THE EFFECT OF STEM PROJECT-BASED LEARNING ON SELF-EFFICACY IN LEARNING PHYSICS, SCIENTIFIC REASONING, AND ACHIEVEMENT IN PHYSICS MECHANICS TEST AMONG FORM FOUR SECONDARY SCHOOL STUDENTS

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by

SEYEDH MAHBOOBEH JAMALI

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DEDICATION

To the sweet memory of my father, Seyed Mahmud Jamali, who died on the completion of this thesis and to my mother, Eftekhar Sadat Taghavipour. They were wonderful parents, remarkable teachers and loved leaders. I had the chance to grow so loved.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Covariance
CTSR	Classroom Test of Scientific Reasoning
DLP	Dual Language Programme
EPU	Economic Planning Unit, Malaysia
HDR	Hypothetical-Deductive Reasoning
NGSS	Next Generation Science Standards
PBL	Problem-Based Learning
PER	Physics Education Research
PISA	Programme for International Student Assessment
PjBL	Project-Based Learning
PMR	Lower Secondary Assessment
SPM	The Malaysia Certificate of Examination (equivalent to General Certificate of Education- GCE O-level)
SPSS	Statistical Package for the Social Sciences
STEM	Science, Technology, Engineering and Mathematics
STPM	The Malaysia Higher School Certificate Examination (equivalent to GCE A-level)
TIMSS	Trends in International Mathematics and Science study
UPSR	The Primary School Assessment Test
USM	Universiti Sains Malaysia

KESAN PEMBELAJARAN BERASASKAN PROJEK STEM TERHADAP EFIKASI KENDIRI DALAM PEMBELAJARAN, FIZIK, PENAAKULAN SAINTIFIK, DAN PENCAPAIAN DALAM UJIAN MEKANIK FIZIK DALAM KALANGAN PELAJAR TINGKATAN EMPAT SEKOLAH MENENGAH

ABSTRAK

Kajian ini bertujuan untuk mengkaji kesan Pembelajaran berasaskan projek STEM terhadap efikasi kendiri dalam pembelajaran fizik, penakulan saintifik dan pencapaian dalam ujian mekanik fizik di kalangan pelajar tingkatan empat sekolah menengah. Sampel terdiri daripada dua kumpulan pelajar, 50 pelajar untuk kaedah pengajaran Pembelajaran berasaskan projek STEM (kumpulan eksperimen) dan 57 pelajar untuk kaedah pengajaran konvensional (kumpulan kawalan). Kajian ini menggunakan metodologi kuasi eksperimen dengan reka bentuk pra-ujian dan pasca ujian. Untuk menganalisis data yang dikumpul, statistik deskriptif dan inferens seperti analisis multivariat kovarian (MANCOVA) telah digunakan. Dapatan kajian menunjukkan bahawa, kaedah Pembelajaran berasaskan projek STEM memberi kesan yang signifikan untuk meningkatkan efikasi kendiri dalam pembelajaran fizik, penakulan saintifik, dan pencapaian dalam ujian mekanik fizik dalam kalangan pelajar sekolah menengah. Kaedah pengajaran STEM Pembelajaran Berasaskan Projek (kumpulan eksperimen) ($M = 14.54$, daripada 20) menunjukkan prestasi signifikan yang lebih baik daripada kumpulan kaedah pengajaran konvensional (kumpulan kawalan) ($M = 9.38$, daripada 20), $F (1, 102) = 86.36$, $p <.0167$ dalam keputusan pencapaian pasca ujian mekanik fizik. Oleh itu, peningkatan 25.80% berlaku dalam perbandingan antara kaedah pengajaran STEM

Pembelajaran Berasaskan Projek dan kaedah pengajaran konvensional dalam keputusan pencapaian pelajar dalam pasca ujian mekanik fizik. Implikasi kajian, dan cadangan untuk kajian masa depan diterangkan. Secara keseluruhannya, penggunaan kaedah pengajaran STEM Pembelajaran Berasaskan Projek memberikan kesan positif terhadap efikasi kendiri dalam pembelajaran fizik, penakulan saintifik dan pencapaian dalam ujian mekanik fizik berbanding dengan kaedah pengajaran konvensional.

THE EFFECT OF STEM PROJECT-BASED LEARNING ON SELF-EFFICACY IN LEARNING PHYSICS, SCIENTIFIC REASONING, AND ACHIEVEMENT IN PHYSICS MECHANICS TEST AMONG FORM FOUR SECONDARY SCHOOL STUDENTS

ABSTRACT

This research aimed to study the effect of STEM project-based learning (PjBL) teaching methods on self-efficacy in learning physics, scientific reasoning and achievement in physics mechanics test among Form Four secondary-school students. The sample consists of two groups of students, with 50 students being exposed to the STEM PjBL teaching method (experimental group), and 57 students the conventional teaching method (control group). The study employed a quasi-experimental methodology with a pre-test and post-test design. To analyze the collected data both descriptive and inferential statistics such as multivariate analysis of covariance (MANCOVA) were utilized. The results revealed that the STEM PjBL method significantly improves self-efficacy in learning physics, scientific reasoning, and achievement in physics mechanics test among the participants of the study compared to the conventional teaching method. It was discovered that the STEM PjBL teaching method (experimental) group (M = 14.54, out of 20) performed significantly better than the conventional teaching method (control) group (M = 9.38, out of 20), F (1, 102) = 86.36, $P < .0167$ in the post-test results of physics mechanics achievement test. Therefore, there was a 25.80% improvement on the post-test results of the students' achievement in physics mechanics test scores, between students who were exposed to STEM PjBL compared to those who were instructed using conventional teaching methods. Implications of the study and recommendations for future study are

described. This study supports the use of the three theories namely, constructivism, social cognitive theory, and situated learning theory which explain the process of STEM PjBL. In addition, this study also indicates that the teachers can implement STEM projects successfully, if the integration of STEM is done through the process of STEM PjBL.

CHAPTER ONE:

INTRODUCTION

1.1 Introduction

In the field of science, physics is reputed to be one of the difficult subjects to grasp (Angell et al., 2004; Boe & Henriksen, 2013; Gill & Bell, 2013; Guisasola et al., 2013; Oon & Subramaniam, 2010; Oon & Subramaniam, 2013). Despite the fact, that most of the concepts of physics are used in daily life, physics subject are identified by students as being difficult, boring and carrying useless information (Erdemir, 2009; Kock et al., 2013; Kurnaz & Çepni, 2012). In most schools, physics subject are taught in the most abstract fashions; mainly focusing on conveying mathematical formulas for physical phenomena, without students getting the opportunity to actually experience said phenomena (Han & Black, 2011). Consequently, some students have comprehension deficiency in the essential concrete concepts of principles of physics (DiSessa, 1993; Han & Black, 2011). Similar to other countries, effective teaching of science, particularly physics, is a challenge in Malaysian secondary schools and has been of considerable concern for a very long time (Goh & Ali, 2014; Halim et al., 2012).

Research has shown that most students are left with confusion about basic concepts of physics when they are subjected to the conventional teaching method (Guisasola et al., 2013; Li, 2012). According to (Rex & Wolfson, 2010; Teodorescu et al., 2008; Wieman & Perkins, 2005) connecting physics with the real world helps students understand what physics is and how it relates to their lives. In addition, numerous examples and applications help students explore the ideas of physics as they relate to real world (Rex & Wolfson, 2010). There is ample evidence from research that students are learning to relate the physics principles to objects and events in the real world; they appreciate the real-world connections between physics taught in classrooms and in the nature (McDermott, 2001; McKagan et al., 2008; Teodorescu et al., 2008; Wieman & Perkins, 2005). Cahyadi (2007) identifies that physics is a way of looking at the universe and understanding it and is very much a part of the world around us. Putting physics in familiar real-world contexts helps students relate the new concepts to their prior knowledge (McKagan et al., 2008).

According to Heil et al. (2013), integrated STEM education is based on the idea that real-world issues require multiple perspectives, skills, and knowledge to be productively addressed (Annetta & Minogue, 2016; Wang et al., 2011). Integrated STEM education can be defined as an approach to learning where two or more STEM contents are integrated during lessons and units (Heil et al., 2013). Integrated STEM education can potentially enhance students' performance and interest in science and mathematics, as well as motivate them to pursue careers in STEM fields. The future success of students is highly dependent on effective STEM education (Stohlmann et al., 2012). Students must apply problem solving skills and their knowledge of STEM content to solve real world problems that help them make connections between school, community, and the world (Park, 2011).

1.2 Background

Physics is commonly considered to be a difficult subject. That includes key concepts such as mass, acceleration, and fundamental principles and models such as Newton's Laws. Two kind of problems, preliminary classes of mechanics are the Pulley system and the simple pendulum (Coelho, 2013). The solving plans of the

Pulley system and simple pendulum problems are based on Newton’s second law (Coelho, 2013). Student difficulties with Newtonian physics have been well documented in the physics education research literature over the past few decades (Close et al., 2013). DiSessa (2001) suggested that physics is best taught through projects, experiments, lab, and demonstrations which help the students to understand physical phenomena conceptually. Students have particular difficulty in comprehending physics concepts which have very few real life referents (Chi et al., 1981; Papadimitriou et al., 2009). Project can serve bridge between phenomena in the classroom and real life experience (Blumenfeld et al., 1991; Holubova, 2008; Slough & Milam, 2013). In other words, the goal of STEM education is to use the thinking skills in science and technology to solve the everyday real life problems. When the lessons have possible real-world connections, the students are applying science content and concepts to real-world problems and that is a wonderful way for them to see how what they're learning in school can be used for the rest of their life.

There are many ways to use STEM education approach in the classroom; one of them is by using PjBL. According to Holbrook et al. (2014), PjBL is a classroom activity model, in which the focus on the teacher is lessened and instead, the role of student activity would increase through a greater emphasis on how to address real-world issues and integrated manner in a practice-based format. PjBL includes various aspects and different combinations of content. Moreover, studies show when students are engaged in meaningful activities they learn respective concepts better (Fortus et al., 2005; Keppell, 2008) which can yield to production of authentic artifacts (Hung et al., 2006). Therefore, exploiting real-world problems within PjBL will make knowledge more applicable and relevant for students, and would improve information and skills transfer based on real world conditions (Bransford, 2000; Satchwell &

Loepp, 2002), and consequently life-long learning would improve (Zheng et al., 2011). Because of the natural overlap between different fields of science, technology, engineering and mathematics, STEM education suites PjBL (Capraro & Jones, 2013) and hence, they match together.

STEM PjBL is an instructional approach utilizing a project. STEM PjBL is defined a precise outcome with an imprecise task (Capraro & Slough, 2013) and is exploited as a student-centered instructional method (Han, 2013a). Thus, it is critical to give students the freedom to make artifacts to construct their knowledge. In addition, STEM PjBL can expose students to a realistic and contextualized problem solving situations. Furthermore, STEM project would connect classrooms' phenomena to real life experience that integrates four subjects of STEM education (Blumenfeld et al., 1991; Holubova, 2008; Slough & Milam, 2013). In this approach students should receive training to listen to others, and contemplate before responding or making any action. Design is often a central component to STEM PjBL. In the discussion over the design, students should get time in order to reflect, include others' ideas, and make their contributions carefully instead of coming up with flawed arguments (Capraro & Slough, 2013).

In reality, taking care of social and natural issues does not occur in isolated territories (Thomas, 2000). Using PjBL in order to implement STEM education approach will probably create meaningful learning in an authentic context. PjBL is probably matched with STEM approach due to the opportunity to design the project which can integrate science, technology, engineering, and mathematics. There are few studies in the literature reporting through integration of STEM into a PjBL pedagogy but these studies are not sufficient enough especially at school level (Han et al., 2014;

Salomon & Perkins, 1989; Tseng et al., 2013). One definition of STEM PjBL describe it as an outcome that is well-defined but y an ill-defined task accompanies it (Capraro & Slough, 2013) and it is used as an instructional method that centers around the student (Han, 2013a). STEM PjBL is not only a word to indicate an instructional approach using a project to integrate the four subject areas of STEM, but also includes teaching orientation grounded on constructivism.

The need to implement STEM PjBL is based on the issue with performance of students in Trends in International Mathematics and Science study (TIMSS) and Programme for International Student Assessment (PISA). Malaysian students have failed to achieve the minimum international standard in TIMSS and PISA (Chin & Zakaria, 2013). Given that STEM education is the fundamental technological foundation of an advanced society, the key to the production and maintenance of a workforce well-versed in these fields is the improvement of STEM teaching in Malaysia (Meng et al., 2014). However, the number of students who choose STEM fields continues to decline in the recent years (Shahali et al., 2015). With reference to Malaysian Education Blueprint 2013-2025 (Ministry of Education Malaysia, 2016), the government planned to strengthen quality of STEM education. According to the Blueprint 2013-2025 (Ministry of Education Malaysia, 2016) especially for science and mathematics, students will also benefit from increased teaching time and an emphasis on the practical application of knowledge through laboratory and project-based work. Therefore, there is a shortage of STEM PjBL method in the Malaysian education system which will be compensated by 2025.

Also, researchers have found positive correlations between student scientific reasoning abilities (Coletta & Phillips, 2005; Lawson et al., 2000) and self-efficacy

(Doordinejad & Afshar, 2014; Jungert et al., 2014) on measures of learning gains in science content (Lawson et al., 2007), at the university level. However, the results of the effectiveness of STEM PjBL for secondary school students are not clear yet. STEM PjBL is in the infancy stage around the globe [including Malaysia (Jayarajah et al., 2014; Rasul et al., 2015)] as far as the studies are concerned (Bondi et al., 2014; Cutright et al., 2014; Jackson et al., 2012; Pleiss et al., 2012). Therefore, this study investigated the extent to which students improve their self-efficacy in learning physics, scientific reasoning and achievement in physics mechanics test through STEM PjBL activities.

Recent scientific applications change constantly and rapidly, therefore science education students need to obtain lifelong skills such as self-efficacy and scientific reasoning, which lead to achievement. Scientific reasoning is complex in nature (Lawson, 1982; Schunn & Anderson, 1999; Zeineddin & Abd-El-Khalick, 2010). Overton (2013) and Holyoak and Morrison (2005) considered reasoning as a specific type or branch of thinking that involves drawing inferences from initial premises and is closely related to judgment, decision-making, and problem-solving (Greenhoot et al., 2004; Williams et al., 2004; Zeineddin & Abd-El-Khalick, 2010). The research has also shown that reasoning is major contributions to academic and everyday life success (Chinnappan et al., 2012; Zeineddin & Abd-El-Khalick, 2010). There are several studies in the literature reporting establishment of students' reasoning abilities as an important factor in science and physics achievement (Ates & Cataloglu, 2007; Cavallo, 1996; Cohen et al., 1978; Lawson et al., 2007; Lawson et al., 2000). Moreover, Bailin (2002); Han (2013b); Schalk et al. (2013) considered that scientific reasoning at least to some extent is equivalent to critical thinking and achievement in learning physics can be achieved through enhancing scientific reasoning.

On the other hand, researchers in various disciplines have studied the change of efficacy in PjBL environment, but less in the STEM project context (Schaffer et al., 2012). There are several studies that empirically support the relationship between self-efficacy and academic achievement (Bong & Clark, 1999; Cheng, 2013; Komarraju & Nadler, 2013; Pietsch et al., 2003; Zimmerman & Kitsantas, 2005). STEM PjBL is an approach leading students to explore ill-defined problems which integrate science, technology, engineering, and mathematics within a constrained environment. Being an as a student centered approach hands-on activities, promoting collaboration, team communication, knowledge construction, and having a formative assessment have been indicated as primary components of STEM PjBL (Barron et al., 1998; Han, 2013a; Slough & Milam, 2013; Thomas, 2000). Considerably more work will need to be done to determine the different impact of STEM PjBL on self-efficacy in learning physics, scientific reasoning, and achievement in learning physics.

1.3 Problem Statement

It is well known that students find physics difficult, and many students perceive it as a difficult subject which deals with abstract laws and models that do not describe the real world (Erdemir, 2009; Schauer et al., 2008; Thomas, 2013). Many researchers have investigated the issue of mechanics, since it is a fundamental subject in physics (Byun et al., 2010). Students have problems understanding the physical concepts of mechanics (Kaufmann & Meyer, 2008). Rakkapao et al. (2014) mentioned that physics mechanics is the most difficult concept for the students.

Over the past three decades, researchers have reported that students face conceptual difficulties in understanding and explaining the physical concepts

(Sengupta & Farris, 2012). Basson (2002) mentioned difficulties in learning physics, are derived from the complexity of the subject. Student difficulty in learning physics mechanics concepts results in low achievements in physics science as general (Byun et al., 2010; Reigosa & Jimenez-Aleixandre, 2007). Jimoyiannis and Komis (2001) documented that the basic knowledge of secondary school is limited and therefore they have difficulties in understanding physics mechanics. Later on at higher levels of physics understanding more complex subjects will be negatively impacted by this lack of basic knowledge and comprehension at earlier stages (Potgieter et al., 2010).

Research has shown that in conventional physics instruction most students have difficulties in understanding the basic concepts of physics mechanics (Dilber et al., 2009; Taasoobshirazi & Carr, 2008). Taasoobshirazi and Sinatra (2011) found conventional physics instruction to be the most common type of instruction in secondary school physics subject. Letchumanan (2015) investigated that teacher-centered approaches is the major shortcoming in the education system in Malaysia and in conventional classroom there is a little interaction between the students and teachers (Kasim & Aini, 2012). Researchers show that in order to increase the level of success in physics education, new teaching methods need to be implemented into physics education (Erdemir, 2009). Physics should be taught in context and related to real world applications (Teodorescu et al., 2008; Wieman & Perkins, 2005). The applications of physics are needed to find solutions for real world problems which necessitate the usage of engineering and technology (Nachtigall, 1990; Teodorescu et al., 2008). Therefore, physics should be taught the context of STEM real world projects (Rex & Wolfson, 2010; Teodorescu et al., 2008).

Low self-efficacy beliefs reduce student's interest and achievement (Pleiss et al., 2012). Students with low self-efficacy may refrain from planning activities that they perceive to be above their capabilities and expend little effort to find solutions for the problems. Self-efficacy can have diverse effects in learning achievement setting as well (Bandura, 1993; Schunk, 2012). Ketelhut (2007) mentioned students with low self-efficacy usually stay away from exploring the complexities of the new world. So there is a need to research how to raise students' self-efficacy (Ketelhut, 2007). Some studies support that in a learning environment with real-life issues embedded into it, students tend to express positive self-efficacy beliefs on that curriculum subject (Hampton & Mason, 2003; Jungert et al., 2014). Furthermore, as Linnenbrink and Pintrich (2003) stated, for meaningful learning and improved self-efficacy, students should be engaged in learning process as well as cognitively and behavioral engagement (Cetin-Dindar, 2016).

The relationship between self-efficacy and reasoning to achievement in introductory college level is strong (Lawson et al., 2007). Secondary students have few opportunities of experiencing reasoning to solve physics problems (Montalbano & Benedetti, 2013). Coletta and Phillips (2005) found that students whose lack of scientific reasoning ability limits their learning to high school are very likely to have limited success in their physics subject as well. Therefore, a new approach such as STEM PjBL is needed to solve the lack of scientific reasoning ability in the secondary school level. The way PjBL works is to set an investigation process for students to engage in, to find a response to a driving question that revolves around a real-life problem, and throughout the process the method guides and organizes the instructional activities of the project (Krajcik et al., 2003). The STEM PjBL focuses on an authentic problem which raises multiple perspectives on the issue, and improves sets of high-order thinking and communication while providing an opportunity for the students to utilize scientific reasoning (Capraro & Slough, 2013; Kamal, 2012; Moore & Rubbo, 2012). According to Han (2013b) the integrated STEM approach have a potential to develop both STEM education content knowledge and scientific reasoning.

1.4 Aims and Objectives of the Study

The aim of the current study is to research the effect of STEM PjBL on self-efficacy in learning physics, scientific reasoning and achievement in physics mechanics test among Form Four secondary school students.

Specifically, the objectives of the study are to research:

O_{1a}: The effect of STEM PjBL on self-efficacy in learning physics among Form Four secondary school students.

O_{1b}: The effect of STEM PjBL on scientific reasoning among Form Four secondary school students.

O_{1c}: The effect of STEM PjBL on achievement in physics mechanics test among Form Four secondary school students.

1.5 Research Questions

The main research question of the study is as follow:

Are there any significant differences on the post-test mean scores of self-efficacy in learning physics, scientific reasoning and achievement in physics mechanics test between students who follow STEM PjBL and conventional teaching method after the effect of mean scores of pre-test are controlled?

Based on the main research question, this study aims to answer the following three specific research questions:

Q_{1a}: Is there any significant difference on the post-test mean scores of self-efficacy in learning physics between students who follow STEM PjBL and conventional teaching method after the effect of mean scores of pre-test is controlled?

Q_{1b}: Is there any significant difference on the post-test mean scores of scientific reasoning between students who follow STEM PjBL and conventional teaching method after the effect of mean scores of pre-test is controlled?

Q_{1c}: Is there any significant difference on the post-test mean scores of achievement in physics mechanics test between students who follow STEM PjBL and conventional teaching method after the effect of mean scores of pre-test is controlled?

1.6 Research Hypotheses

To answer the main research question, the following main hypothesis will be tested in this study.

H_{01}: There are no significant differences on the linear combination of post-test mean scores of self-efficacy in learning physics, scientific reasoning, and achievement in physics mechanics test between students who follow STEM PjBL and conventional teaching method after the effect of pre-test mean scores is controlled.

In order to answer the specific research question of Q_{1a} the following sub-hypothesis will be tested in this study.

H_{01a}: There is no significant difference on the post-test mean scores of self-efficacy in learning physics between students who follow STEM PjBL and conventional teaching method after the effect of pre-test mean scores is controlled.

In order to answer the specific research question of0 Q_{1b}, the following sub-hypothesis will be tested in this study.

H_{01b}: There is no significant difference on the post-test mean scores of scientific reasoning between students who follow STEM PjBL and conventional teaching method after the effect of pre-test mean scores is controlled.

In order to answer the specific research question of Q_{1c}, the following sub-hypothesis will be tested in this study.

H_{01c}: There is no significant difference on the post-test mean scores of achievement in physics mechanics test between students who follow STEM PjBL and conventional teaching method after the effect of pre-test mean scores is controlled.

1.7 Significance of the Study

Through this study, being active was promoted above being passive and students were encouraged to cooperate with each other rather than competing, through employing STEM PjBL to learn physics. Even more, the students and teachers would be able to run more STEM education projects for new problems by following two teaching materials to develop a new teaching material. The researcher does not say that this is an easy step but definitely an important one which should not be neglected.

The findings of the present study encourage physics teachers to adopt alternative method like STEM PjBL to attain educational objectives in the secondary school levels. However, a well-designed PjBL instruction brings new rigor and relevance to learning and STEM education is taking away science and mathematics from their isolation from each other and from technology and design, out in the real world. The project itself is not designed from the STEM education perspective. This study designs STEM project which helps students make connections across subjects and provide opportunities for science, technology, engineering and math to be integrated. Also the classroom learning gets the benefits of greater relevance to the real-world and students get more engagement and deepened understanding.

Researchers can adapt the research instruments, and benefit from the findings of the current study in secondary school, since, most planning and implementation of STEM PjBL has taken place at university levels. The argument of this study is, if Form Four secondary school students are given opportunities to represent and explain physics word problems through the use of STEM PjBL they probably would gain a deeper self-efficacy in learning physics, scientific reasoning, and achievement in the physics mechanics problems. The present study also provides a guideline to carry out further research in other physic topics like Thermodynamic, Electricity and Nuclear physics as well as other science fields like biology, chemistry and Mathematics.

1.8 Limitation of the study

The limitations of this study are as follows:

1. The samples students consist of Form Four students in two schools of Pudu zone in Kuala Lumpur. Therefore, the findings cannot be generalized in all Malaysian schools. It also cannot be generalized in other countries since the physics syllabus are different.

2. The findings may not be generalized to other science classes such as biology and chemistry.

3. The present study sample comprises of Form Four students of secondary school. Therefore, the findings may not be extrapolated beyond the Form Four students of secondary school to university and college levels.

4. This study only utilized quantitative data from questionnaire which are mentioned in chapter 3. Therefore, the result may be different if different questionnaires are used and different methodology such as qualitative methodology is used.

5. This study defined STEM PjBL education based on an approach of integrating four subjects which are science, technology, engineering, and mathematics.

Therefore, this study began by how the teaching materials have been prepared with subtopics of preparation of teaching material being described in chapter 3. The result may vary if different perspective of defining STEM education or different approach of preparing the teaching material, are used.

1.9 Operational Definitions

Operational definitions of the terms used in the study are the following:

1.9.1 Integrated STEM Education

The integrated STEM education is defined based on a method of learning where two or more STEM education contents are integrated in a real world project (Heil et al., 2013). The transdisciplinary approach as a part of the integrated STEM approach was used based on (Vasquez et al., 2013). This study chose transdisciplinary approach due to students doing STEM PjBL because; it has an extensive degree of integration.

1.9.2 STEM Project-Based Learning (PjBL)

STEM PjBL is defined as a learner-centered instructional model (Hou et al., 2007) and tends to model real-world work situations, with a focus on group work and hands-on experiences (Pleiss et al., 2012). In STEM PjBL students are engaged in activities designed to either find the response to a question or appropriate solution to a problem (Frank et al., 2003; Gardiner, 2014; Lou et al., 2011b; Olivarez, 2012; Vega et al., 2013).

Thus the project involved in this study requires that the students apply physics in the science of measurement and exposes the students to applying physics in the context of science and engineering, and along the process mathematical calculation is used to apply physics formula in order to solve the physics problem.

1.9.3 Conventional Teaching

In this study conventional teaching refers to the common physics teaching method based on the Malaysian physics curriculum syllabus. The researcher observed some conventional teaching method being employed in physics class of Form Four of Malaysian daily secondary schools. The researcher observed that, teachers start the class with review of the main topics from previous lesson and ask review questions. Then, present the new topic by power point presentation slides which are extracted from the textbook.

1.9.4 Self-Efficacy in Learning Physics

Self-efficacy refers to the beliefs one hold about their own capabilities to perform or learn behaviors at certain levels (Bandura, 1988, 1993). This study uses the terminology of self-efficacy in learning physics according to Bandura (1977) who defined self-efficacy as the ability of an individual to perform a particular task, with an emphasis on the specificity of the learning task in physics. In this study the self-efficacy in learning physics is measured by instrument developed by Sawtelle (2011).

1.9.5 Scientific Reasoning

Bailin (2002); Han (2013b), and Schalk et al. (2013) considered scientific reasoning at least to some extent equivalent to critical thinking. Lawson (2004) defines the pattern of scientific reasoning as a mental strategy, plan, or rule that is used to process information and make conclusions in a way that surpasses direct experience. In this study, the Lawson (1978) Classroom Test of Scientific Reasoning (CTSR) instrument is used to measure the students' level of scientific reasoning before and after the intervention. The test measures the ability of the students in application of scientific reasoning in order to analyze a situation, predict, or find a solution to a problem (Lawson, 1995).

1.9.6 Achievement in Physics Mechanics test

Learning achievement refers to test scores (Lin et al., 2013) of a multiple choice questionnaire. The test consist of 10 questions developed based on Giancoli (2005) for pendulum project and Myneni (2011) for pulley project. Therefore, in this study learning achievement is equal to achievement in physics mechanics test, which is the level of improvement which is measured by total value of test score.

1.10 Summary

This study aims to research the effect of STEM PjBL on self-efficacy in learning physics, scientific reasoning and achievement in physics mechanics test among Form Four secondary school students. In order to understand the overview of the research a background and a problem statement have been provided as a basis to understand the direction of the research. Operational definitions have been prepared in order to ensure the clarity of the variables involved the study. Objectives of this study, research questions and research hypotheses were explained in the first chapter.

CHAPTER TWO:

LITERATURE REVIEW

2.1 Introduction

The aim of this study is to research the effect of STEM PjBL on self-efficacy in learning physics, scientific reasoning and achievement in physics mechanics test among Form Four secondary school students. This chapter provides a comprehensive overview of the related work to understand the important key concepts and issues which will be used throughout the study. The chapter is arranged into the following sub-sections; STEM education, characteristics of STEM education, science and STEM education in Malaysia, STEM education around the world, PjBL, STEM PjBL, past research finding about STEM PjBL, self-efficacy in learning physics, scientific reasoning, achievement in physics mechanics test, theoretical framework, constructivism theory, theory of social cognitive, situated cognitive theory, conceptual framework, and summary of findings from previous studies and brief discussion.

2.2 STEM Education

STEM education is well placed to teach skills that are relevant in the information-rich modern economy, such as problem solving. STEM education skills include problem solving, rigorous analysis of evidence and theories, numeracy, and the development of logical arguments. Because STEM fields are intrinsically investigative, they are ideal training grounds for promoting objective and critical thinking (West, 2012). According to Turner (2013) STEM education is not only an area of study but it is also a project-based and collaborative way of teaching and learning that focuses on finding solutions for real-world problems. STEM programs aim to educate student as a whole while emphasizing problem solving, innovation, critical thinking and creativity. With the technological advances and resources the STEM professionals rely upon, they have become great influencers on the daily lives of people. STEM education is the future of educational system because, critical thinking, collaboration, and working in groups are essential for the future (Turner, 2013).

In 1991 at USA, the directorate for science and engineering education was reorganized and renamed the directorate for education and human resources with emphasis on STEM education for ALL, although it was still largely science and mathematics education. The interest in technology education increased, and Congress mandated the advanced technological education program to develop technicians for the high performance workplace. In the early 2000s, the assistant director for education and human resources at the national science foundation (NSF) coined the acronym STEM for science, technology, engineering, and mathematics to replace SMET (Association, 2009).

In the last few decades, many reform initiatives have shaped teaching and learning in STEM disciplines. These reform focused on an attempt to shift from a teaching method where students were taught to remember and execute isolated facts and skills to encouraging them to experience learning the same way scientists and engineers do (Asghar et al., 2012). Reform efforts within each of the STEM education disciplines have focused on such strategies as inquiry learning (Minstrell, 2000), project-based learning (Swartz et al., 2007), constructivist learning (Mayer, 2004), problem-based learning and the integration of technology across all STEM education disciplines (Asghar et al., 2012).

Expressively, Lou et al. (2011b) mentioned that science, technology, engineering, and mathematics are a form of instruction that is integrated and combines scientific study, technology, engineering design and mathematical analysis. Within this context, science emphasizes on searching for natural principles, engineering emphasizes on applying scientific findings to designing equipment needed for everyday life, technology tries to manufacture the tools designed by engineering, and mathematics accumulates a base of scientific knowledge and by integrating it with science, it aims for using the knowledge for analysis and statistics. Accordingly, there are five fields that need to be included in the design of a knowledge system that wants students to become knowledgeable in STEM-related topics. These five fields are: application of scientific concepts, applied mathematics, concepts of technology systems and engineering, and individual interaction with technology. Based on these areas, STEM education builds a whole curriculum (Lou et al., 2011b; Verhage, 2012).

In the 1990s, the National Science Foundation (NSF) began using SMET as shorthand for science, mathematics, engineering, and technology. One NSF program officer objected that SMET was very similar to smut, and then the acronym STEM was created (Sanders, 2009). Barakos et al. (2012) illustrated that by reviewing different definitions of STEM education, one can develop a rationale for choosing one STEM methodology among others. Jones et al. (2011), in the State Educational Technology Directors Association's (SETDA) STEM report present this definition: "STEM refers to the areas of science, technology, engineering, and mathematics. STEM initiatives started as a way to promote education in these related areas hence that students would be prepared to study STEM fields in college and pursue STEM-related careers".

STEM education is an approach to learning where rigorous academic concepts are coupled with real world lessons as students apply science, technology, engineering, and mathematics in context that makes connections between school, community, work, and the global enterprise enabling the development of STEM education literacy and with the ability to compete in the new economy (Bruce-Davis et al., 2014; Gerlach, 2012). Another view published in an article by Brown et al. (2011) defined STEM education as "a standard-based, meta-discipline residing at the school level where all teachers, especially STEM teachers, teach an integrated approach to teaching and learning, where discipline-specific content is not divided, but addressed and treated as one dynamic, fluid study (Barakos et al., 2012)." These along with other studies reflect that STEM education has the potential to become an important bridge to link related disciplines, as well as offering essential cognitive abilities and developing problem-solving skills. Thinking of STEM education instruction as a stand-alone course or courses alongside standard instruction in the disciplines enables the education system to maintain the integrity of curricular, especially in subject areas like physics (Barakos et al., 2012). According to Heil et al. (2013), integrated STEM education is based on the idea that real-world issues require multiple perspectives, skills, and knowledge to be productively addressed (Annetta & Minogue, 2016; Wang et al., 2011).

Barakos et al. (2012) while adopting a well-reasoned approach to STEM education that reflected an elaborate continuum, discovered that the range can begin from improving and expanding available STEM content instruction, and lead to implementing a fully integrated STEM education curriculum where the connections of all four disciplines are the point of emphasis (Figure 2.1). Integrated STEM education is an effort to combine science, technology, engineering, and mathematics into one class that is based on connections between the subjects and real world problems.

However, in general, integrated STEM education can involve multiple classes and teachers and does not have to always involve all four disciplines of STEM. Engineering is becoming more prevalent in K-12 schools and can provide great problem solving opportunities for students to learn about mathematics, science, and technology while working through the engineering design process (Stohlmann et al., 2012).

What the educators choose as their method can significantly influence the effectiveness of STEM education programs. Integrated STEM can have positive effects on youth achievement, especially at the K-12 level. The largest effects are seen when all four components of STEM education are integrated, though the relative weight of those components could vary depending on context and intent (Annetta & Minogue, 2016; Becker & Park, 2011). Integrated STEM education can potentially motivate students to pursue careers in STEM fields and may increase interest and enhance their performance in mathematics and physics. For the future success of students, effective STEM education is deemed to be a vital element (Stohlmann et al., 2012). Although there is still some debate about what defines STEM education integration, a dominant theme in the literature is that integrated STEM involves problem solving and inquiry, two key aspects of STEM project (Annetta & Minogue, 2016; Wang et al., 2011).

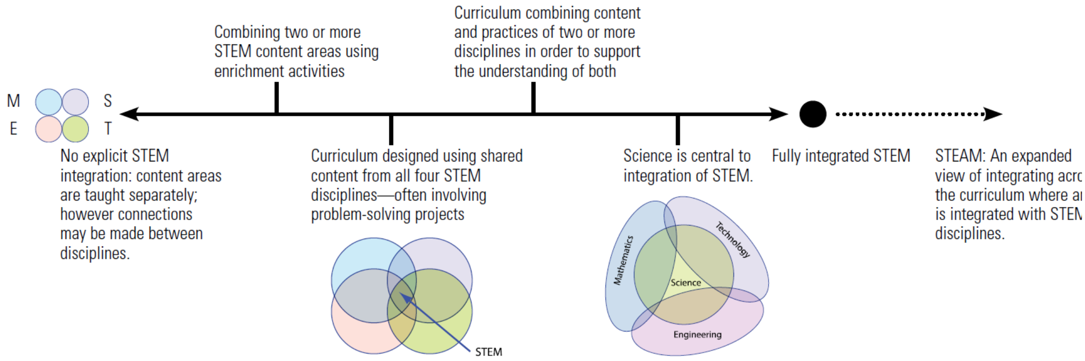

Figure 2.1 Approaches to STEM Education - Source: (Barakos et al., 2012)

In summary, many interesting results indicate that schools with a strong emphasis on STEM education often integrate Science, Technology, Engineering, and Mathematics into the entire curriculum (Barakos et al., 2012). One view of STEM focuses on exposing students to authentic experiences and applying rigorous content to finding solutions for real-world problems. Integrated STEM education can be defined as an approach to learning where two or more STEM contents are integrated during lessons and units (Heil et al., 2013). However, Morrison (2006) defines a true STEM education integration as a combination of problem solving, innovation, invention, and logical thinking (Annetta & Minogue, 2016). In this research two real world problem defined as two different projects. Students must apply problem solving skills and their knowledge of STEM content to solve real world problems that help them make connections between school, community, and the world (Park, 2011). For example, a STEM education lesson might merge mathematics and science content logically through an engineering lesson, unit, or project (Merrill & Daugherty, 2010). Further, STEM education activities should be standard based, real world, and employ problem-based teaching strategies (Breiner et al., 2012).

2.2.1 Characteristics of STEM Education

According to Deslauriers et al. (2011) teachers should adopt a variety of methods of instruction, with one being a method like STEM, where students are engaged in the learning procedure actively. While literature has reported several characteristics for STEM, the following are the most common ones. First, it is integrated; a curriculum that covers principles from science, technology and engineering, and mathematics, enables students to learn application of previously obtained information to develop creative solutions to new problems. Second, STEM education is inquiry-based, as opposed to the conventional classroom, which is typically lecture-based. In a STEM education classroom students are asked to collectively solve problems, through questioning and answering techniques which incorporate research throughout the process. Third, STEM education incorporates teamwork and instruction in soft skills which will be required in business and industry. Being asked to practice these skills boosts the confidence of students while simultaneously offering them insights into their own characters, revealing previously unknown personal traits such as leadership skills. The fourth characteristic is that STEM education is appealing; students enjoy classroom discussion and participation to solve a meaningful problem. Finally, the fifth characteristic is that STEM education is fulfilling. In this method teachers get to go beyond being mere instructors and get to see themselves as facilitators in the learning process (Roberts, 2012).

In another study Heil et al. (2013) identified additional set of defining characteristics which draw the distinction between integrated STEM education and other methods and content arenas. These additional characteristics include:

- In tandem teaching of two or more of the STEM education subjects,