper 1 from the same topic that requires students only to re-call some of the concepts and definitions (Norsaliza, 2018; Ghagar et al., 2011; Malaysian Examination Board, 2010; 2008; 2003). This is further supported the meta-analysis done by Fatin et al (2014). The meta-analysis showed that students also showed weak mastering over science and math knowledge and displayed

difficulty in building an integrated understanding towards learning this subjects. This is due to their formal and concrete thinking rather than critical thinking.

Fatin et al., further adds that another reason for students' low achievement in science subjects such Biology is due the weak mastery over science subject related skills such as ability to collect information by observing, analysing, researching and etc. Most importantly, they are unable to show proficiency in comparing data, re-testing the finding, analysing and evaluating the data and display collected information in a systematic manner. This reflects on the very minimal usage of hands on learning in classrooms and students practicing these skills only during the lab sessions which too by following the instructions like in a cook book (Fatin et al.,2017; Kamisah *et al.,* 2007). Students rarely utilise these sessions to build their understanding towards science concepts or cognitive skills to prove a hypothesis. Hence, they score low scores in Biology whereby they have to use scientific concepts to explain a scientific phenomenon (Fatin *et al.,* 2014).

Apart from that, despite Ministry of Education's emphasis on critical thinking skills since 1994, students still struggle to apply it in international examinations such as TIMSS and PISA and national examination such Malaysian Certificate of Education (*Sijil Pelajaran Malaysia, SPM)* (Ghagar et al., 2011). Critical thinking is an important element to excel in Biology (Lee, 2013). Critical thinking in Biology helps students to understand a process and able them to provide reasoning. Unfortunately, this skill is scarce among students as they merely being a passive absorber of a huge chunk about the world and reproduce it in assessment using short term memory (Lee, 2013). This is again relatable to the topic Nutrition in Biology when a hundred and ninety-six students from form four identified that 90 percent of the subtopic covered under the topic

Nutrition is difficult as the concepts requires them to think critically and digest many different science concepts (Norsaliza, 2018). It was also revealed that most of the SPM students showed low performance in this topic as they unable to critically think and make connection between the science concepts and scientific phenomenon (Norsaliza, 2018). Lee (2013) mentioned that the exam oriented learning which is learning based on pass year questions and targeted questions in exams among students have made things even harder as students were unable to answer non-routine questions in Biology. This is very concerning as Ministry of education gradually plans to increase the non-routine questions in the public examinations which requires critical thinking (Ghagar et al., 2011).

On top of this, things became even more precarious when the number of students who opt out of science stream itself started increasing. There are many reasons that caused this to take place in Malaysia. Students often feel lack of confidence to be in science stream or chose a career in STEM field assuming it is hard (Abdullah *et al.,* 2013). Even if they do choose science stream, they are afraid of being in a STEM career. Many of them do not understand the vast career opportunities that exist in STEM (National Academies of Sciences, Engineering, and Medicine, 2016). Abdullah et al. revealed that, secondary school students have negative presumption about STEM career in Malaysia by assuming that the job scope is very limited to commonly known jobs such as medical doctors, dentist and etc (Abdullah *et al.,* 2013; Badlilshah *et al.,* 2016; Fatin et al., 2014).

This have made the number of students' enrolment in first degree level in public institute of higher learnings in Malaysia from 1997 to 2007 for arts and technical courses to incline positively while the number of students' enrolment in science courses has

been on a declining since 2005 until 2007. If this persist, it will deflate the STEM workforce in Malaysia (MOSTI, 2008; Zainudin *et al.,* 2016). The lesser the STEM professions that get filled, the more severe impact Malaysia's economy and global competitiveness will face (MOSTI, 2008; Zainudin *et al.,* 2016).

It is undeniable that Malaysia's Ministry of Education embarked on National STEM initiation to overcome all the above issues among students. In the STEM implementation guideline *("Panduan Pelaksanaan Sains, Teknologi, Kejuruteraan dan Matematik (STEM) dalam Penagajaran dan Pembelajaran")* document by Curriculum Development Unit, it is mentioned that STEM able to improve the content knowledge, thinking skills, science process skills and interest towards STEM subjects and STEM career (MOE, 2016). But, researchers such as Jayarajah et al., and Bunyamin et al., highlighted that, the integration especially integration of engineering and technology is very low or almost absent (Jayarajah *et al.,* 2014; Bunyamin *et al.*,2016) when it comes to STEM approach in Malaysia.

Slavit et al. mentioned that, often such issues of inadequate integration of subjects in STEM approach is caused by lack of clear and constant vision of STEM approach and limited number of available instructional materials. Adequately coordinating key disciplinary content in STEM approach based environment often requires new instructional practices (Slavit et al., 2016). Rose (2016) mentioned that teachers of primary and secondary schools in Malaysia is still learning and trying to understand about STEM education as it is something new for them; let alone to exert the STEM pedagogical approach in schools. She mentioned that Malaysian students and teachers are facing the challenge of finding the right way to teach and learn STEM

education. This will make STEM subject difficult for students and eventually shutters the confidence of the students to proceed to STEM related career (Rose, 2016).

As far as known, there are less instructional materials which are available for integrated STEM-EDP approach that can be used in mainstream education. Studies on how this integrated STEM-EDP approach can impact students' achievement, critical thinking skill and interest in STEM related career is available in scarce. Identifying these outcomes is very crucial and will be meaningful as it can contribute to meet both the micro and macro objectives of STEM initiation in Malaysia which is to develop human resource that is knowledgeable, highly skilled, innovative and competitive in order to face the global economic challenges (MOE, 2016).

1.4 Research Objective

This study specifically focuses on the below research objectives:

1. To develop an integrated Science, Technology, Engineering and Mathematic through engineering design process approach module (iSTEM-EDP Module) for the topic Nutrition that effects students' achievement in the topic Nutrition, critical thinking skill and STEM career interest.
2. To determine the effect of the iSTEM-EDP Module towards form four students' achievement in the Nutrition achievement test and its retention.
3. To determine the effect of the iSTEM-EDP Module towards form four students' critical thinking skill and its retention.
4. To determine the effect of the iSTEM-EDP Module towards form four students' STEM career interest and its retention.

1.5 Research Question

This study specifically focuses on answering the research questions below:

RQ 1: How to develop an integrated Science, Technology, Engineering and Mathematic through engineering design process approach module (iSTEM-EDP Module) for the topic Nutrition that effects students' achievement in the topic Nutrition, critical thinking skill and STEM career interest?

RQ 2: Does the use of iSTEM-EDP Module effect students' achievement in the topic Nutrition?

a. Is there any significant increase on post-test scores in Nutrition achievement test between experimental and control group after the influence of the pre-test is controlled?

b. Is there any significant increase on delayed post-test scores in Nutrition achievement test between experimental and control group after the influence of the pre-test is controlled?

RQ 3: Does the use of iSTEM-EDP Module effect students' critical thinking skill?

a. Is there a significant increase on post-test score in critical thinking test between experimental and control group after the influence of pre-test is controlled?

b. Is there a significant increase on delayed post-test score in critical thinking test between experimental and control group after the influence of pre-test is controlled?

RQ 4: Does the use of iSTEM-EDP Module effect students' STEM career interest?

a. Is there any significant increase in students' STEM career interest post-test between experimental and control group after the influence of the pre-test is controlled?
b. Is there any significant increase in students' STEM career interest delayed post-test between experimental and control group after the influence of the pre-test is controlled?

1.6 Research Hypothesis

Based on the research objectives and research questions mentioned above, there are two hypotheses for each sub-questions that comes under the main questions.

The below is the alternative hypothesis that is formed for question 2.

H_{a1a}: The mean score value of the post-test in Nutrition achievement test is significantly higher for experimental group compare to the control group after the influence of the pre-test is controlled.

H_{a1b}: The mean score value of the delayed post-test in Nutrition achievement test is significantly higher for experimental group compare to the control group after the influence of the pre-test is controlled.

The below is the alternative hypothesis that is formed for question 3.

H_{a2a} : The mean score value of the post-test in critical thinking test is significantly higher for experimental group compare to the control group after the influence of the pre-test is controlled.

H_{a2b} : The mean score value of the delayed post-test in critical thinking test is significantly higher for experimental group compare to the control group after the influence of the pre-test is controlled.

The below is the alternative hypothesis that is formed for question 4.

H_{a3a} : The mean score value of the post-test in STEM career interest survey is significantly higher for experimental group compare to the control group after the influence of the pre-test is controlled.

H_{a3b} : The mean score value of the delayed post-test in STEM career interest survey is significantly higher for experimental group compare to the control group after the influence of the pre-test is controlled.

1.7 Significance of studies

In this research, an integrated STEM-EDP module for the topic Nutrition was developed, and evaluated for its' effect towards student's achievement, critical thinking skill and STEM career interest. The outcome for this study will be beneficial for many stake holders as it will be a source to refer while integrating STEM approach in teaching and learning.

(i) Teachers

Through this study, teachers will be able to have a resource to refer on integrating STEM approach through Engineering Design Process in Biology based on real world problem. STEM as an interdisciplinary approach being used in this module enables teachers to provide a quality education by blurring the lines between science, mathematics, technology and engineering and teach using the crosscutting concepts and science and engineering practices that are commonly found in the four disciplines in general. As the content of the module was based on Malaysian culture and industry, it makes the learning more situated and relevant for both teachers and learners. This module also provides an alternative way to foster critical thinking skill among students while they gain the knowledge of the topic Nutrition in classroom. Apart from that, infusing exposure to STEM career as part of the lesson in the iSTEM-EDP Module also makes teaching and learning more meaningful as teachers can provide a broader vision to learning biology and its concepts and its application in learner's future career.

(ii) Students

The iSTEM-EDP Module which was developed in this study is a learning module made for students. They are not only will be able to experience learning the topic Nutrition but also experience on its application in real world problem. This module encourages active, hand on learning that is made relatable to students' culture and society. It provides them a multiple STEM professional roles to play in order to solve a design problem which

requires science and engineering practice and critical thinking. Learning through this module prepares them to be part of 21st century workforce that show excellency in both soft and hard skills especially in an industrialised country like Malaysia.

(iii) Ministry of Education

As the STEM initiation in Malaysia is being an important agenda for Ministry of Education, this module can serve as an instructional resource. This module was developed to meet the objectives of STEM implementation in the nation which is to produce capable students who can think critically and who will be interested and retained in STEM workforce. It is hoped that this module might help teachers and students to meet the STEM standards as required by the Ministry of Education.

(iv) Other Researchers

Currently, many researchers in the field of science and mathematics education is looking into ways of implementing STEM efficiently in Malaysian education system. Researchers who are interested in the field of STEM shows less focus on engineering design process and even more scarcely focuses on how engineering design process can be applicable into subject like Biology. This module can be a stepping stone to see how engineering design can be fused into any science subject seamlessly. There is also a gap among research that understands students' STEM career interest upon completing a STEM intervention. This study can also be taken as an exemplary on how future studies can provide focus on the area of STEM career interest.

1.8 Operational Definition

1.8.1 STEM Approach

This study adapts the definition of Tsupros et al which is integrated STEM approach as an interdisciplinary approach to learning where rigorous academic concepts are coupled with real world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy" (Tsupros *et al.,* 2009). Interdisciplinary approach is an approach whereby closely linked concepts and skills are learned from two or more disciplines with the aim of deepening knowledge and skills (Vasquez et al., 2013). Based on this two important definition, the module that is developed in this study contains learning of the concepts in the topic Nutrition through applying science, technology, engineering, and mathematics in an interdisciplinary manner. This lessons are based on real world application in the context of school, community, work and global enterprise.

1.8.2 Engineering Design Process

The engineering design process (EDP) is a decision-making process, often iterative, in which basic science, math, and engineering concepts are applied to develop optimal solutions to meet an established objective (Mangold & Robinson, 2013). The engineering component in STEM emphasis on the process and design of solutions instead of the solutions itself which makes it the catalyst for integrating learning across STEM (Hernandez et al.,2014). Based on this definition, the module developed in this study integrates STEM through the steps mentioned in Hynes et al (2011) engineering

design process model. This is a nine step model that is iterative. The steps in this model are 1) Identify need or problem, 2) Research need or problem, 3) Develop possible solutions, 4) Select best possible solution 5) construct a prototype 6) Test and Evaluate solution, 7) Communicate the solution, 8) Redesign, and 9) Finalize design (Hynes et al., 2011). Each step integrated with STEM approach in an interdisciplinary manner in learning the content of topic Nutrition.

1.8.3 The Topic Nutrition

Nutrition is the sixth topic and it is under the theme of investigating the physiology of living things in the Integrated Biology Curriculum for Form Four by Ministry of Education (2005). According to the curriculum, the topic Nutrition is divided into two parts which are nutrition for animal and nutrition for plants. The curriculum accentuates the integration of thinking skills and psychomotor skills as part of the learning outcomes for each lessons (MOE, 2005). The module developed in this study is for lessons covered under nutrition for animal. The incorporation of integrated STEM-EDP approach in the subtopics of the topic Nutrition will provide a base for student to enhance their thinking and psychomotor skills.

1.8.4 Integrated STEM-EDP Approach Module for the Topic Nutrition

The integrated STEM-EDP approach module for the topic Nutrition is a learning module that discusses the selected subtopics in the topic Nutrition in a systematic and organized manner. The module contains lesson plans that are considered the small parts of their own but they are complete and related to one another. The lessons in this module are based on the learning outcomes and objectives mentioned in Integrated Biology

Curriculum for Form Four by Ministry of Education (MOE, 2005). In this module, the lessons are learned using integrated STEM-EDP approach. For this, the crosscutting concepts and science and engineering practices are adapted into this lessons. Crosscutting concepts and science and engineering practices are used to integrate STEM-EDP approach in an interdisciplinary manner. The lessons are connected to one another based on the steps in Hynes et al (2011) Engineering Design Process Model. In summary, this module merges both STEM and EDP together as an integrated approach whereby the rigorous academic concepts are coupled with real world lessons as students use EDP to make decision by applying science, technology, engineering, and mathematics in an iterative manner in contexts that make connections between school, community, work, and the global enterprise that converts resources to meet a stated objective.

1.8.5 Student's achievement in Nutrition Test

The most common indicator of achievement generally refers to a learner's performance in academic (Cunningham, 2012). In this study, researcher adapted test questions from past year SPM Biology Papers that able to measure students' achievement in the topic of Nutrition. This instrument will be known as Nutrition Test in this study. This is a short answer question paper that measures students learning in the topic Nutrition.

1.8.6 Critical Thinking Skill

Watson and Glacer (1980) defined the concept of critical thinking skill as five steps which are (1) recognizing and defining a problem; (2) clarifying the problem by collecting necessary facts or information and recognizing assumptions being made; (3) formulating possible explanations; (4) selecting one or more possible hypotheses for testing and verification and (5) making final conclusions. This definition provides the theoretical foundation for the Watson-Glaser Critical Thinking Appraisal (WGCTA), which is an 80-item, multiple-choice test with five subtests. In this study, the critical thinking skills of students are measured based on their achievement in Watson-Glaser Critical Thinking Appraisal that contain five constructs which are making inferences, recognition of assumptions, deduction, interpretation, and evaluation of arguments (Watson & Glaser,1980).

1.8.7 STEM Career Interest

Career interest is a result from self-efficacy and outcome expectations which fed by learning experience (Lent, Brown & Hackett, 1994). The interest formed from this leads to setting goals that enables one to attain the career of one's choice. Hence, this study focuses on evaluating the effect of student's STEM career interest through learning experience which will be provided using the integrated STEM-EDP approach module for the topic, Nutrition. This will be measured using STEM Career Interest Survey (STEM-CIS) instrument developed by Kier et al., in the year 2014 (Kier, Blanchard, Osborne & Albert, 2014).

1.9 Summary

This chapter discussed about how the nations began to focus on integrated STEM knowing that teaching and learning STEM in segregated manner disinterest students and reduces the relevancy of learning. The ability of integrated STEM approach to make learning more interesting and relevant to real world application, engages student in the content of learning. STEM approach along with Engineering Design Process that requires students to think beyond disciplinary boundaries and solve real world problem encourages students to think critically. Such learning might able to increases students' interest in STEM career which in a long run able to increase STEM workforce. Similar outcomes are desired by Malaysia's Ministry of Education based on the documents released for STEM initiation in mainstream education. Hence this study, tries to fill the gap of lack of integrated STEM instructional material that can effect students' achievement, critical thinking skills and STEM career interest by developing an integrated STEM through engineering design process (iSTEM-EDP) module for the topic, Nutrition.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This study is about developing and evaluating an integrated STEM-EDP approach module for the topic Nutrition towards student's achievement, critical thinking skill and STEM career interest. In implementing STEM, the most important thing to be done first is in deciding how it will be integrated as there are plenty of ways for it to be done in teaching and learning. Therefore, a subtopic has been dedicated to review on integrated STEM. Along with this, it is important to know and critically review about the aspects of STEM from a global level to the local level in order to ensure the design and development of the module is relevant and accurate. As such, the subtopics on STEM from a Global view, and STEM in Malaysia is followed. To understand ways to integrate STEM as an interdisciplinary approach, subtopics on adopting crosscutting concepts and science and engineering practice and engineering design process were included. In order to identify how this approach can be used in the topic Nutrition, a critical review was also done on this subtopic. The subtopics on critical thinking skills and STEM career interest was included to understand the gaps in these dependent variable and how integrated STEM can effect these dependent variables. The critically reviewed data will be used to develop the module using a suitable instructional system design (ISD) model. For this, a review is also done to compare different ISD models. Based on the review, a theoretical framework and a conceptual framework is formed at the end of this chapter.