INTEGRATED STEM-PBL MODULE IN ENHANCING THE INTEREST AND ACHIEVEMENT TOWARDS GENETICS CONCEPTS AND CRITICAL THINKING SKILLS

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by

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TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

LIST OF ABBREVIATIONS

ADDIE	Analysis, Design, Development, Implementation, and Evaluation
CCTST	California Critical Thinking Skills Test
GCAT	Genetics Concepts Achievement Test
GEQ	Genetics Interest Questionnaire
HEI	Higher Education Institutions
HEP	Higher Education Provider
ID	Instructional Design
MOE	Ministry of Education
MOHE	Ministry of Higher Education
MOSTI	Ministry of Science, Technology and Innovation
MQA	Malaysian Qualification Agency
MQF	Malaysian Qualifications Framework
NSF	National Science Foundation
PBL	Problem Based Learning
STEM	Science, Technology, Engineering, and Mathematics
UM	Universiti Malaya
USM	Universiti Sains Malaysia
UTM	Universiti Teknologi Malaysia

MODUL INTEGRASI STEM-PBL DALAM MENINGKATKAN MINAT DAN PENCAPAIAN TERHADAP KONSEP GENETIK DAN KEMAHIRAN BERFIKIR SECARA KRITIS

ABSTRAK

Masyarakat yang saintifik dan inovatif boleh diwujudkan dengan memberikan keutamaan dalam Sains, Teknologi, Kejuruteraan, dan Matematik (STEM) seperti yang telah ditekankan di dalam Rangka Tindakan Pendidikan Tinggi Malaysia (2015-2025). STEM perlu dilaksanakan di peringkat pendidikan tinggi kerana universiti perlu menghasilkan graduan yang kompeten untuk membantu dalam pertumbuhan ekonomi dan pembangunanan kelestarian negara. Pembelajaran STEM melalui Pembelajaran Berasaskan Masalah (PBL) mungkin membolehkan pelajar menjadi lebih bersemangat apabila arahan berasaskan masalah digabungkan dengan STEM dengan melaksanakan tugasan secara pasukan dan teknik menyelesaikan masalah untuk melibatkan pelajar tahun pertama ijazah sarjana muda sepenuhnya dengan pembelajaran. Kajian ini telah dijalankan untuk menyiasat sama ada modul Bersepadu STEM-PBL dapat meningkatkan minat dan pencapaian dalam konsep genetik dan kemahiran berfikir secara kritis di kalangan pelajar tahun pertama ijazah sarjana muda. Untuk membangunkan modul Bersepadu STEM-PBL, reka bentuk pengajaran ADDIE yang merangkumi fasa Analisis, Reka Bentuk, Pembangunan, Pelaksanaan, dan Penilaian telah digunakan sebagai rangka. Reka bentuk penyelidikan Pra-Eksperimen dengan satu kumpulan-ujian pos telah digunakan dalam kajian ini. Seramai 50 orang peserta yang merupakan pelajar tahun pertama (semester kedua) dari Fakulti Biologi dari salah sebuah universiti awam di Malaysia terlibat dalam kajian ini. Untuk mengukur minat dalam konsep genetik, kajian ini menggunakan Soal Kaji

Selidik Genetik (GEQ) yang telah disahkan oleh pakar dengan nilai Alpha Cronbach adalah 0.979. Untuk mengukur pencapaian dalam konsep genetik, kajian ini menggunakan Ujian Pencapaian Konsep Genetik (GCAT) yang telah disahkan oleh pakar dengan nilai kebolehpercayaan Kuder-Richardson 20 (KR-20) iaitu 0.732. Kajian ini mengukur kemahiran berfikir secara kritis dengan menggunakan Ujian Kemahiran Pemikiran Kritikal California dengan nilai kebolehpercayaan KR-20 adalah 0.684. Kajian rintis telah dijalankan dengan ciri-ciri yang hampir sama dengan sampel kajian sebenar untuk memperolehi maklum balas pensyarah dan pelajar tahun satu ijazah sarjana muda mengenai kecukupan, penambahbaikan, dan kesesuaian penggunaan modul bersepadu STEM-PBL sebelum intervensi sebenar bermula. Ujian pra sebelum intervensi, ujian pos selepas intervensi dan ujian pos lanjutan menggunakan GEQ, GCAT, dan CCTST. Statistik deskriptif dan inferensial dianalisis dengan menggunakan Statistik IBM® SPSS® Versi 24. Modul Bersepadu STEM-PBL Bersepadu dapat meningkatkan dan mengekalkan minat dan pencapaian dalam konsep genetik, tetapi ia tidak dapat meningkatkan dan mengekalkan kemahiran berfikir secara kritis selepas menerima rawatan dengan modul. Tahap kemahiran berfikir kritis ini dilaporkan sama walaupun selepas rawatan.

INTEGRATED STEM-PBL MODULE IN ENHANCING THE INTEREST AND ACHIEVEMENT TOWARDS GENETICS CONCEPTS AND CRITICAL THINKING SKILLS

ABSTRACT

Scientific and innovative society can be produced by giving priorities in Science, Technology, Engineering, and Mathematics (STEM) as emphasized by Malaysian Higher Education Blueprint (2015-2025). STEM need to be implemented in higher education because universities need to produce competent graduates to support economy growth and sustainable development. Learning STEM through Problem Based Learning (PBL) might allow the undergraduates to become more enthusiastic when problem-based instruction is incorporated with STEM by implementing teamwork and problem-solving techniques to engage the first-year undergraduates fully with the learning. This study was conducted to investigate whether Integrated STEM-PBL module could enhance the interest and achievement towards genetics concepts and critical thinking skills among first-year undergraduates. To develop the Integrated STEM-PBL module, ADDIE instructional design which comprises Analysis, Design, Development, Implementation, and Evaluation phases were used as a framework. A Pre-Experimental research design with one group-posttest design was applied in this study. A total of 50 participants who are first-year undergraduates (second semester) from Faculty of Biology from one of the public universities in Malaysia were involved in this study. To measure the interest towards genetics concepts, this study used the Genetics Interest Questionnaire (GEQ) which was validated by expert with Cronbach's alpha coefficient for internal consistency reliability measure was 0.979. To measure the achievement towards genetics concepts, this study used the Genetics Concepts Achievement Test (GCAT) which was validated

by expert with Kuder-Richardson 20 (KR-20) internal consistency reliability measure was 0.732. This study measures critical thinking skills by using the California Critical Thinking Skills Test with KR-20 internal consistency reliability measure was 0.684. The pilot study with almost similar characteristics with the real study sample was conducted to get lecturer and first-year undergraduates' feedback on adequacy, possible improvements, and feasibility of Integrated STEM-PBL usage before intervention. A pretest before intervention, posttest and delayed posttest after intervention administered using the GEQ, GCAT, and CCTST. Both the descriptive and inferential statistics were analysed using the IBM® SPSS® Statistics Version 24. The Integrated STEM-PBL module was able to enhance and retain the interest and achievement towards genetics concepts, but it could not enhance and retain the critical thinking skills after receiving the treatment with the module. This level of critical thinking skills is reported the same even after the treatment.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Science and Technology in the field of education has always given higher priority in Malaysia. Osman and Saat (2014) states that education in Malaysia both at school and university level is to make science education more appealing to students to indirectly invites more of them to pursue studies in science related areas in order to realize Malaysia's goal of becoming an industrialized country. To make this a reality in higher education setting, Malaysia Higher Education Blueprint (2015-2025) had moved a step closer in achieving the goal in producing scientific and innovative society by giving priorities in Science, Technology, Engineering, and Mathematics (STEM) in the blueprint itself.

At the moment, one of the increasingly popular topics in field of education is integrated approaches to STEM as stated in Bybee (2010). Thus, there is an urgent need to understand the effects of integrated STEM with its implementation in higher education context to promote integrated STEM among the university students to support the Malaysia government's plan in promoting the STEM as stated in Malaysia Higher Education Blueprint (2015-2025). As stated in the blueprint, to support higher-income jobs and raise competitiveness, not only proficiency in English is required but a greater emphasis should be given on STEM.

Education is a fast-moving field and has always faced many challenges along with the passage of time. The need for a skilled and knowledgeable human resource in higher education is also increasing worldwide (Knight, 2001). The skilled and knowledgeable human resources are very important to the needs of development,

economy and social development of a country. According to Blackie, Le Roux, and McKenna (2016) states that understanding the significant of STEM at higher education's fields have a direct role to play in economic productivity and innovation in a country. It is also supported by UNESCO (2009) and World Bank (2009) which states that both developed and developing countries' economies identified STEM will drive the national growth. According to Langdon, McKittrick, Beede, Khan, and Doms (2011) current generation's education in the area related to STEM need to be given priority because it is the key to shift the world's population towards having a greater understanding of the importance of achieving economy growth and sustainable development. This is because the implementation of STEM in higher education will impacts on demands whereby the universities needs to provide competent graduates in a sufficient number.

Align with reports from UNESCO (2009) and World Bank (2009), Malaysia also highlights the need of STEM education. This can be seen in Edy Hafizan, Ihsan, and Lilia (2018) which had reported that the success of Malaysia relies on the quality of STEM education provided to their students both at school and university level. The importance of STEM in Malaysia can be seen when Ministry of Education (MOE), Ministry of Science, Technology and Innovation (MOSTI) with Ministry of Higher Education (MOHE) develop a National STEM action plan (Edy Hafizan, Ihsan, & Lilia, 2018). This action plan will involve all government agencies in Malaysia and will also build collaboration with private sectors. STEM education will not only help Malaysia to fulfil the goal of becoming an industrial country but according to Shernoff, Sinha, Bressler, and Ginsburg (2017) states that by implementing STEM in all level of education will drive the economic growth and improves the quality of life.

Undergraduates are the pillars of the nation. Investing in them will benefits the future of a country. This is in line with study by National Academics of Science, Engineering, and Medicine (2018), which states that STEM professionals will fuel STEM related jobs which will boost national economy growth of a country. This can be possible if STEM in higher education level gives the opportunity for the undergraduates to develop knowledge and skills in order to prepares graduates for today's and tomorrow STEM professions. Thus, this study serves as a stepping stone to introduce and to give opportunity to the undergraduates to get familiarize with STEM approach in the higher education environment.

The aim of this study is to research whether Integrated Science, Technology, Engineering, Mathematics through Problem Based Learning (STEM-PBL) module able to enhance the interest and achievement towards genetics concepts and critical thinking skills among first-year undergraduates in one of public universities in Malaysia. This first chapter presents the background of the study, statement of the problem, research objectives, research questions, research hypotheses, significance of the study, limitations of the study, the operational definitions of variables and ends with summary of chapter one.

1.2 Background of Study

With the latest industrial revolution 4.0, societies have been in a new mission to be able to cope with the global developments, to compete within the economic and technological arena, and as a consequence of the mission. To realizing the mission, according to Türk, Kalayci, and Yamak (2018), education is considered one of great importance in the success of the societies' and global development. This is mainly because the main objectives of education are to raise individuals that the society needs

and provide labour force which will fuel the development of the society process by maintaining the economic, social, scientific, and technological advances.

In order to achieve Malaysia's goal in producing scientific and innovative society, it is necessary to drive the STEM education to prepare the undergraduates to face the real situations in future. The current demand for STEM-capable workers surpasses the supply of applicants who have trained for STEM related careers. The Ministry of Science, Technology and Innovation (MOSTI) estimates that there will be a shortfall of 236,000 professionals in STEM-related fields as reported in MOSTI (2012). According to Edy Hafizan, Ihsan, and Lilia (2018), the decline for a STEM-capable workforce, the nation's economic future depends on preparing more students to enter these fields. According to Ismail (2011), recent evidence suggest that Malaysia is facing a deficiency in high skilled local workforces in the fields of STEM. This is supported by the Policy of 60 (science):40 (art) students as it reported as to be a failure (Mohamed Yusof, 2008). Data shows that students' inclination towards the science related subject is still relatively low. Since 2007 only 29% of secondary and tertiary students enrolled into science streams (Bernama, 2012). If there is no attempt done to overcome this problem, this may stunt the Malaysian government's efforts to improve attainment in STEM fields thus affecting the aim to become a high-income country.

Many countries that desire to have an advanced economy and technology aim to build a society that is advanced at Science, Technology, Engineering, and Mathematics and have sustainable development in these fields, and this has been one of the main educational strategies of those countries as stated in Türk, Kalayci, and Yamak (2018). According to Cachaper Spielman, Søndergaard, Dietrich, Rosenzweig, Tabor, and Edmister, (2008), Cullum, Childress, Dorward, Hailey, Householder, and Maurizio (2007) and Hynes and Dos Santos (2007), STEM education learning prepare

undergraduates for the global economy of the 21st century and to make this possible a solid STEM for the future benefits. Shernoff, Sinha, Bressler and Ginsburg (2017) stated that the innovation in STEM fields drives not only economic growth, but also the quality of life. This is because the STEM education offers students one of the best opportunities to make sense of the world holistically, rather than in bits and pieces. This rings true because STEM education removes the traditional barriers between the four disciplines, by integrating them into one cohesive teaching and learning paradigm.

Development in the fields of science and technology are very crucial because it directly have influences on economic development of a country especially the developing country. Thus, the developing countries need to invest in quality education for their students in all levels to contribute to the country development. Malaysia is one of the developing countries that gives priority in science and technology, this can be seen in the Malaysia Higher Education Blueprint (2015-2025), which states that Malaysia must adapt in order to thrive in an increasingly competitive global economic environment. This includes the transformation of Malaysia's higher education system which require a greater emphasis on STEM education. Zin (2003) also reported that Malaysia is aware of the priority to science and technology. Despite the views of society, science is seen as useful because it brings the benefit to society directly. Hence, the challenge faced by scientists is not only to practice good science but also to sustain it as a carrier of well-being and development of a country.

According to Allan (2019) states that the learning and teaching practices in higher education are changing. The reason for changing is due to the embedding of new teaching and learning approaches into the learning and teaching environment whereby become a challenge to the traditional mode of learning in university, particularly in the STEM related disciplines. Blackie, Le Roux, and McKenna (2016)

identified one of the challenges is the introduction of the importance of involvement science and engineering in higher education. Apart from this, Allan (2019) states that higher education become pressure towards student agency, discipline pressure from an ever-increasing knowledge burden, industry pressure towards competent graduates and student pressure towards employability.

As stated by Blackie, Le Roux, and McKenna, (2016), science in higher education become a challenge. Study by Shedlosky-Shoemaker and Fautch (2015) also had reported that the number of undergraduates completing degrees in STEM related courses has been declining over the last few decades. Study by Graham, Frederick, Byars-Winston, Hunter, and Handelsman (2013), Seymour (1997), Watkins and Mazur (2013) reported almost similar outcome which states that in some countries shows a deficit of university graduates from science, technology, engineering, and mathematics' field. One of the ways that can be introducing to make learning more connected and relevant for adult learner like undergraduates is through integrated STEM education approach. Heil, Pearson, and Burger (2013) stated that integrated STEM education is appealing to the students because is based on the idea that real-world issues which require multiple perspectives, skills, and knowledge to be productively addresses.

Acronym of STEM stands for the study of professional practice in the areas of science, technology, engineering, and mathematics. STEM education is given a higher priority because of its importance towards students both in schools and higher educations. According to Becker and Park (2011), Berlin and Lee (2005), Kuenzi (2008) and Reiss and Holman (2007), it states that STEM is given higher priorities because STEM education become a very important current trends in the field of education. According to Allan (2019), growing dialogue on STEM in higher education

is highlighted across the world. One of the main concerns to discuss about the importance of STEM in higher education is because STEM education will be able to power innovation and economic growth and it has actively engaged in strategies which concern on twenty first century skills (Trilling & Fadel, 2009).

Realising the benefits of STEM education on the national economy as reported in UNESCO (2009) and World Bank (2009), educators and educational institutions work really hard in order to achieve the level of integration between science education and STEM as reported in David and Sharon (2006) and Tseng, Chang, Lou, and Chen (2013). Not only educators and educational institutions plays roles in bringing the STEM practices into an education practices, but undergraduates also welcome STEM related courses because the courses help them to relate and solve their daily problems (Dewaters & Powers 2006). Stohlmann, Moore, and Roehrig (2012) states that the future success of students is highly dependent on effective STEM education (Stohlmann, Moore, & Roehrig, 2012). They must apply their knowledge of STEM content and problem-solving skills to solve real world problems that help them make connections between institutions, community, and the world (Wang, Moore, Roehrig, & Park, 2011). Apart from this, the STEM related courses help the undergraduates to gain awareness of meaningful learning by systematically integrating information, concepts and skills (Sari, Alici, & Sen, 2018). Tseng et al. (2013) states that STEM related courses and programs can increase their competences for STEM-related job and allow scientific and engineering related works to be understood in better way.

There are few ways of bringing STEM into higher education. One of significant ways is through problem-based learning as reported in (Sari, Alici, & Sen, 2018). The idea of bringing STEM through problem-based learning because the content of science education should not solely rely on syllabuses alone, but it should also relate to science

and technology in the society. This statement also supported by Zeegers (2004), which states that there is a gap between what undergraduate experience with what undergraduates gained while facing problems in the real-world context learnt. Thus, it become an urgent need for the lecturers and undergraduates in first-year study to play their roles in encourage STEM learning through problem-based activities using real world as example. Delivering STEM through problem-based activities will promote the critical thinking, identify the relationship and implications among undergraduates when they solve genetics related problems. This way will not only create critical thinking skills among the undergraduates but according to Zeidler, Sadler, Applebaum and Callahan (2009), Zeidler, Applebaum, and Sadler (2011) states that informal discussions using genetics related problems will expose to more open views and will create meaningful experience.

Malaysia needs a new workforce of problem solvers, innovators, and inventors who have the knowledge and skills to innovate and compete in the global marketplace in different fields. According to Labov, Reid, and Yamamoto (2010) and National Research Council (2003), preparing future biologists without offering them the exposure and experience with engineering and technology skills will fail to produce students who can perform effectively in an increasingly competitive environment. As studied by Meng, Idris, Leong, and Daud (2013), a key to developing the knowledge and skills is by enhancing STEM education. STEM will educate students to identify, apply and integrate concepts from science, technology, engineering, and mathematics field to understand complex problems and to innovate to solve them. According to Roehrig, Moore, Wand, and Park (2012), integrated STEM encourages student centered. Problem based learning will be appropriate to introduce into STEM learning because as stated by Barrow (1997), problem-based learning is student centered.

Students are encouraged to be responsible for self-directed learning. The teacher acts as a facilitator to help students in the right directions.

As suggested by Brown, Collins, and Duguid (1989) and Ram (1999), problem solving is best learned when it is integrated with learning in a domain. PBL specifically engages students in solving large complex, interdisciplinary problems while emphasizing the need for a deep, conceptual understanding. STEM education can help the next generation of students to solve real-world problems by applying concepts that cut across disciplines as well as capacities of critical thinking skills a student required (Shernoff et al., 2017). There are many approaches can be practice achieving the STEM mission. One of it is through, PBL.

Through STEM-PBL, students are required to practice mathematics and science if the concepts and skills are embedded within a rich context or problem (Beach, Henderson, & Finkelstein, 2012; Savery & Duffy, 1995). Students must explore interesting and integrated situations that require them to use STEM concepts in an integrated way, reflecting on solution methods, examining why the methods work, comparing methods, and relating methods to those used in previous situations (Ogot & Okudan, 2007). Students are required to build more robust understanding of STEM concepts and related procedures in PBL environments. A problem centered instructional approach helps students to make sense of the mathematics and science and helps them to process the mathematics and science content in a retrievable way (Kilpatrick, Swafford, & Findel, 2001).

Empirical evidence showed that the engineering thinking can be an effective way to facilitate and sustain the integration of concepts from multiple STEM disciplines (Estapa & Tank, 2017; Guzey, Moore, & Harwell, 2016). This study uses engineering thinking as one way to teach STEM disciplines. According to Daugherty

(2012), the implementation of engineering design process into science curriculum may help increase student interest in the learning sciences.

Integrated STEM education has quickly become a way with a focus on innovation, designing solutions, and leveraging technology (Kelley & Knowles, 2016). Students are expected to engage in a rigorous curriculum, with instruction and assessment in math and science inquiry, as well as engineering design (Kelly & Knowles, 2016). In this study, engineering thinking process is one way to teach STEM in PBL steps to see whether it enhance and retain the interest and achievement towards genetics concepts and critical thinking skills among first-year undergraduates in one of public universities in Malaysia.

Genetics is considered as one of the important professional courses for the undergraduates who major in biology in the universities and has an important meaning for the undergraduates' learning in further courses and for employment purposes (Li, 2009). In order to permit undergraduates' learning in pure science courses, undergraduates need to master the genetics concepts at the beginning of the study before registering for further pure science related courses during the undergraduate's study. Genetics course was offered during the second semester in first-year degree program in one of public universities in Malaysia. Genetics is chosen to apply research because according to Marlene Murray (2011), the disciplines in genetics serves as the core of biology education by providing a set of unifying concepts essential for the other disciplines in biology. According to Bahar, Johnstone, and Hansell (1999), Banet and Ayuso, (2000), Finley, Stewart, and Yarroch (1982), Johnstone and Mahmoud (1980), Kinfield (1994), Lewis and Wood-Robinson (2000) and Tsui and Treagust, (2004) agrees that the contents in genetics is important as reported by Marlene Murray (2011) but it is also difficult to teach and learn.

Apart from its importance and difficulties in teaching and learning, the genetics course is chosen to research on because according to Klug and Cummings (2006), genetics knowledge reported in an increasingly population and complex world like ours. Knowledge in genetics are also applicable in diverse area such as crop and animal improvement, drug development, gene therapy, crime detection, medicine and many others too as reported in Klug and Cummings (2006). Thus, selecting genetics course to research will be an added value for the undergraduates to experience because it may be helpful for them if they plan to continue their studies to postgraduate level or find jobs related to genetics once they complete their first degree in university.

According to Collins and Stewart (1989), it states that an integral part of genetics is required in the application of complex content to the complex task of problem solving when undergraduates learn. Collins and Stewart (1989) states that the reason for this complexity in solving genetics problem is because there may be more than one approach to solve a problem in genetics and it is unlike problems in mathematics and physics which have one correct answer usually derived by a clearly defined algorithm. Apart from the complexity due to more approach in solving involved, the traditional study habits such as memorization are also ineffective as reported in Griffith (2008). Thus, it is considered common for an undergraduate who can perform well in other biology courses but not in genetics course (Banet & Ayuso, 2000; Griffith, 2008).

The idea of integration is very important when it comes to science education (Kaur & Sidhu, 2009). According to Stohlmann, Moore, and Roehrig (2012), integrated STEM education in science is one way to make learning more connected and relevant for the undergraduates. This statement rings even better when Shernoff et al. (2017) stated that integrated approaches to STEM education are increasingly

popular in current education system. Heil, Pearson, and Burger (2013) defined integrated STEM education as an approach to learning where two or more STEM contents are integrated during lessons and units. The integrated approaches to STEM education can help the next generation of undergraduates to solve real-world problems by applying concepts that cut across disciplines as well as capacities of critical thinking and other skills (Burrows & Slater, 2015). The implementation of integrated STEM can potentially enhance students' performance and interest in science and mathematics, as well to motivate them to pursue to postgraduates' studies or to secure careers in STEM fields once they leave the university

In conclusion, genetics course is one of important basic courses in biology faculty because the knowledge from this course will be the fundamental to many other biology related courses in higher education learning for the pure science undergraduates. Allowing undergraduates to experience STEM learning might encourage the undergraduates to learn the most difficult and important course. In this study, it refers to genetics course which might help in enhancing the interest in learning difficult course among undergraduates. This will allow the undergraduates to further their studies in postgraduates' programs or enter the STEM related professions with full of confidence. Apart from that, the exposure of STEM might improve undergraduates' academic performance in genetics course due to the ability to think critically as it is considered as important life skills which have to be mastered by the undergraduates. This will eventually be helpful for the undergraduates to face the real world with confidence.

1.3 Problem Statements

According to Baharom and Palaniandy (2013), due to the complexity of biology related courses at undergraduate level, new approach is needed to teach and learn contents in biology related courses in an interesting way. To a naive undergraduate, they may feel it is too laborious and irrelevant if no attempts were done to solve their problem. Baharom and Palaniandy (2013) stated that if teaching and learning remained teacher-centered, exam oriented and painstaking memorization of facts and concepts in biology related courses it will dwindle enrolment to the science courses at the higher education level.

Genetics is one of biology related course undergraduate level. Genetics course selected because genetics is considered as one of the critical courses taught at undergraduate level. This research might be a stepping stone to attract more undergraduates towards STEM related courses. Undergraduates need to master the genetics knowledge as the knowledge from this course will be used as fundamental to other courses in biology (American Association for the Advancement of Science, 1993; Banet & Ayuso, 2000; Tsui & Treagust, 2004). Apart from its importance, genetics course was studied because Kılıç, Taber, and Winterbottom (2016) stated topics in genetics was considered one of the most important and difficult to teach and learn. Altunoglu and Sekar (2015), Bahar, Johnstone, and Hansell (1999), Haambokoma (2007) and Johnstone and Mahmoud (1980) stated that genetics has been identified as the most problematic topics in learning biology for undergraduates. Thus, topics in genetics was selected to introduce STEM which might help undergraduates to excel in higher education.

According to Trumper (2006) stated that a better fit between the curriculum and undergraduates' interests could lead to better cognitive and affective outcomes as

well as increased enrolment into science subjects. Schaefer (1979) stated that if the concepts in genetics taught are not related to undergraduates' everyday lives, they may fail to use them adequately when they face real-world problem. Therefore, their knowledge may remain in the form of isolated knowledge. Effective learning requires them to apply newly acquired concepts or skills to different contexts as reported in Cimer (2007), Gallagher (2000) and Yip (2001). Thus, through this research it might be able to allow the undergraduates to use their knowledge or skills to solve the problems in undergraduates' everyday lives.

Since biology is difficult topics at undergraduate level, the difficulty affects undergraduates' achievement. The difficulty makes students less motivated to learn the topics in biology (Johnstone & Mahmoud, 1980). As a result, it is hard for them to achieve a good result in particular course. As eloquently stated by Bloom (1976), the way learners become aware of and evaluate their understanding with any type of knowledge is very significant in their education. Bybee, Fensham, and Laurie (2009) stated that, if they are not interested in learning, they have tendency not to try to study and know the meaning of ideas, notions, concepts or topics that are taught to them. It was proven that when learners feel that they are familiar with concepts or issues from their previous studies, and feel confident enough to explain them, it gives positive effects on their achievement (Eilks, Marks, & Feierabend, 2008). It brings the meaning when undergraduates interested in studying genetics and understand the genetics concepts, they will achieve more compared to those who have learning difficulties in genetics due to its complexity.

University as an institution of higher education, it is well known as a place for higher level of learning. The needs and expectations for higher level of thinking are thus inclined on each student who enrolled at university. Baharom and Palaniandy

(2013) stated that graduated undergraduates from higher institution in Malaysia faced with criticisms from employers pertaining the lack of critical thinking skills. Ministry of Higher Education has announced that public universities in Malaysia must introduce soft skill elements and incorporate them in the undergraduate syllabus (Baharom & Palaniandy, 2013). The ability to think critically can be considered as crucial to each undergraduate. This is because the undergraduates' ability to think critically would therefore have important impact on the success and failure in their entire academic journey at the university. Undergraduates need to be critical thinkers to be able to survive as undergraduates at any institution of higher education.

According to Rodzalan and Saat (2015), undergraduates need to equip themselves with critical thinking as this is the focus of employers in hiring new people. Unfortunately, there are past studies and news reported that most university graduates are still lacking with this skill. According to Director of Students Affairs Development in the Ministry of Higher Education Malaysia, Professor Dr. Mohd Fauzi Ramlan, claimed that graduates who are lack this skill need to improve themselves. If they ignore to improve, an implication would be an increase in number of unemployed graduates in future. This statement is also supported by Kivunja (2015) as it says that critical thinking is one of the important 21st century skills, and it is called as "super skill". Critical thinking skills is fundamentals skills for undergraduates to success in college, university, career and life outside educational institutions. Upon graduation, undergraduates might pursue studies to postgraduates' level or get a job and face a highly competitive world which needs them to face real-world problems that demands more skills to make them survive in the new generation.

Hence, in this study, STEM with problem-based activities were used to learn genetics concepts. This intervention was expected to enhance interest and achievement

towards genetics concepts and critical thinking skills among the first-year undergraduates. Subsequently, undergraduates that apply the STEM-PBL approach to learn genetics concepts will apply the knowledge and skill to other genetics related courses at university.

1.4 Research Objectives

The objectives of this study are as follow:

i. To develop an Integrated Science, Technology, Engineering and Mathematics through Problem Based Learning (STEM-PBL) module in genetics concepts for first-year undergraduates.

ii. To research whether the Integrated STEM-PBL module able to enhance and retains first-year undergraduates' interest towards genetics concepts.

iii. To research whether the Integrated STEM-PBL module able to enhance and retains first-year undergraduates' achievement towards genetics concepts.

iv. To research whether the Integrated STEM-PBL module able to enhance and retains first-year undergraduates' critical thinking skills.

1.5 Research Questions

The research questions of this study are as follows;

i. How to develop an Integrated STEM-PBL module in genetics concepts to enhance and retains first-year undergraduates' interest, achievement and critical thinking skills?

ii. Does the use of Integrated STEM-PBL module enhance first-year undergraduates' interest towards genetics concepts?

iii. Does the use of Integrated STEM-PBL module retains first-year undergraduates' interest towards genetics concepts?

iv. Does the use of Integrated STEM-PBL module enhance first-year undergraduates' achievement towards genetics concepts?

v. Does the use of Integrated STEM-PBL module retains first-year undergraduates' achievement towards genetics concepts?

vi. Does the use of Integrated STEM-PBL module enhance first-year undergraduates' critical thinking skills?

vii. Does the use of Integrated STEM-PBL module retains first-year undergraduates' critical thinking skills?

1.6 Research Hypotheses

Based on the research objectives and questions, the following six null hypotheses are formed to guide this study. These hypotheses are tested at 0.05 level of significance and will be discuss in Chapter 5. There is no hypothesis tested to answer research question 1 as its' aim is to develop the module. The module development process will be explained in Chapter 3. Based on research questions of this study, the null hypotheses (H_0) are formed. Null hypotheses are as follows:

To answer the research question 2 the following null hypotheses were tested in this study. Thus, for the main null hypothesis:

Null Hypothesis 1:

H_{01}: There is no significant difference between the pretest, posttest, and delayed posttest on the mean score on interest towards genetics concepts among first-year undergraduates following Integrated STEM-PBL module.

Subsequently, the null hypothesis is divided into two sub-hypotheses, which are:

H_{01a}: There is no significant difference between mean score of pretest and mean score of posttest on interest towards genetics concepts among first-year undergraduates following Integrated STEM-PBL module.

H_{01b}: There is no significant difference between mean score of posttest and mean score of delayed posttest on interest towards genetics concepts among first-year undergraduates following Integrated STEM-PBL module.

To answer the research question 3 the following hypotheses were tested in this study.

Null Hypothesis 2:

H_{02}: There is no significant difference between the pretest, posttest, and delayed posttest on the mean score on achievement towards genetics concepts among first-year undergraduates following Integrated STEM-PBL module.

Subsequently, the null hypothesis is divided into two sub-hypotheses, which are:

H_{02a}: There is no significant difference between mean score of pretest and mean score of posttest on achievement towards genetics concepts among first-year undergraduates following Integrated STEM-PBL module.

H_{02b}: There is no significant difference between mean score of posttest and mean score of delayed posttest on achievement towards genetics concepts among first-year undergraduates following Integrated STEM-PBL module.

To answer the research question 4 the following hypotheses were tested in this study. Null Hypothesis 3:

H_{03}: There is no significant difference between the pretest, posttest, delayed posttest on the mean score on critical thinking skills among first-year undergraduates following Integrated STEM-PBL module.

Subsequently, the null hypothesis is divided into two sub-hypotheses, which are:

H_{03a}: There is no significant difference between mean score of pretest and mean score of posttest on critical thinking skills among first-year undergraduates following Integrated STEM-PBL module.

H_{03b}: There is no significant difference between mean score of posttest and mean score of delayed posttest on critical thinking skills among first-year undergraduates following Integrated STEM-PBL module.

1.7 Significance of Research

This study research whether STEM through PBL module able to enhance and retains undergraduates' interest, achievement towards genetics concepts and critical thinking skills among first-year biology undergraduates' in one of public university is really relevant. Consequently, this study is important in terms of education for several reasons.

Science and Technology education has always been a priority in Malaysia. This rings true with the implementation of the First National Science and Technology Enrolment Policy of 60:40, which refers to 60 percent of students would have enrolled in science and 40 percent in arts. This policy is supported with Malaysia Higher Education Blueprint (2015-2025) desires, where the STEM education is important in

education system in Malaysia. In conclusion, STEM education is important to help Malaysia to moves to greater heights. If STEM education is not implemented and practice, Malaysia will continue to fall in world ranking in STEM subjects and will not be able to compete with other countries.

In align with Malaysia Higher Education Blueprint (2015-2025) desires to invest in Malaysia's youth, this study will be a beneficial for Ministry of Higher Education. This is because, to thrive in an increasingly competitive global economic development, it requires the transformation of Malaysia's higher education system. Apart from proficiency in English, the jobs of tomorrow will require a greater emphasis on STEM. It is hope that the private higher education sectors in Malaysia will also play its roles in supporting STEM education in Malaysia. The Government cannot transform the higher education sector alone. Both Government and private sectors in higher learning institutions need cooperate so that can contribute and support the process of STEM implementations in Malaysia's higher education environment.

From this study, it is expected that the learning will be more relevant as students are exposed to the genetics concept of what they learn based on current and real-world situations. With STEM as a priority in Malaysia Higher Education Blueprint (2015-2025), our younger generation is on the way to have a strong foundation to be better citizens and future innovators in a rapidly evolving world.

Malaysia need graduates who have the necessary worldview and life- guiding principles and learning skills to deal with present and future demands. Thus, this study can be considered as a bench mark in producing graduates with critical thinking and a high degree of knowledge in STEM. By participating in this study, they can become lifelong learners who are motivated to continuously develop their knowledge and skills, think critically, and be open to change, new ideas and new ways of doing things.

Thus, the increased involvement of each undergraduate in a small group provides them with the ideal opportunity to practice explanation to one another in the group. This approach will challenge them to learn through engagement in a real problem. It is a format that simultaneously develops both problem-solving strategies and disciplinary knowledge bases and skills by placing undergraduates in the active role of problem solvers confronted with an ill-structured situation that will stimulate the kind of problems that they will face in their complex working organizations.

1.8 Limitations of the Study

Despite the benefits, this study also has some limitations. Limitations is a condition beyond the control of a researcher, who may limit the conclusions of the study and its ability to apply in another situation (Best & Kahn, 1998). The limitations of this study are as follow.

First, the present study sample comprises of first-year undergraduates. Therefore, the findings may not be generalized beyond the first-year level such as second and third year or below the first-year level such as pre-university level or at matriculation level.

Second, for the purpose of this study, the undergraduate's samples are from one public university in Northern Region of Malaysia. Therefore, the findings may not be generalized to all Malaysia first-year undergraduates from different public universities as well as other countries.

Third, this study focusses on basic genetics concepts which is covered in the Semester two of the first-year of study for undergraduates in biology faculty. These basic genetics course is compulsory to register by the undergraduates in Semester two during first-year of their study. This is because the knowledge from this course will be

fundamental to other genetics related courses in upcoming semesters. Hence, the findings may not be generalized to other science courses such as chemistry and physics or other programs of study within the faculty.

Fourth, this study employed one-way repeated measure design and thus there is no control group involved. The one-way repeated measure design within subject reduces the error in variance between individuals to increase the statistical power of the test because every single participant is subjected to every single treatment (Ellis, 1999) and few participants are involved in completing the entire experiment to detect the desired effect sizes (Howitt & Cramer, 2011). However, control group treatment allows comprehensive comparison to be made and add strength to the findings obtained in this study. Besides that, control group is useful to set as a bench mark to measure the results of the other groups.

Lastly, the collected data in this study will be analyse by quantitatively. The investigation would have been enriched using the qualitative research, such as data from interviews session. However, due to time and organisational constraints, these could not be carried out. The performance might arguably include some rote learning because the undergraduates might put extra hard works in the intervention. It would be interesting to assess their performance after a couple of months or even longer to minimise the effects of rote learning. Few follow-up assessments are not possible because of time limitations for the undergraduates to involve in the few follow up after the delayed posttest. Only posttest and delayed posttest were done to study whether the Integrated STEM-PBL module will be able to enhance and retains interest and achievement towards genetics concepts and critical thinking skills among the first-year undergraduates.

1.9 Operational Definitions of the Study

The following are the operational definitions of the variables in the study.

1.9.1 Integrated STEM Education

STEM education is an integrated approach to learning which removes the traditional barriers separating the four disciplines of science, technology, engineering, and mathematics, and integrates them into real-world rigorous and relevant learning experiences (Vasquez, Sneider, & Corner, 2013). Integrated STEM education is an interdisciplinary approach to learning where academic concepts are coupled with real-world lessons as undergraduates apply science inquiry, technology literacy, engineering design process, and mathematics thinking in contexts that make connections which enabling the development of STEM learning and the ability to compete in the new economy (Tsupros, Kohler, & Hallinen, 2009) once the undergraduates graduates from their first degree.

In this study, the integrated STEM education is defined as the instructional approach where there are rigorous academic concepts, without ignoring core science concepts, to encourage the STEM content of two or more STEM domains. Moreover, the integrates STEM instruction focused on connecting with real-world problems including local and global issues to enhance student learning and skills in competitive new economy. In this study, integrated STEM education be complimentary by prevailing learning PBL approach.

1.9.2 Problem Based Learning

21st century graduates are individuals who skilfully apply their knowledge of STEM to solve real-world problems. In PBL, the learning is driven by challenging and open-ended problems. The students work in small collaborative groups and the

teachers take on the role as "facilitators" of learning (Boud & Feletti, 1997). PBL is a learning method where students are given the relevant problems with daily practice or student environments. Students need to complete the given problems by the lecturers in a small group (each group member will have different roles to achieve the learning objectives). In this study, PBL means that the learning is centered on real world problems in genetics and the learning is students centered. The lecturer in the study act as facilitators to facilitate the entire process successfully.

1.9.3 Integrated STEM-PBL Module for the Genetics Concepts

In this module, PBL is used in the context of STEM learning. The Integrated STEM-PBL module for the genetics concepts is a learning module that discusses the selected genetics topics in the genetic course. Each problem scenario in this module are based on real-world problems. Each of these activity in the module challenges first-year undergraduates to combine Science, Technology, Engineering, and Mathematics concepts in pursuit of a solution to particular genetics problem. The lessons in the Integrated STEM-PBL module are based on the learning outcomes and objectives that been stated by program of study in the selected Faculty of Biology. It incorporates a PBL approach and requires the first-year undergraduates to be independent and collaborative working to solve the given task. In this module, both formative and summative assessments were given. Each module is centered on a real-world issue in which the first-year undergraduates are given the task of identifying, generating, discussing, synthesizing, applying and reflecting the solution to a genetics problem. The activity is based on fundamental genetics concepts in one or more form that might encounter. The four activities in the Integrated STEM-PBL module are Who Is The Victim?, Assist In Karyotyping!, Test Your Hypotheses Now!, and Help Me!.