The Effectiveness of Problem-Based Learning Strategy in STEM Education for Enhancing Students' 21st Century-Skills.

دراسة لفعالية استراتيجية التعلم المرتكزة على المشاكل في تعليم العلوم، والتقنية، والهندسة، والرياضيات (ستيم) بغرض تعزيز وتنمية مهارات القرن الحادي والعشرين لدى الطلاب.

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Abstract

The STEM education is one of the new reforms in the science education that enhances students' scientific and cognitive skills. STEM education is best taught through problem based learning strategies as there are three types of learning that cut across the PBL; cognitive learning, content learning, and collaborative learning. These three types of learning set as a conceptual framework that has guided this study. The main purpose of this study is to measure to what extent using the PBL strategy in STEM education enhances students' development of the 21st century skills :cognitive skills, collaborative skills, and content knowledge? The participants of the study comprised two groups: 112 teachers and 1800 grade eleven students selected from seven schools around UAE.

A mixed-method design has been used in this study using multiple tools. A teachers' questionnaire that included open and closed-ended questions was administered. The students' achievements have been measured qualitatively using rubrics and quantitatively by collecting students' scores from the Robotics module. In addition, students' perceptions were also measured using a closed question survey. The results revealed from the study that the STEM education is best taught through the problem based learning approach that enhance students' cognitive, content, and collaborative skills. The science and engineering teachers demonstrated good evidence in integrating those skills in their practices. In addition, the students' perceptions towards the subjects show a great interest in the engineering and science subjects which enhance careers in STEM fields.

Keywords: STEM, PBL, cognitive skills, collaborative skills, Robotics.

الملخص

يعتبر تعليم [STEM] (العلوم، والتقنية، والهندسة، والرياضيات) هو أحد الإصلاحات الجديدة في مجال التربية العلمية التي تعزز مهارات الطلاب. والطريقة المثلى في هذا التعليم هو عبر استراتيجية التعلم التي ترتكز على المشاكل. وهناك ثلاثة أنواع من التعلم تتوافق مع التوجه الذي يرتكز على المشاكل، وهي؛ التعلم المعرفي، التعلم التعاوني وتعلم المحتوى. و تعتبر هذه الأنواع الثلاثة هي الإطار الفكري الذي تم اتباعه في هذه الدراسة. والغرض الأساسي من الدراسة هو قياس إلى مدى يمكن للتعلم الذي يرتكز على المشاكل أن يعزز تنمية مهارات القرن الحادي والعشرين لدى الطلاب (المهارات الادراكية ، و المهارات التعاونية ومعرفة المحتوى)؟ وشارك في هذه الدراسة مجموعتان، المجموعة الأولى مكونة من 112 مدرس، والثانية مكونة من 1800 طالب من طلاب الصف الحادي عشر الذين تم اختيارهم من سبع مدراس من كل مناطق الامارات العربية المتحدة.

والتعلم الذي يرتكز على المشاكل ليس أمراً سهل القياس خاصة وأنه يتطلب توفر العديد من الأدوات التي تقود الى التحقق من صحة البيانات. وعلى هذا الأساس، روعي في تصميم الدراسة استخدام عدة منهجيات ومجموعة أدوات. فهناك استبيان للمدرسين تضمن أسئلة مفتوحة وأخرى مغلقة. أما الانجازات المحققة بواسطة الطلاب فقد تم قياسها عبر وحدات قياس نوعية وأخرى كمية من خلال تجميع علامات الطلاب من الروبوتات. بالإضافة إلى ذلك، تم أيضا قياس مدى استيعاب الطلاب عبر مسح استقصائي باعتماد الأسئلة المغلقة. وأظهرت نتائج الدراسة بأن منهجية التعلم الذي يرتكز على المشاكل هي الأمثل لتعليم ستيم (STEM) وذلك لتعزيز المهارت المعرفية، والمهارات التعاونية والمحتوى لدى الطلاب. و الدليل الجيد على هذ التوجهتبين من خلال قيام مدرسي مادتي العلوم والهندسة بدمج هذه المهارات في ممارساتهم التعليمية.وفضلاً عن ذلك، فإن استيعاب الطلاب صاحبه اهتمام كبير ورغبة في مادتي الهندسة والعلوم مما يعزز من المستقبل المهني في حقول (STEM).

الكلمات والعبارات الرئيسية: (STEM) ، التعلم الذي يرتكز على المشاكل، المهارات المعرفية، المهارات التعاونية، الروبوتات

Dedication

The completion of my dissertation is one of the most challenges that I had to face. This couldn't be possible without the support of my family and friends. I dedicate my dissertation work to my family and friends. My parents' words of encouragement and their push for tenacity that still ring in my ears.

A special feeling of gratitude is to my husband Kareem who supported me and inspired me that I can do the best in my life. I dedicate this work and give special thanks to my lovely kids Jumana, Yaseen, and Yousuf for always making me smile and for understanding of those times I took to complete my study instead of playing games. I also dedicate this work to my best friends and colleagues who supported me with their words during the years of my study.

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Chapter 1: Introduction

One of the most significant current reforms of science education is implementing interdisciplinary science, technology, engineering and mathematics (STEM) subject in middle and high schools because of its impact on increasing students' interest in STEM professions in addition to increasing students' 21st century skills (Asghar et al., 2013; Mosier, Levine & Perkins, 2013;Wyss, Heulskamp & Siebert, 2012;Asunda, 2012).

Science, technology, engineering, and mathematics (STEM) education is being named as a meta-discipline. It is the integration of knowledge across the disciplines that are intertwined together forming a new curriculum to be taught as a whole.

1.0 Problem Based Learning

Problem based learning is based on the knowledge that individuals experience on their existing knowledge. It is the inquiry method of learning that allows learners to build new information in the way that suits their natural brain process (Capraro& Morgan, 2013; Ronis, 2008). STEM is an interdisciplinary approach that aims to teach through integrated subjects by solving real-life problems. Robotics is one of the famous projects in STEM education. It requires solving real life problems with integrated subjects in order to implement the project. Prior studies have noted the importance of teaching Robotics as one of the famous projects of STEM in the middle and high schools that relies on engaging students in real-life problems (Lin et al., 2013; Hendricks, Alemdar & Olgedree, 2012; Ownes et al., 2012; Casteldine& Chalmers, 2012). Questions have been raised about the best teaching strategy to teach STEM models or topics. In the recent history of STEM education, problem-based learning (PBL) has been thought as a key factor in teaching students how to solve the authentic and ill-structured problems that require integrated knowledge from different disciplines (Capraro& Morgan, 2013). Recently, researchers have shown an increased interest in teaching STEM in the high school because of its impact on increasing students' interest in STEM professions (Lin et al., 2013, Hendricks et al., 2012; Brophy et al., 2008).The new reform of science education aims to increase the professional careers of STEM subjects (ITEA/ITEEA, 2009; Brophy, Klein, Portsmor, & Rogers, 2008; Congressional Research Service, 2006; Ehrlich, 2007; National Science Board, 2007). The benefits of STEM education are that it correlates the real world problems with the contents being taught. The clear benefits from this correlation that it increases students' interest and motivation in STEM careers as well as avoiding questions about why they have to learn this subject (Asghar, Ellington, Rice, Johnson & Prime, 2013; Mosier, Levine & Perkins, 2013; Merrill & Daugherty, 2010; Brophy, Klein, Portsmor, Rogers, 2008; NSB, 2007; Suddreth & Itamura, 2007). Many researchers emphasized that STEM education contributes to students' acquiring skills in problem-solving, critical thinking, collaboration, management, self-directed learning, communication, creativity and innovations, and analytical thinking, as well as a connection to real world problems (Capraro& Morgan, 2013; Asghar, Ellington, Rice, Johnson & Prime, 2013; Mosier, Levine & Perkins, 2013; Casteldine& Chalmers, 2012; Wyss, Heulskamp& Siebert, 2012; Ownes, Shelton, Bloom & Cavil, 2012; Asunda, 2012; Brophy, Klein, Portsmor, Rogers, 2008; National Science Board, 2007).

The STEM disciplines combine different strategies such as; guided-inquiry (Minstrell & Van Zee, 2000), constructivism learning (Mayer, 2004), project-based learning (Starkman, 2007; Swartz et al., 2007), problem-based learning (Bottge et al., 2001; Goodnough & Cashion, 2007), and integrated technology (Clark & Ernest, 2007).

PBL by its nature apply the process used by scientists to solve authentic real-life problems (Crawford, 2000; Colliver, 2000) through the use of content knowledge in a constructivism environment that promote the cognitive and collaborative learning (Goodnough & Casion, 2006; Lieux, 1996), and understandings of the concept (Mosier, Levine & Perkins, 2013; Asghar et al., 2012; Barnes & Barnes, 2005; Frykholm& Glasson, 2005; Loepp, 1999; Moseley & Utley, 2006; Sage &Torp, 1997; Venville, Rennie& Wallace, 2004).

A strong relationship between interdisciplinary STEM problems and PBL-Strategy has been reported. The constructivism, cognitivism, motivational, social, and brain-based theories identify the key concepts behind using PBL as the best effective strategy in teaching STEM concepts (Capraro& Morgan, 2013; Barry, 2012; Webb et al., 2010; Frankena et al., 2002; George, 1964).PBL combines between three types of learning; cognitive learning (the use of the higher-order thinking skills), collaborative learning (social constructivism), and the content learning (the use of knowledge). It is a useful teaching strategy that used to assess students' prior knowledge and raising them to the steps of *what do we know? What do we need to know? And how can we find out what we need to know?* Higher-order thinking skills included critical thinking, creative thinking, reasoning, problem solving and decision-making. It is the expanded use of the mind to meet new challenges with increased ability to analyze, synthesize, communicate, and integrate knowledge in order to solve a problem that inevitably leads to use of higher-order thinking skills (Onosko & Newmann, 1994). Marlowe & Page (1998) mentioned that constructivism learning includes questioning that is filtered through our experiences and modifies our comprehensions. Kauchak, Eggen& Carter (2002) contend that constructivism is the thinking process where students direct themselves in being users of information rather than receivers of information to form a student-centered environment. The authors also further believe that constructivism focuses mainly on the real-life tasks and on the process of discovering and solving problems of these tasks (Kauchak, Eggen& Carter, 2002). These are not new beliefs as Vygotsky (1978) focused on the social interactions of peers, language, and culture of the learning process. More recently, Capraro& Morgan, (2013) pointed out that learning occurs when learners interact with each other in solving authentic tasks. Robotics is one of the famous subjects in STEM that has been taught in the middle and high schools. Robotics requires integrated knowledge from different disciplines and offers opportunity to students work on collaboratively.

1.1 Background of the Research

In the past decade, there has been special interest in STEM education, especially when it is taught through effective teaching strategies in order to prepare students to STEM professions like scientists, technologists, engineers, and mathematicians (Innovation America, 2008). Several studies have produced estimates of considering PBL is the best strategy to teach STEM (Mosier, Levine & Perkins, 2013; Asghar et al., 2012; Barnes & Barnes, 2005; Frykholm& Glasson, 2005; Loepp, 1999; Moseley & Utley, 2006; Sage &Torp, 1997; Venville, Rennie& Wallace, 2004), but there is still insufficient data especially in the United Arab Emirates about measuring to what extent using the PBL strategy in teaching grade eleven students STEM project to enhance their 21st century skills.

STEM education is new in the UAE and there are no researches have been done to measure the impact of teaching STEM for students. Robotics is one of the famous curricula of STEM that include knowledge from physics, technology, electrical and mechanical engineering, and mathematics that are integrated in ill-structured problems where students solve these problems collaboratively.

The Robotics curricula can enhance the outcomes of the Ministry of Education in the UAE (2010-2020) that states the following:

- Improve curriculum that produces creative learners that are proficient in all relevant subjects.
- Students should develop their critical thinking skills, analytical reasoning and communication skills.
- Students should acquire motivation and self-direction skills in leading their learning journey.
- Educators should be creative in using innovative teaching strategies that let them be facilitators in constructivism classrooms.

Accordingly, this paper will focus on using PBL in teaching STEM project (Robotics curriculum) give an account in students' skills development, interests, and achievements in addition to teachers' practices and perceptions.

1.2 Statement of the Problem

The aim of integrated disciplines is to demonstrate a paradigm shift from the separate subject approach to teach real-life problems (Capraro & Morgan, 2013; Jonassen& Hung 2008) that require integrated knowledge from different disciplines (Dugger W. & Fellow J., 2011; and Merrill, 2009), to solve the problems collaboratively in a constructivism approach(Mayer, 2004). STEM education is new in the UAE as there are no schools in the UAE that apply STEM education. However, there are few private and governmental schools that teach the robotics project in the high schools.

The PBL includes three types of learning that by implementing them in STEM education the objectives of the Ministry of Education in the UAE will be met. In addition, the types of learning that cut across PBL are discussed with its relation to STEM and how these enhance the use of higher order thinking skills, the use of knowledge, and the social constructivism environment.

1.3 Purpose and Objectives

The significance of this research is to understand and explain that the PBL-strategy is best taught within the STEM curriculum for enhancing students 21st century skills. In addition, students will acquire more benefits from being exposed to this type of learning in shaping their careers that suit the workforce. Further recommendations will be raised in order to improve STEM education.

The research questions that guided this study were:

To what extent does using the PBL strategy in STEM education to enhance students' development of the 21st century skills (cognitive skills, collaborative skills, and content knowledge)?

1. What are the teachers' perceptions and practices in developing students' skills through the PBL teaching strategy in solving STEM problems?
2. How does the PBL strategy impact students' achievement in STEM curriculum?
3. What are the students' experiences towards solving authentic problems in STEM curriculum?

According to the previous studies about using the PBL strategy in solving STEM problems, show that students acquired essential 21st century skills such as critical thinking, problem-solving, collaboration, communication, management, creativity, and self-direction (Capraro & Morgan, 2013; Chang, Lee, Wang & Chen, 2010; Chang, Lee, Chao, Wang & Chen, 2010; Liu, Lin & Chang, 2010; Kanwar, 2010; Suzuki & Collins, 2009).

The hypothesis of teachers' perceptions and practices will be that they believe they teach students these skills through the classroom practices where they will be "guide on the side" instead of "sage on the stage" and will act as facilitator to facilitate learning to all students (Asghar et al., 2013).

The objective of students' achievements in using PBL as a strategy is the increase in students' engagement in positive classrooms (Mosier, Bradely-Levine & Perkins, 2013).

Finally, The hypothesis of students' experiences toward solving authentic problems in constructing the robotics (STEM project) will be that they will be able to reflect on the problem-solving decisions they made and are able to relate their strategies in solving problems to real-world contexts (Capraro & Morgan, 2013; and Chamers & Casteldine, 2012). In addition, students' interests in the STEM careers will be increased (Hendricks, Alemdar & Ogletree, 2012; Wyss, Heulskamp & Siebert, 2012; Asunda, 2012).

1.4 Scope of Work

As the PBL-strategy that used in learning STEM, cut across three types of learning; cognitive, collaborative, and content learning. Accordingly, the purpose of this study is to explore and explain to what extent using PBL as a strategy can enhance students' 21st century skills that inherit in the cognitive skills, collaborative skills, and content knowledge. A mixed-method design is used to extend the depth and breadth of the study by using quantitative and qualitative data (Johnson B. & Christensen L., 2012). Previous studies stated that the skills are interrelated in a very complex way and cannot be easily measured (Lai E. &Viering M., 2012). It was decided that the best way to measure the students' skills in this study is by using multiple tools, i.e: to measure students' skills, perceptions, achievements and teachers' perceptions and practices. Teachers' perceptions and practices data were collected quantitatively and qualitatively from the teacher questionnaires. In addition, the perceptions of the students have been measured quantitatively by the students' survey and the achievements were measured quantitatively and qualitatively using performance rubrics for the robotics module. Accordingly, the main question of the study sets as an umbrella of three sub-questions that cover the different aspects of measuring students' skills. The participants were teachers (N (1) =112) of the four disciplines of the STEM and the eleventh grade students (N (2) =1800) from seven schools around the UAE. A representative sample of the population has been selected non-probability from one school in UAE.

1.5 Structure of Dissertation

This study consists of five chapters. This chapter introduces the rationale, background, significance of the study, research questions, the purpose of the study, and the scope of work. The next chapter reviews relevant literature related to STEM education, PBL, robotics, types of learning, and the skills acquired. The results of previous studies within the same areas are also documented here.

Chapter 3 outlines the methodology of the study where the research design, population, sample, instrumentation, data collected method, validity, and ethical consideration are explained in details. Chapter 4 presents the data analysis and discussion. This chapter will take the reader through the analysis of the captured data. The tables and diagrams are used to enhance the reader understandings. The results are then analyzed and compared to literature to strengthen findings. Finally, chapter 5 summaries the study, the discussions of the findings and makes some recommendations.

Chapter 2: Literature Review

The purpose of this study is to understand to what extent using PBL strategy will enhance students' cognitive, content, and collaborative skills. In this chapter a vast amount of literature is documented and reviewed on STEM education, PBL as a teaching strategy, and the relationship between STEM and PBL. PBL will then be compared with other strategies, followed by detailed exploration of the three types of learning that are included in PBL, and the corresponding skills students could acquire. The framework of William and Flora Hewlett Foundation (2010) has been developed by modifying some of the sub-skills to suit this study.

2.0 Conceptual Framework

As a result, the conceptual framework of this study incorporated the sub-skills that inherit in each of the three types of learning that cut across the PBL. The following figure shows how theories are interrelated to construct this study.

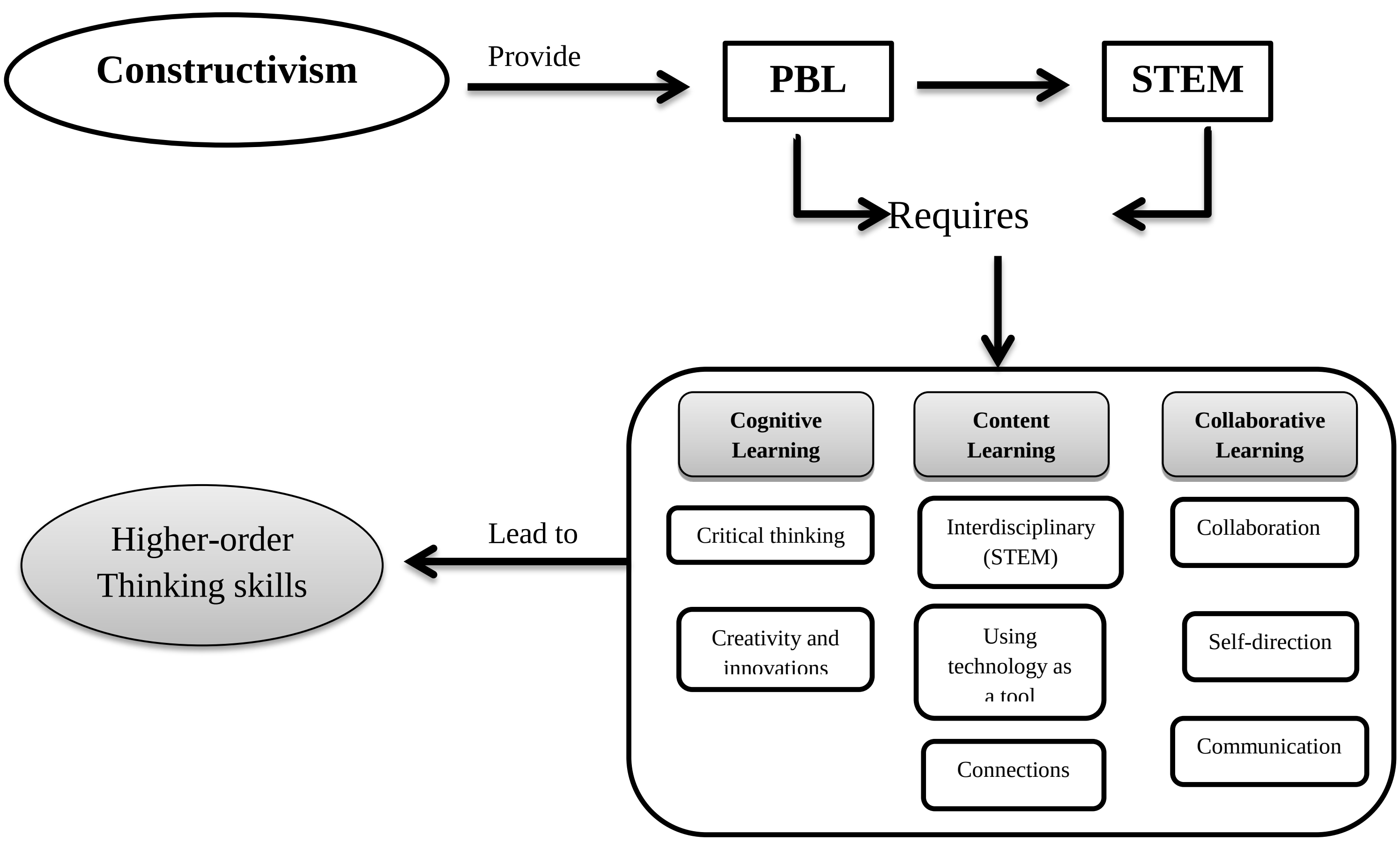

Figure 1: A conceptual framework illustrates how theories are incorporated in the study.

The most important challenge is how to transform teaching practices in classrooms to provide an environment which is conducive for developing students' skills to the higher-order thinking skills. Constructivism is the theory that guides this study. It requires the use of PBL strategy to teach STEM. A wide range of implementation models and practices of PBL mentioned that there are three types of learning cut across PBL; cognitive learning, collaborative learning, and content knowledge (Du et al., 2009; Kolmos et al., 2009; Ravitz, 2010; Savery, 2006; Darling-Hammond, 1994). The cognitive learning focuses on the critical thinking, creativity and innovation skills while the collaborative learning focuses on the collaboration, self-direction, and communication skills. Finally, the content learning focuses on the integrated knowledge through STEM disciplines, using of technology, and connection to the real life.

2.1 Interdisciplinary STEM

Science, technology, engineering, and mathematics (STEM) education is usually named as a meta-discipline. It is the creation of integrated knowledge across disciplines to form a new curriculum to be taught as a whole. STEM education has been defined as "a standards-based, meta-discipline residing at the school level where all teachers, especially science, technology, engineering, and mathematics (STEM) teachers, teach an integrated approach where discipline-specific content is not divided, but addressed and treated as one dynamic, fluid study" (Merrill, 2009, P.49). STEM education gives opportunities to students to understand the world around them and solve real world problems. According to the Organization of the Economic Co-operation and Development (OECD) report, productive individuals should have a high level of technical skills and also be independent, cooperative, and flexible in improving their qualifications (Hakkarainen et al., 2004). Kaufman (2003) has reinforced the concept of STEM education. STEM was coined first by the national science foundation as an educational term in the early 2000s. National Science Foundation (NSF) has formed many of STEM projects; Technology of all Americans projects (1994-2005) that is conducted under the International Technology Education Association (ITEA, 2003).

In order to understand STEM, it is significantly important to understand the relationship between its disciplines. Science seeks consistency and understanding of the external world (NRC, 1996). There is a strong link found between science and technology to the extent that most individuals thought that technology is applied science. The processes that are used in learning about science encompass exploring, discovering, or inquiring. The use of scientific method is the most important to apply science.

Technology is the modification of the natural world into a shape that could meet the humans' needs (ITEA, 2000; 2002; 2007). This definition is very close to what NRC stated about technology goals, which are to modify the world to meet the humans' needs (NRC, 1996; NAE & NRC, 2002). By the rapid changes in technology, the progressions of professions become more difficult and the problems become more complex and ill-structured which in turn can affect students' skills (Nielsen, Du, &Kolmos, 2010).

Engineering is the profession that needs study, experience, application, and knowledge of science and math in order to utilize economical the materials that could benefit the humanity (ABET, 2007). The National Academy of Engineering supports the technology and engineering literacy because of the strong relationship between the two disciplines (Dugger& Fellow, 2011). Finally, Mathematics is the patterns and relationships of sciences (AAAS, 1993). Mathematics is a common discipline that is used in many disciplines such as science, technology, and engineering.

There are a number of ways that STEM can be taught in schools. The first option is to teach each discipline of STEM as an independent subject with no or little integration. It is known as S-T-E-M. The second way is to teach each of the STEM disciplines with emphasis on one or more of the subject and it is known as SteM. Another strategy is to integrate the three disciplines into one discipline that can be taught. For example, robots are an engineering project, but require integration between science, technology, and mathematics. In this case, the engineering teacher will take the responsibility in teaching the subject.

However, the collaboration between teachers of the other discipline is very important in teaching the subject. This is known as E→ STM (Dugger & Fellow, 2011). The figure below illustrates the three types of interdisciplinary STEM.

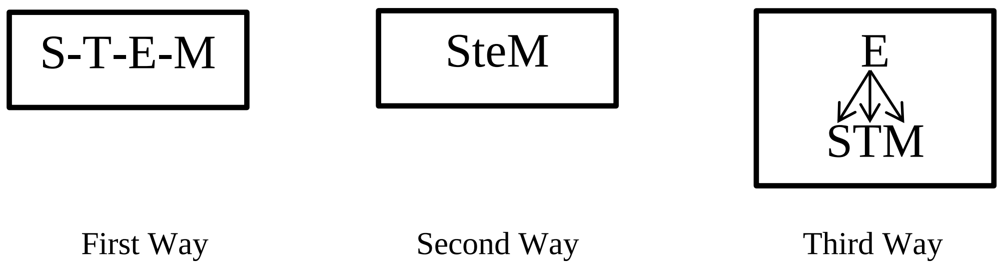

Figure 2:The different ways of Interdisciplinary STEM (Dugger & Fellow, 2011).

Dagger and Fellow (2011) themselves recommend that the more comprehensive way is to integrate the four disciplines into each other as one subject. They contend that as there are technological, engineering, and mathematical contents in science, so the science teacher takes the responsibility to teach this integrated content with the help and collaboration of other teachers .Accordingly, the third way of interdisciplinary STEM has been reviewed in this study. The study focuses on the robotics curriculum in a government school. Robotics is an engineering project with integrated knowledge of science, technology, and math.

Dugger& Fellow (2011) further emphasizes that efforts should be taken in order to choose the best teaching strategy that suit STEM education. STEM requires hands-on methods, technological tools, equipment, and procedures to be used in creative ways to teach and learn authentic content and problems that meet human needs (Merrill, 2009).The STEM projects or concepts could be taught in different strategies such as models (Atkinson, Hugo, Lundgren, Shapiro & Thomas, 2007), school-based STEM programs (Toulmin&Groome, 2007), distance learning (Demski, 2009), mentoring programs (Atkinson et al., 2007), and special STEM schools (Cavanagh, 2006). However, Asghar et al. (2013) argue that these methods have failed to address the nature of real-life STEM problems.

A huge body of literature suggests that STEM education can suit all different learning styles when appropriate pedagogy, technology, and content are combined (Capraro, Capraro, and Morgan, 2013; Access STEM, 2008; Bell, Gess-Newsome & Luft, 2008). This is because the STEM disciplines focus on some teaching strategies such as; guided inquiry (Minstrell & Van Zee, 2000), constructivism learning (Mayer, 2004), project-based learning (Starkman, 2007;

Swartz et al., 2007), problem-based learning (Bottge et al., 2001; Goodnough & Cashion, 2006), and the integration of technology (Capraro, Capraro, and Morgan, 2013; Clark & Ernst, 2007).

2.2 Relation Between PBL and STEM

STEM education by its nature requires ill-structured problems that are connected to the real world. Prominent research has been done on the nature of the problems used and their impact on the students. The results from these studies have stipulated that the more complex the problems are, the more skills students gain (Capraro, Capraro, and Morgan, 2013; Russell, Hancock, &McCullough, 2007; Hunter et al., 2007; Seymour, Hunter, Laursen, &DeAntoni, 2004; Celia, 2005; Lopatto, 2004; Bauer and Bennett, 2003; Zydney, Bennett, &Shahid, 2002a; Zydney, Bennett, &Shahid, 2002b). According to Jonassen& Hung (2008), problem-based learning strategy requires ill-structured and complex problems with a moderate degree of structure that are contextualized to real-life in order to engage and challenge students, adapt their cognitive development and prior knowledge.

Furthermore, Barrows (1986) developed a taxonomy that categorized PBL into six categories in three levels by using two variables. The first variable is self-direction that varies from the teacher-directed, to student and teacher-directed, and to student-directed. The second is the problem structure that differs according to the complexity of the problem; well-structured, between ill-and well-structured, and ill-structured. The following diagram illustrates the PBL taxonomy.

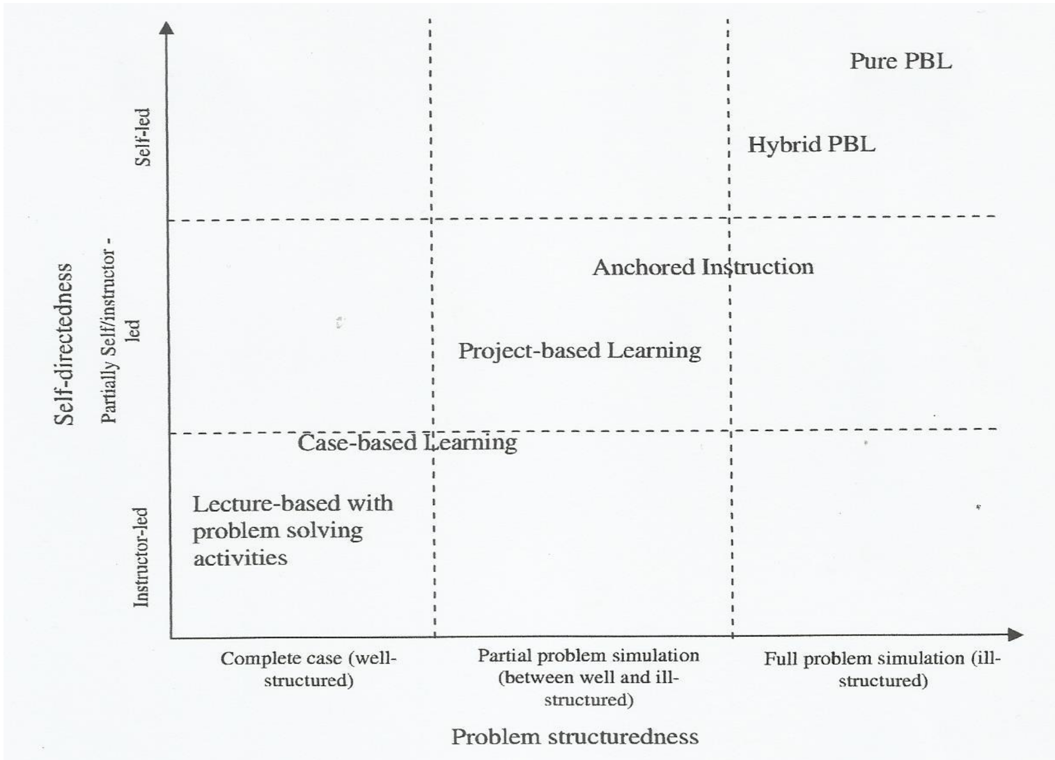

Figure 3: The representative models of Barrows' PBL taxonomy (Hung, 2011, P. 481)

Harmer & Cates (2007) mentioned that pure PBL is the best pedagogy applicable to teach authentic real world problems that require interdisciplinary STEM. PBL models require students' active engagement in using knowledge and delving deeply in finding information about the most ill-structured problem, then, synthesizing and following metacognitive process to solve the problems which result in the use of higher-order thinking skills (Capraro, Capraro, and Morgan, 2013; Liu &Bera, 2005; Kolodner et al., 2003).

2.3 Problem-Based Learning

Problem solving has been defined as "a goal-directed sequence of cognitive operations" (Anderson, 1980). Jonassen (2000) points out the importance of problem-solving that it is the most important cognitive activity in everyday life. The national reports of the United States mentioned that the current education is not adequate to prepare engineers and scientists in solving complex problems (National Academy of Engineers, 2005; Committee on Science Engineering and Public Policy, 2006; Friedman, 2005; Boyer Commission Report, 1998 & 2002; National Science Foundation, 1996; American Association for the Advancement of Science, 2002; National Research Council, 2003). A huge number of schools in the UAE follow the American Curriculum. Accordingly, this should be considered.

Problem based learning is a student-centered pedagogical approach that combines the inquiry approach and problem solving process (Etherington, 2011). The problems have different variety of practices in problem-based learning; ill-structured problems or complex scenarios that can be adapted to students' cognitive development (Du et al., 2009; Kolmos, Graaff& Du, 2009; Ravitz, 2009; Jonassen& Hung, 2008; and Savery, 2006). Learning with PBL occurs when students go through three steps: What do they know? What do they need to know? And how can they find it out?

There are some theoretical principles that support PBL which are constructivist process, metacognition, and cultural and social factors. The PBL theory is a constructivist theory as it requires that learners need to build their own understanding of new ideas. The constructivist process is contained in " what do they know? What do they need to know? How do they know?" In other words, explicit attention should be paid to students' prior and existing knowledge, and the ability to construct new knowledge based on prior knowledge. Piaget (1954) described this cognitive process in three stages: assimilation, accommodation, and equilibrium, in which learners incorporate new experiences into existing experiences. The learner's cognitive structure is thus modified in response to the environment, and achieves balance between what is being understood and what has to be understood. The co-constructed process in which individuals interact and work collaboratively in solving problems are internalized by the individual and become part of the student's cognitive development (Vygotsky, 1978).

Metacognition, which is a skill required to think about thinking is accessed through "how can they find it out?". It is the process that construct in solving the ill-structured problem and how they direct themselves in the learning journey. In addition, the responsibility they take in judging the difficulty of the problem, monitoring their learning, and assess their own progress. The most important element of metacognition is that it helps students acquire higher-order thinking skills. It is also significant to consider, the social and cultural factors that are important in integrating real-life scenarios to the curriculum.

A large and growing body of literature has investigated that there are three types of learning included in PBL models; cognitive learning, content learning, and collaborative learning (Hewlett& Hewlett, 2010;Graaff&Kolmos, 2003; 2007). Barrows (1996) believes that PBL equips students with self-directed learning and collaborative skills in solving real-life problems that require integrated knowledge. Furthermore, Barrows (1996) emphasized that PBL strategy aims students to apply knowledge in a way that is conducive learning in a student-centered environment where the teachers act as facilitators, guides, or coaches. The goal of this strategy is to increase students' self-directed learning and problem solving skills. Yelland, Cope and Kalantzis (2008) emphasized that this constructivist approach not only promotes communication and collaborative skills, but also fosters reflection from multiple perspectives. This in turn enhances students critical thinking skills where students analyze the problems, apply deductive and inductive processes to understand problems, and find creative alternatives of the problems. They use their prior knowledge and new knowledge to reason intellectually in collaboration with their peers in small groups (Capraro, Capraro, and Morgan, 2013; Carroll, Clark, Kane, Sutherland & Preston, 2009).

2.4 Cognitive, content, and collaborative learning cut across PBL

There is a metaphor for learning proposed by Hakkarainen et al. (2004) called a knowledge-Hakkarainen et al. (2004) proposes a metaphor for learning called a knowledge-creation metaphor. This approach sets a guide of new strategies of teaching and learning that promote cognitive learning, collaborative or social learning, and the challenges and innovations of integrated knowledge in a specific content (Nielsen, Du, &Kolmos, 2010).Many researchers agree that there are three types of learning occur in the implementation of PBL models and practices which are cognitive learning, collaborative learning and content knowledge (Du et al., 2009; Kolmos et al., 2009; Ravitz, 2010; Savery, 2006; Aleman, 1992; Darling-Hammond, 1994).

The cognitive learning focuses on the ill-structured problems, the process of solving complex problems, and developing students’ critical thinking, creativity, and motivation skills through applying this approach.

Critical thinking has been defined as “the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action” (Scriven& Paul, 2007, p. 1). It has been referred to as metacognition or the process of thinking about thinking (Tempelaar, 2006). It is a mental habit that requires students to use their higher-order thinking skills in synthesizing, analyzing, and evaluating information to solve problems and make decisions (Scriven& Paul, 2008; Schafersman, 1991; Templeaar, 2006). Critical thinking is described to be the abilities that students can acquire it in a short-term. The individuals usually behave more or less not only by the ability, but also by tendencies and this aspect is called critical thinking dispositions (Baron, 1985; Bereiter, 1995; Cacioppo& Petty, 1982; Ennis, 1986). Critical thinking disposition takes a long time to be acquired and is essential for learners to have practice in thinking critically about an issue (Norris, 1985). Forawi (2012) believes that critical thinking dispositions can be developed in students by applying the intellectual standards to the elements of reasoning.

However, there are many arguments that teachers do not know how to teach critical thinking skills in their instructions or the way to integrate critical thinking skills in the teaching strategies. Brodbear (2003) contends that teachers have deeper information about content knowledge, but do not have the pedagogical content knowledge that is based on Shaulman’s idea.

Moreover, most philosophers describe creativity as a skill that enables individuals to produce something new and valuable, and analyze situations in a creative way (Sternberg, 1988; 2001;Standler, 1998;and Yau, 1995). Psychologists such as Vygotsy and Guliford have emphasized the importance of developing creativity in children in order to change the future (Beghetto, 2010; Guliford, 1950). Many educators suggested that engaging students in tasks that foster them to think creatively can help their cognitive, emotional, and social development (Sawyer, 2006) in addition to the self-direction skills that they acquire (Sternberg, 2007). Many studies suggest that teachers need to know how to integrate creativity in their teaching practices (Jacucci & Wagner 2007; Do & Gross, 2007). Dewey (1934) pointed out that teachers can facilitate and support students to think creatively but cannot teach them creativity. Kaufman and Sternberg (2007) stated that creativity is relevant to the process of solving the problem or task that is created. Barry and Kanematsu (2008) suggest that teachers should focus in the interdisciplinary approach and multisensory in creating a learning environment. Piggot (2007) points out that mathematics as a subject forces students to think creatively in solving problems. One of the factors of science and engineering education is that they make students change the world by exploring new ideas from the materials existing in the environment. Most researchers recognized the combination of the cognitive skills, dispositions, and environmental factors in achieving creativity (Sternberg, 2006a; Torrance, 997; Treffinger et al., 2002; Tassel-baska &MacFarlane, 2009). Cognitive skills related to creativity include the ability to identify problems (Sternberg, 2010; Torrance, 1997), generate ideas and think of alternatives (Treffinger et al., 2002; Tassel-baska & MacFarlane, 2009), and solve problems (Torrance, 1997).

Creative learners tend to have the intrinsic motivation in learning and thinking of new ideas (Russ, 1996; Sterberg, 2010; Tassel-Baska & MacFarlane, 2009). Motivation is known as all the reasons that are behind human behavior (Guay et al., 2010). Learners were willing to take intellectual risks to fall into mistakes and learn from them, and have self-efficacy in creating new ideas that face resistance from society (Beghetto, 2010; 2009; Russ, 1996; Sternberg, 2006a; 2010; Treffinger et al., 2002). However, environmental and cultural factors play an important role in limiting students thinking about the new ideas (Runco, 2004; and Sternberg, 2006a). In addition, in order of some ideas to be creative, it must have a positive impact on the society.

In previous studies, it has been mentioned that PBL has a positive impact on students' motivation in solving a specific problem (Diggs, 1997; Ram, 1999; Senocak, Taskesenligil & Sozbilir, 2007; Tarhan & Acar, 2007; Rajab, 2007; Serin, 2009; Kelly & Finlayson, 2009).

One of the most important notions of constructivism is the real-world tasks (Brown et al., 1989; Woo & Reeves, 2007; and Jaworski, 1994). Meaningful learning occurs in considering knowledge of contents as a starting point that is required to solve real-life problems by applying the metacognitive process (Hmelo et al., 1997) and connecting this information and knowledge to solve real-life problems (Harris &Grandgenett, 2002). The STEM focuses on the depth of knowledge in terms of communicating new ideas to prior knowledge, connecting knowledge to real-life, integrating knowledge in solving problems, and reflecting on the strengths limitations of the solutions (Capraro& Morgan, 2013). By applying this type of learning, the students will be able to communicate their ideas, integrate knowledge across disciplines, and use technology to facilitate their learning.

The PBL as a strategy is a top-down process that requires students to solve problems, analyze, synthesize, think critically, and communicate knowledge from several disciplines which has been promoted by constructivism (Steffe&Nesher, 1996; Koc & Demirel, 2007; Murphy, 1997; Terhart, 2003; and Tynjala, 1999). Accordingly, teachers take the responsibility to guide, facilitate, and coach students in order for them to acquire and improve the top-level skills (Slavin, 2012; Bay E., Bagceci B., & Cetin B., 2012). Metacognition is a path to learning (Bruning et al., 1998). It is defined as the executive control of thought that involves monitoring, self-regulation, and awareness (Cross & Paris, 1988; McLeod, 1997; Schneider & Lockl, 2002; Kuhn & Dean, 2004; Martinez, 2006). Students who use metacognitive process are able to use this information in new situations as they can remember it longer (Dochy, Segers, Van den B., & Gijbels, 2003; Schwartz & Martin, 2004; Storbel & Barneveld V., 2008; Cognition and Technology Group at Vanderbilt, 1992; Gallaher, Stepien, & Rosenthal, 1992; Hmelo, 1998). Integrated knowledge is a type of using knowledge that is involved in STEM education which requires students to apply the metacognitive process. One of the goals of the interdisciplinary curriculum is emphasizing that the real-world problems cannot be separated into isolated subjects (Capraro R., Capraro M., and Morgan J., 2013; Beane, 1995; Czerniak et al., 1999; Jacobs, 1989).

The role of technology in education is also an important factor that cannot be ignored (Wernet, Olliges, &Delicath, 2000; Almekhalfi, 2006a; 2006b; Almekhalfi & Almekdadi, 2010). Technology can provide students with a large amount of information and set as a tool to control their learning process (Lam & Lawrence, 2002). Extensive research studies have explored the positive impact of using technology with students in teaching and learning process (Holinga, 1999; Guha, 2000; Sandholtz, 2001; Manzo, 2001; Sherry et al., 2001; Hong & Koh, 2002; Zorfas & Rivero, 2005; Almekhalfi, 2006a; 2006b; Almekhalfi & Almekdadi, 2010). Sherry et al. (2001) emphasized that teachers should guide students in using the metacognitive skills, inquiry of learning, and problem-solving process as they integrate technology into their academic content areas. Becker & Ravitz (2001) study reported that using technology in classrooms as a tool to facilitate learning is strongly related to the constructivist views and practices in its compatibility by student-centered approach. Andreson & Maninger (2007) pointed out the changes in students' abilities, self-efficacy, and beliefs in using technology as a tool in learning. Furthermore, many researchers investigated different aspects of integrating technology in learning that it allows students to learn more in less time and allows them to focus on the real-world scenarios and problems (Capraro R., Capraro M., and Morgan J., 2013; Kotrlik & Redmann, 2005; Bauer & Kenton, 2005; Judson, 2006; Totter et al., 2006; ChanLin et al., 2006; Zhao, 2007; Gulbahar, 2007; Anderson & Maninger, 2007; Abbit & Klett, 2007; and Wood & Ashfield, 2008).

Collaborative learning is the ability of students to work on a task collaboratively, which develop students in collaborative and self-direction skills. Vygotsky (1978) focused on the role of social interactions between students, language and culture in the learning process (Fosnot, 2005; Jonassen et al., 1995; Varsidas, 2000; Woo & Reeves, 2007). Dillenbourg et al. (1996) distinguished the difference between the cooperative learning and the collaborative learning. The cooperative learning is that each learner is working parallel on separate portions of specific tasks while the collaborative learning is that students are working together on the same task. Collaboration may divide the cognitive process into intertwined layers (Lai E. & Viering M., 2012). The meaningful learning occurs when students work collaboratively in small groups (Chinn, O'Donnell, and Jinks 2000; Draskovic et al. 2004; Veennman et al. 2005; Webb, Farivar, & Mastergeorge 2002). The social constructivists emphasized the interactions of students with their peers in solving authentic and real-life problems (Azzarito and Ennis, 2003). Boxtel et al. (2000) mentioned that collaborative learning allows students to reflect on their work, provide explanation, elaborate and recognize their knowledge. Collaborative learning includes many sub-skills that inherit in coordination, problem-solving, decision-making, communication, and conflict resolution (Blatchford et al., 2003; Fall et al., 1997; Webb, 1995; and Webb & Mastergeorge, 2003). In addition, there are many forms of communication when students work collaboratively such as providing explanation, asking questions, and answering to others' requests (Gillies, 2003; Kouros & Abrami, 2006; Webb, 1995; and Webb & Mastergeorge, 2003).

Self-direction is the responsibility that learners take in directing their learning and is a personal attribute of learners (Brockett & Hiemstra, 1991; Caffarella, 1993; Garrison, 1997; Long, 1998; Merriam, Caffarella, & Baumgartner, 2007). Brockett and Hiemstra (1991) have viewed self-direction in learning as an instructional process and a personal characteristic of learners. Brookfield (1986) stated that the true self-directed learning comes from the inner transformation of schemes with the attention to self-discipline. Tough (1971) research reported that the self-directed learning is a commonplace event in the life of learners. Self-directed skills occurred in the constructivism classrooms where students work collaboratively in solving real-life problems and have the intrinsic motivation to feel the responsibility in directing their learning.

2.5 The Relation Between The skills

These skills are interrelated in a very complex way (Lai E. & Viering M., 2012). Critical thinking skills such as analyzing, synthesizing, and evaluating are usually identified as a creative process (Paul & Elder, 2006). Creative learners usually think critically in determining alternatives to solve the problems or in generating new ideas (Treffinger et al., 2002). Flavell (1979) and Martinez (2006) described metacognition that it involves critical thinking. Furthermore, Schraw et al. (2006) pointed out that metacognition, motivation and critical thinking subsumed in self-regulated learning which is the ability to understand, control, and direct one’s learning. Halonen (1995) noted that the individuals’ disposition of skills relates to the motivation in demonstrating the higher-order thinking. Previous researches reported that the challenging tasks and ill-structured problems are motivating to students more than easy tasks or well-structured problems (Turner, 1995; Linnenbrink & Pintrich, 2002; 2003). For the learners to be creative, they must have intrinsic motivation in generating new ideas irrespective the resistance they may face from society (Sternberg, 2006a). Self-directed learning is strongly related to self-discipline and motivation (Cunningham J., 2010). Finally, all these skills relate to collaboration. Students’ who work collaboratively on a task may stimulate their critical thinking, creativity, motivation, communication, self-regulation, self-direction, and metacognition (Dekker et al., 2006; Kramarski & Mevarech, 2003; Kuhn & Dean, 2004; Van Boxtel et al., 2000).

2.6 Robotics as a Curriculum

The interdisciplinary STEM curriculum such as robotics faced an increasing in the educational field (Chen, Chiang, Liu, & Chang, 2012; Feng, Lin, & Liu, 2011; Liu, 2011; Liu & Lin, 2009; Miller & Robertson, 2010; Nelson, Erlandson, & Denham, 2011), and the ability to use technology in the learning process has a great attention (Chang & Liu, 2011; Chang, Liu, Lee, Chen, Hu, & Lin, 2011; Chang, Shieh, Liu, & Yu, 2012; Liu, Lin, Jian, & Liou, 2012). The robotics curriculum that has been used as a STEM project of this study to measure students’ interests and skills is the Lego Mind Storm Robotoc (Carnegie Mellon Robotics Academy, 2009). Previous studies stated that teaching robotics develop students creativity, problem-solving abilities and critical thinking skills (Lin, Liu, & Huang, 2012; Chang, Lee, Wang, & Chen, 2010; Chang, Lee, Chao, Wang, & Chen, 2010; Liu, Lin, & Chang, 2010; Chambers & Carbonaro, 2003; Chambers, Carbonaro & Rex, 2007; Chambers, Carbonaro & Murray, 2008; Norton, McRobbie & Ginns, 2007; and Portz, 2002). A prominent competition about students' interests in sharing of robotics project resulted that students' interests in the STEM courses and careers have been increased (Hendricks, Alemdar & Ogletree, 2012). A study of Melchior, Cutter & Deshpande (2009) found that the majority of students were more interested in science and engineering disciplines. Another study of lego-robotics stated that the robots are considered to be a useful real-life and complex problem that requires the use of PBL strategy to develop students' skills (Casteldine & Chalmers, 2012).

In teaching robotics, there is more emphasis on robotics applications that require solving complex problems (Stienecker, 2008). Ahlgren et al. (2004) categorized the benefits of implementing the robotics curriculum into educational, professional, retention and outreach.

The educational benefits are to integrate concepts, knowledge, and theories from different disciples of STEM. Students are able to practice and develop their soft skills such as; project management, teamwork, and communication. They are able to integrate knowledge and connect it to the real-life problems.

The professional benefits are to provide flexibility and variations within the applications and provide hands-on engineering practices.

The retention and outreach benefits are to develop students' cognition and creativity skills where students are able to solve ill-structured problems and find creative alternatives to solve these problems. In addition, it allows students to directly experience science, technology, mathematics, and engineering.

2.7 The Results of Previous Studies

Nielsen, Du, & Kolmos (2010) mentioned that the requirements of the globalization demand new trends in PBL models and practices such as interdisciplinary Projects. Vast amounts of literature emphasized that learning PBL-STEM can improve students' cognitive, content, and collaborative skills, in addition it influences thinking across disciplines borders and shaping students' careers (Wyss et al., 2012; Asunda, 2012; Hendricks et al., 2012; Toker & Ackerman, 2011; Russell et al., 2007). Many studies also emphasized the important role of technology as it helps students in using knowledge, getting deeper into the contents, and develop the reasoning skills (Wai et al., 2010; Rockland et al., 2010; Dani & Koeing, 2008). Moreover, previous studies emphasized the important role of PBL as a strategy that teach integrated subjects in developing students' skills such as critical thinking, collaboration, creativity, management, communication, and motivation skills (Mosier et al., 2013; Casteldine & Chalmers, 2012; De Graff & Kolmos, 2003;2007; Du & Kolmos, 2006; Du, 2006; Savin-baden, 2003; Evensen & Hmelo, 2000). However, to what extent using PBL strategy to teach the robotics as a STEM curriculum can enhance students' skills? How the students' perceptions differ across the integrated disciplines? And how the teachers' perceptions and practices differ according to each discipline?

The skills students acquire is not easy to measure and needed multiple tools in order to measure it such as standardized assessments, observational measures, self-reports, and global rating scales (Lai, Viering, 2012). The next chapter illustrates the mixed method used in conducting this study and what tools have been used in order to find the results that address the research questions.

Chapter 3: Methodology.

The research carried out over a period of ten weeks in a public school in United Arab Emirates that teach interdisciplinary STEM project. The study mainly focuses on students' development of cognitive skills, collaborative skills and content knowledge of STEM through learning the Robotics curricula. In addition, teachers' perceptions and practices on the same skills through a questionnaire survey. Previous studies stated that these skills are interrelated in a complex way and cannot be easily measured (Lai E. &Viering M., 2012). Accordingly, research has recommended several practices for assessing these skills, which require multiple measures (Lai E. &Viering M., 2012). Thus, multiple instruments are used in this study. First, a teacher questionnaire was used to measure teachers' perceptions and practices. Then, the students' scores were collected, a student survey was administered to know the students' achievements and experiences.

In this chapter, the population and sample, research design, conceptual framework, instrumentation and procedures are presented. Furthermore, the ethical considerations are presented.

3.0 Research Design

An expansion mixed-method design is used to explain and explore the extent of using the PBL strategy in STEM education to enhance students' cognitive skills, collaborative skills and content knowledge (Du et al., 2009; Kolmos, Graaff & Du, 2009; Ravitz, 2009).It is called expansion as it seeks to extend the breadth and depth of different methods for different inquiry components (Johnson & Christensen, 2012). The overall design is characterized by having several tools to measure students' skills, experiences, achievements, and teachers' practices and perceptions in order to produce results that combine between the complementary strengths and non overlapping weaknesses. In order to understand the phenomenon or the research problem, Creswell (2008) recommends collecting multiple data to be integrated together. Based on the philosophy of pragmatism, it is significantly important to combine between qualitative and quantitative data (Johnson & Christensen, 2012). The mixed-methods design allows the researcher to cover all the aspects in order to have a clear idea about the study.

The research study is conducted both concurrently and sequentially in three stages. The concurrent data are collected quantitatively and qualitatively at the same time where the sequential data are collected one after the other (Johnson & Christensen, 2012). Concurrent data were collected from teachers at the beginning of the study, which is considered to be the first stage. The second stage was collection of qualitative data via observations which were done sequentially during 8-10 weeks and the final stage was the collection of quantitative data from the students. Figure (4) below illustrates the sequential stages of the data collection.

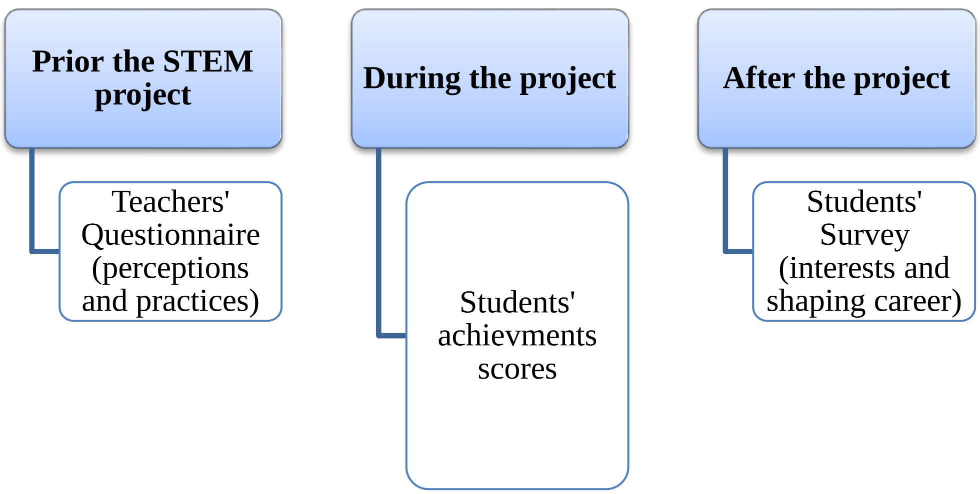

Figure 4: The research design of this study.

3.1 The Population of the study

According to Paul and Dick (2004), the population is the entire aggregation of people where the researcher chose for the study. The participants of the study are two groups; teachers (N (1) =112), and grade eleven students (N (2) =1800) from seven schools around UAE. The study measured the teachers' perceptions and practices. In addition, the students' attitudes and achievements were also measured. The robotics curricula is taught to grade eleven students who have been selected for the research.

3.2 The Samples Selected

The sample of the study is a representative sample. It has been selected non-probability. The sample is more efficient when it is selected as proportional stratified sampling in order to be perfectly representative (Kalton, 1983). The sample selected is one school that has been chosen out of seven schools to be the subject of the study. The participants are the teachers and students. Grade eleven students in the school are four sections of 18 students in each one. They have been selected all for the study to form n (1)=72. For each section, there are science, technology, engineering, and mathematics teachers. Teachers of the four sections of grade eleven are selected to form n (2)=16.

3.3 Instrumentation

Multiple tools are used in this study; teachers' questionnaire, students' survey, students' scores and field notes. The first tool administered in this study was the questionnaire that was used to measure teachers' practices and perceptions in teaching STEM through PBL strategy. Next, was the survey used to measure students' experiences in addition to the rubrics that were used to measure students' achievements. Finally, the field notes were used to fill the gaps that might occur with the surveys by providing detail and clarification of teachers' practices and students' skills development.

3.3.1 Teacher Questionnaire

The questionnaire for the teachers was specifically designed to address the first research question: what are the teachers' perceptions and practices in developing students' skills through the PBL strategy in solving STEM problems? The questionnaire started with a cover letter explaining the purpose of the study. In addition, there was a demographic section that asked participants to answer questions on the grade level they teach, years of experience, gender, and subjects taught. The questionnaire is then divided per the skills measured; critical thinking, collaboration, communication, creativity, self-direction, interdisciplinary STEM, connection, and using technology skills (see Appendix 1). Each skill of those contains three questions:

- The first question is the teachers' practices. The responses differ from: almost never, a few times of the semester, 1-3 times per month, 1-3 times per week, and almost daily.
- The second question is the teachers' perceptions. The responses used are the Likert scale.
- The third question is an open-ended question filled with the teachers' explanations. It is used to validate the data of the closed ended questions.

The questionnaire is from a study by Hixon, Ravitz& Whisman (2012) that measured students' 21st century skills are used in this study. However, it has been revised and edited according to the framework of this study. The skills as mentioned in the main question of the study are the three types of learning that cut across the PBL; cognitive skills, collaborative skills, and content knowledge (Du et al., 2009; Kolmos et al., 2009; Ravitz, 2010; Savery, 2006; Aleman, 1992; Darling-Hammond, 1994). Each type of learning has several skills which are reflected within the categories of the questionnaire. The cognitive learning includes critical thinking and creativity and innovations. Then, the collaborative learning includes the collaboration, self-direction, and communication. Finally, the content learning includes Interdisciplinary STEM, using technology as a tool, and connections of the contents to the real-life.

The questionnaire begins by the teachers' teaching experiences and professional development programs. The questions are categorized according to sub-skills and each sub-skill has three questions; two quantitative questions and one qualitative question. This is referred to as intra-method mixing questionnaire. According to Johnson & Christensen (2012), the intra-method mixing questionnaire is a combination of open-ended qualitative questions and standardized closed-ended items. The first question relates to the teachers' practices and is a multi-barreled question. The responses to this question are to measure the frequency of teachers' practices with students. The second question relates to the teachers' perceptions and is triple-barreled in each sub-skill. The second question is asked to illustrate to what extent teachers tried to teach and assess students' skills. The responses to the second question are a Likert-scale (see Appendix 1). The last question in each sub-skill is an open-ended question. This question has been revised from the original survey. The purpose of this question is to clarify and explain the aspects that cannot be explained quantitatively. The qualitative part that has been added to the questionnaire allows further exploration and clarification of the teachers' perceptions. As Creswell (2003) maintains, qualitative research determines the meanings participants have established from their experiences. The figure below elaborates the construction of the teachers' questionnaire used.

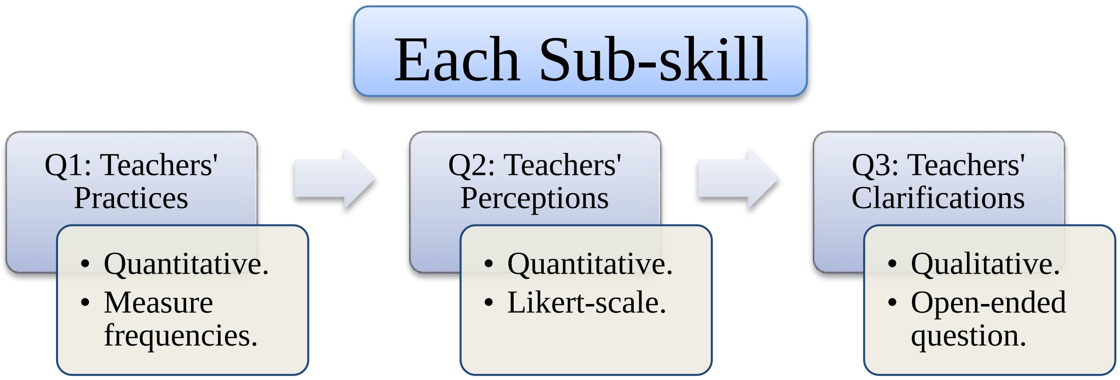

Figure 5: The construction of the intra-method mixing questionnaire.

3.3.2 The Module Description and The Rubric Scale For Students' Achievements

PBL addresses ill-structured and complex problems and the assessments were designed to identify and measure the students' areas of achievements and weaknesses. Robotics is a STEM subject that is taught in the schools. It is designed in the sense of forming robotics projects and solving ill-structured problems while forming the robotics.

The module of the robotics used is the robotics for Lego Mindstorms. The robotics module moves in two phases; the self-guided lab experiments and the hands-on project. The description of the module has been described (see appendix 3).

The three types of learning have been clearly illustrated during this project. A collaborative learning is essential in the process of PBL. A cognitive learning occurred during the learning process and the students' use of knowledge in integrating and breaking down set as a fundamental part of the STEM education. Each lesson in the robotics moved in two parts together; the lecture and the practical.

Students' achievements have been measured quantitatively and qualitatively using the rubrics scale. The type of assessments used in this project is assessment rubrics that were designed to suit different learning types of students. The rubrics used in assessing students are used in

“Teaching Robotoc for Lego Mindstorms” in the Carnegie Mellon Robotics Academy (Shoop, 2009). The rating scales used involve qualitative description of many aspects as well as the four point scale that used quantitatively. This method of rubric has a high degree of reliability. It is significantly important to provide students by the criteria of the rubrics for achieving clarity. The purpose of providing students these criteria is to act as self-assessment and self-regulation in evaluating their performance. In addition, the rubrics allow teachers to see what is being assessed. The rubrics used in this project are categorized according to the projects’ needs. They are four rubrics; the engineering journal rubric, the internal design review rubric, the external design review rubric, and the rubric for the presentation (see appendix 3).

3.3.3 Students’ Survey

The survey administered to the students in this study was developed by Whitehead (2010) for his doctoral dissertation that culminated from Mississippi Information Technology Workforce Project. The original survey used the TEM subjects (technology, engineering, and mathematics) only as the study intended to measure students’ beliefs and interests towards mathematics in a STEM project. However, the purpose of this present study differs in students’ interests and beliefs towards the STEM subjects. Accordingly, science items were added to the survey. The survey consists of 14 statements of students’ beliefs and interest. These statements are repeated for each strand of the STEM (science, technology, engineering, and mathematics). The statements mainly originated from the National Science Foundation Student responses were measured by a Likert-scale questions from 1-5 (1- Strongly disagree to 5 strongly agree). Students were asked to answer the questions on the survey at the end of the project. The instrument was delivered in a traditional paper format (see Appendix 2)

3.4 Data Collection Method

Data collected from the first stage of the study which was the teachers’ questionnaire was done in the first two weeks of the term. The data collected from the questionnaire focus on teachers’ practices and perceptions. It is formed from closed-ended and open-ended questions. The teachers got the questionnaires at the first week of the term before starting the project. Ethics were considered while asking teachers’ permission to share in the study. All the data has been kept confidential. Science, technology, engineering, and mathematics teachers voluntarily participated in this study. Teachers received the questionnaire by emails. All questionnaires were completed and returned by the second week.

The second stage is collating the rubrics that used to assess the students' development of the project. Results for the first three rubrics were collected by the teachers during the 8 weeks of the project. Then, the assessment results from the fourth rubric were collected at the end of the term. Collation of rubric assessments was done simultaneously during the same period of the project.

The final stage was the student survey that was used to determine students' interest and beliefs of the STEM subjects. Ethics were considered and students were asked about their participation in the study. All data were kept confidential and students were asked not to write their names on the survey. Students received the survey handouts and it took 10 to 15 minutes to answer the survey questions.

3.5 Validity of the Study

To conduct a research study that is used to answer the research questions, a strategic plan is designed and developed. This strategy allows collecting data that will lead to a valid conclusion. The validity of the data used in the mixed-method varies according to the type of data used (Johnson B. &Christensen, L., 2012).

In this study, multiple validities were used in order to fit the mixed-design of the research. External validity was applied to determine to what extent the instruments used could be generalized to the population while the internal validity was used to establish integrity within the evidence of cause and effect.

The external validity is about generalizing validity (Johnson & Christensen, 2012). The external validity used in this study is called 'population validity'. It is the ability to generalize the sample to the target population from selecting one sub-population (Johnson& Christensen, 2012). The sub-populations represent the seven campuses of the schools. One sub-population has been selected to represent the larger target population.

The "commensurability mixing validity" is a type of internal validity that is known as the ability to switch between the qualitative and quantitative points of views of participants (Johnson& Christensen, 2012, P.85). It has been used in the teachers' questionnaire where the closed-ended questions are used to explain the teachers' perceptions and practices while the open-ended questions are used to clarify and validate the participants' responses. Furthermore, the questionnaire items have been modified from the original survey.

Additionally, the students' survey has commensurability mixing validity as it consists of closed-ended questions and open-ended questions that are used to explore and explain the students' interests in shaping their careers according to each subject of the STEM project. In addition, the students' survey used to originate from the National Science Foundation (2004) Mississippi Information Technology Workforce project and had already been validated by 24 agriculture and biology teachers.

The "extended field work strategy" is one of the theoretical validity strategies. The theoretical validity is the degree to which a theoretical explanation fits the data and the extended fieldwork strategy involves collecting data over an extended period of time (Johnson& Christensen, 2012). The field notes observation conducted in this study over the period of 8-10 weeks allowed data collection of students' progress over a period of time which is considered to be credible and defensible. Furthermore, the students' scores that were collected according to the rubrics used to assess students during the project stages added extended field work validity to the students' progress.

3.6 Ethical Considerations

It is significantly important to understand the differentiation between the two terms which are ethics and morality. Ethics are defined as "the philosophical study of morality" (Vaughn, 2010, P.3). However, Morality refers to beliefs, principles, rules or values that concern right or wrong and good or bad (Vaughn, 2010, P.4). In other words, we are ethical because society says that we have to be but we practice morality because we believe in something being right or wrong. Bell (1999) mentioned that there is no excuse for the researcher in not considering ethics while conducting a study. The ethical issues have been put into consideration in conducting this research based on Hart's ethical principles (2005); integrity, competence, professional and scientific responsibility, people's rights and dignity, and social responsibilities.

First, informed consent was sought in which participants were given an informed and voluntary choice in participating in the study. Participants' privacy was respected and confidentiality was assured with regards to them sharing their beliefs, opinions, perceptions and records with others.

Following this rigorous research design and intensive data collection, the next chapter proceeds to present the data analysis, the findings, and the discussions that have arisen from this mixed-methods research study.

Chapter 4: Analysis of Data and Results.

This study aims to determine what extent using PBL strategy within STEM enhances students' skills. The results will be presented according to three stages that data was collected. The first stage will be for the teachers' practices and responses. The second stage will be the student achievements. The third stage will be for the student survey. The last stage will be for observations that were conducted over 8 weeks.

4.0 Results of The Teachers' Practices and Perceptions

The teachers' questionnaire is categorized into three categories; practices, perceptions, and open-ended illustrations. The purpose of this questionnaire is to measure teachers' perceptions and practices in enhancing students' skills through using PBL strategy.

4.0.1 Teachers' Practices

This part of the questionnaire aimed to find out teachers' practices. The questions are divided into sections. In each section, there are questions on teachers' practices and the use of PBL teaching strategy in their daily classrooms. The sections are divided into some skills that should be found by using PBL strategy and have been used as variables in order to measure the mean and the standard deviation. The tables below show the mean and standard deviation of the teachers' responses according to the critical thinking, collaboration, communication, creativity, self-direction, interdisciplinary, connection skills, and using technology as a tool.

4.0.1.1 Critical Thinking

In the critical thinking skills, the highest mean is at the first item of comparing information from different resources is 4.06 while the lowest mean is in the fifth item of developing persuasive arguments based on evidence is 2.87.

Critical Thinking	Mean	SD
a. Compare information from different sources before completing a task or assignment.	4.06	0.715
b. Draw their own conclusions based on analysis of numbers, facts, or relevant information?	3.81	0.39
c. Summarize or create their own interpretation of what they have read or been taught?	3.62	0.484
d. Analyze competing arguments, perspectives or solutions to a problem?	3.5	1.369
e. Develop a persuasive argument based on supporting evidence or reasoning?	2.87	0.78
f. Try to solve complex problems or answer questions that have no single correct solution or answer?	3.56	0.496

Table 1: Mean and standard deviation of teachers' responses on their practices of critical thinking.

4.0.1.2 Collaboration

In collaborative skills, the mean of the items are close to each other however the highest mean is at the item of giving feedbacks to others (4.62).

Collaboration	Mean	SD
a. Work in pairs or small groups to complete a task together?	4.56	0.508
b. Work with other students to set goals and create a plan for their team?	4.37	0.484
c. Create joint products using contributions from each student?	3.75	0.75
d. Present their group work to the class, teacher, or others?	4.37	0.484
e. Work as a team to incorporate feedback on group tasks or products?	4.37	0.484
f. Give feedback to peers or assess other students' work?	4.62	0.484

Table 2: Mean and standard deviation of teachers' responses on their practices of collaboration.

4.0.1.3 Communication

The mean of the communication skills' items is the same 4.37 except one item is low which is for preparing and delivering an oral presentation 3.75.

Communication	Mean	SD
a. Data structure for use in written products or oral presentations (e.g., creating charts, tables or graphs)?	4.37	0.484
b. Convey their ideas using media other than a written paper (e.g., posters, video, blogs, etc.)?	4.37	0.484
c. Prepare and deliver an oral presentation to the teacher or others?	3.75	0.75
d. Answer questions in front of an audience?	4.37	0.484
e. Decide how they will present their work or demonstrate their learning?	4.37	0.484

Table 3: Mean and standard deviation of teachers' responses on their practices of communication.

4.0.1.4 Creativity and Innovation

In creativity, the item of the brainstorming and concept mapping has the highest mean 4.43 while the lowest is at the item of creating the original product 2.37.

Creativity and innovation	Mean	SD
a. Use idea creation techniques such as brainstorming or concept mapping?	4.43	0.718
b. Generate their own ideas about how to confront a problem or question?	3.81	0.949
c. Test out different ideas and work to improve them?	3.25	0.75
d. Invent a solution to a complex, open-ended question or problem?	3	0.612
e. Creates an original product or performance to express their ideas?	2.37	0.484

Table 4: Mean and standard deviation of teachers' responses on practices of creativity and innovation.

4.0.1.5 Self-direction

In self-directed skills, the highest mean is about taking initiative when confronted with a difficult problem 3.31while the lowest mean is for the item of using their peers' and teacher's feedback.

Self-direction	Mean	SD
a. Take initiative when confronted with a difficult problem or question?	3.31	0.691
b. Choose their own topics or learning or questions to pursue?	2	0.866
c. Plan the steps they will take to accomplish a complex task?	1.93	0.658
d. Choose for themselves what examples to study or resources to use?	2.37	1.111
e. Monitor their own progress towards completion of a complex task and modify their work accordingly?	2.43	0.998
f. Use specific criteria to assess the quality of their work before it is completed?	3.06	0.658
g. Use peer, teacher or expert feedback to revise their work?	1.5	0.5

Table 5: Mean and standard deviation of the teachers' responses on their practices of self-direction.

4.0.1.6 Interdisciplinary STEM

In interdisciplinary STEM, the mean is close in all items: however, the highest is in choosing what discipline to use in solving problems (3.5).

Interdisciplinary STEM	Mean	SD
a. The PBL strategy is helpful to analyze and handling of the STEM problems?	3.18	0.806
b. In solving problems, I facilitate the use knowledge from different disciplines?	3.43	0.704
c. Plan the steps they will take to integrate knowledge to accomplish a complex task?	3.37	0.695
d. Choose for them what disciplines to use in solving real life problems?	3.5	0.707
e. Guide them to integrate, classify, and keep track of	3	0.612

knowledge they obtained?		

Table 6: Mean and standard deviation of teachers' responses in their practices of interdisciplinary STEM.

4.0.1.7 Connection

In connection, the highest mean is for the item of talk to one or more members about the project 2.5 while the lowest is the item about responding to a question or task.

Connection	Mean	SD
a. Investigate topics or issues that are relevant to their family or community?	1.62	0.505
b. Apply what they are learning to local situations, issues or problems?	2.12	0.695
c. Talk to one or more members of the community about a class project or activity?	2.5	0.707
d. Analyze how different stakeholder groups or community members view an issue?	2.31	0.681
e. Respond to a question or task in a way that weighs the concerns of different community members or groups?	1.31	0.463

Table 7: Mean and standard deviation of teachers' responses on their practices of connection.

4.0.1.8 Using Technology as a Tool

In using technology as a tool, the mean in all the items are close to each other.

Using Technology	Mean	SD
a. Use technology or the internet for self-instruction (e.g., videos, tutorials, self-instructional websites, etc.)?	4.68	0.463
b. Select appropriate technology tools or resources for completing a task?	4.56	0.704
c. Evaluate the credibility and relevance of online resources?	4.18	0.881
d. Use technology to analyze information (e.g., databases, spreadsheets, graphic programs, etc.)?	4.5	0.5

e. Use technology to help them share information (e.g., multi-media presentations using sounds or video, presentation software, blogs, podcasts, etc.)?	4.68	0.463
f. Use technology to support team work or collaboration (e.g., shared workspaces, email exchanges, giving and receiving feedback, etc.)?	4.68	0.463
g. Use technology to interact directly with experts or members of local/global communities?	4.5	0.5
h. Use technology to keep track of their work on extended tasks or assignments?	4.5	0.5

Table 8: Mean and standard deviation of teachers' responses on their practices of using technology as a tool.

The most striking result to emerge from the data is the teachers' responses differ according to their specializations. The science and engineering teachers have the highest score in their responses. The graph below shows a clear idea about the difference between teachers' responses, their teaching practices, and their expectations about the students. The science and engineering teachers have positively shown that their students are engaged in the learning process and that they are practicing the PBL strategy daily. The technology teachers responded that they do practice these skills but not to the same extent as the science and engineering teachers. However, there is a significant difference between the mathematics teachers and the other teachers where they have the lowest value of the results.

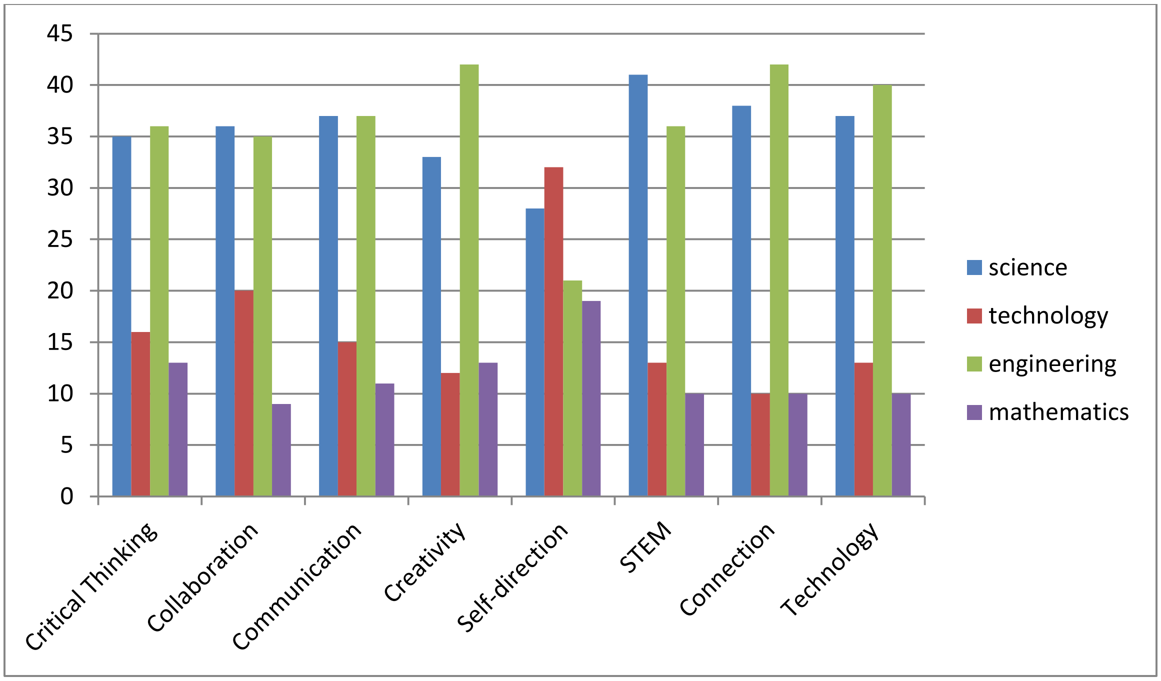

Figure 6: Teachers' responses (%) of their practices for the skills according to their specializations.

Science and engineering teachers' responses have shown high percentages. They have more than 70% both of the responses about their practices and use of the PBL strategy of all skills whereas the mathematics and technology teachers have lower than 30% in both those areas. However, in the self-direction skills the results differ, where technology teachers' responses were 32%. The second higher percentage was for science teachers at 28%. The engineering teachers' responses were 21%, while the mathematics teachers have the lower percentage at 19%.

4.0.2 Teachers' Perceptions

All the teachers agreed that they tried to develop students' critical thinking, collaboration, and communication skills. All of the teachers also agreed that they tried to develop students' creativity skills and they have learned the skills, while 45% of the teachers agreed about assessing students creative skills. 45% of the teachers agreed about developing and assessing students' self-direction and only 40 % agreed that students learned the skills. All teachers agreed that they develop and assess the students' integration of knowledge and that students learned this skill. In connection skills, 60% of teachers disagreed about assessing students' skills while 60% agreed that students had acquired this skill. All teachers agreed that they have developed and assessed students' skills and that students learned these skills. The following chart shows the teachers' responses by percentage according to their specialization. The results reveal that the science and engineering teachers have the highest scores in their responses.

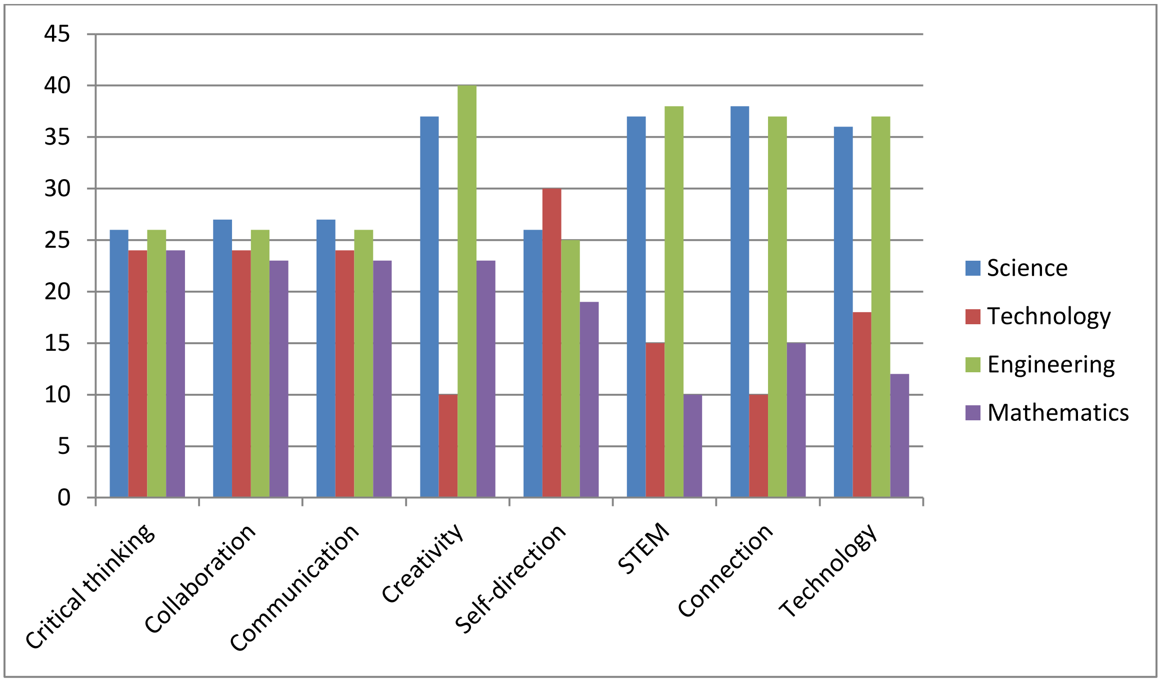

Figure 7: Response percentages of teachers' perceptions of the skills according to their specializations.

The results of teachers' perceptions in critical thinking, collaboration, and communication skills are close to each other, however, the science and engineering teachers have the highest values and the mathematics teachers have the lowest values. The results of the engineering teachers in creativity and innovations have the highest value of 40%. The science teachers' responses followed the engineering teachers with 37%, then the mathematics teachers at 23%, and lastly, the technology teachers have the lowest value in these skills at 10%. The highest value of the self-direction skill was for the technology teachers at 30%, followed by the science teachers at 26% and the engineering teachers at 25%, and the mathematics teachers again have the lowest value of 19%. More than 35% of the responses in the interdisciplinary STEM, connection, and technology use were for the science and engineering teachers followed by the technology teachers and lowest percentages were from mathematics teachers.

4.0.3 Teachers' results of open-ended questions

The last part of the questionnaire was for the teachers' to share their perceptions through open-ended questions. This part has been added to the questionnaire as further evidence was needed to validate quantitative responses.

The importance of critical thinking skills

The science and engineering teachers stated how their students infer, analyze, interpret data, and find the reasoning to support their results. They believe in integrating critical thinking skills through following this process as an essential step of PBL. On the other hand, the Mathematics and technology teachers did not show the same level of interest in teaching their students to be engaged in this process deeply. The reason that students need to connect their learning to the real-life.

The teachers' roles in collaborative learning

All the teachers mentioned that they are able to facilitate, guide, and coach students in their learning. Teachers understand the multi-sensory roles in the learning process and while arranging groups. They believe that students have different learning styles and according to their styles, they have to arrange them and shuffle between groups in order for all students to benefit from each other. Accordingly, students are responsible about their learning and are confident to check their peers' work and learn from giving feedbacks to each other during solving the problems.

Incorporation of discussions and reflection on the PBL topic

Students' discussions and reflections are very important as stated by the science and engineering teachers. However, mathematics and technology teachers do not believe that discussions and reflections take an important role as they rarely carry out tasks in solving STEM problems.

The complexity of problems in developing students' creativity

The engineering and science teachers felt that more complex and ill-structured problems increase students' creativity in finding alternatives to solve these problems where they are able to "think outside the box". Technology and mathematics teachers believe that the well-structured problems are better in meeting the objectives of the lesson in a direct way.

Teachers' roles in acquiring students' self-direction skills

Science and engineering teachers show how to guide students to be self-directed as they set borders not to go outside the parameters. These results from the fear of potential dangers students could face in the laboratories through directing themselves in the learning process. The mathematics and technology teachers facilitate the way for students and leave them to direct themselves. In mathematics, the trial and error strategies are better for students in order to find the best way to solve problems. In technology, students can acquire literacy skills in directing their learning.

PBL strategy in teaching students integrated knowledge

Science teachers described how students analyze, integrate, and classify knowledge in STEM education and the links to the science discipline. The engineering teachers mentioned that it is significantly important to know how to use knowledge in analysis or integration as knowledge is the starting point. Technology teachers illustrated how the students use technology in solving complex problems through following the PBL process. Mathematics teachers believe that the process of PBL strategy is useful in solving problems in a meaningful way where ill-structured problems consist of intertwined knowledge.

Connection of students' learning to the real-life

Science and engineering teachers responded how the learning becomes more meaningful in connecting knowledge to real-life. However, the technology and mathematics teachers mentioned that rarely do their students integrate knowledge to real-life. This is because mathematics and technology were used only as a tool in solving STEM problems.

All teachers mentioned that nowadays, students can be described as technology natives, who are interested in technology and rarely struggle with it.

4.1 The students' achievements

The robotics project has set as a variable for the statistical results. The results of the students' scores have been analyzed in several steps of the rubric assessments during the 10 weeks, the end of term written exam, and the total score for the project.

Table 9 below shows the detailed scores that students obtained in the four different stages of, assessment within the Robotics module that lasted for 8 weeks. Evaluations began two weeks into the module. The rubrics assessments that have been applied during the 10 weeks to assess students' progress have been done in four stages. The first stage was for the engineering journal. The students have been evaluated after the first 2 weeks. The engineering journal rubric was a checklist and scoring out of 10 marks. The total number of grade (11) students was N=72. The minimum score of students was 6 and the maximum score was 10. As shown in the table the mean is 8 and the standard deviation is 1. The rubric for the presentation was out of 10 marks. In the table below, the mean is 9 and SD is 0.9. The internal design review assessment rubric is out of 10 and it was more difficult stage in the project. The minimum score was 4 while the maximum was 10. The mean is 8 and the SD is 2.3. The external design assessment rubric is out of 30 as it is the stage of applying what they have learned and conducting the project. The students have been evaluated of the external design in week 8. The minimum score of the students was 18 while the maximum was 28. The mean is 23 while the SD is 2.3. The end of term written exam score that conducted in week 10 was out of 40 marks. The minimum score of students was 17 while the maximum was 36. The total score of students in the robotics course mentions that the minimum score of students is 60 while the maximum score is 92.

Grade (11) students	N	Median	Minimum	Maximum	Mean	SD
Engineering Journal Rubric (out of 10)	72	8	6	10	8	1
Rubric for Presentation (out of 10)	72	10	6	10	9	0.9
Internal Design Review Sample Assessment Rubric (out of 10)	72	8	6	10	8	1.5
External Design Review Sample Assessment Rubric (out of 30)	72	22	18	28	23	2.3
End of Term Written Exam (out of 40)	72	25	20	40	34	4.08
Total Score of the Project	72	72	60	92	82	6.3

Table 9: Descriptive statistics of the students' scores in the robotics course.

The students' scores reflect the success of the robotics curriculum. The results of students' scores show that there is no failure. It is interesting to note that the highest percentage of students' marks were in the presentations that used technology and other multimedia resources. The total score of the project shows that 80% of students got scores above 80 and that there are no scores below 60. The table below represents the students' scores of the marks by percentage.

Range of students' marks	**(60-69)**	**(70-79)**	**(80-89)**	**(90-100)**
Engineering Journal Rubric	11%	25%	32%	32%
Rubric for Presentation	1%	6%	8%	85%
Internal Design Review Sample Assessment Rubric	26%	24%	44%	6%
External Design Review Sample Assessment Rubric	12%	21%	29%	38%
End of Term Written Exam	8%	10%	21%	61%
Total Score of the Project	3%	17%	60%	21%

Table 10: Students' scores (in %) for each assessment

4.2 Students' perceptions

The student survey was conducted in the final week after they finished the project and the end of term exam in order to measure students' interests towards the subject they learned and how this could shape their career choices. The survey was categorized according to the STEM disciplines and consisted of repeated items in each discipline. Descriptive statistics were conducted to find the mean and standard deviation of the survey items. Appendix (3) shows the table of the survey items with the mean and standard deviation. Interestingly, the standard deviation was zero in the same item repeated in the STEM disciplines, which referred to collaborative work. This means that there is no variance in the students' responses. In addition, it was clear in the table below that all students like to work in groups. Furthermore, the SD was zero also in the other two items within the technology discipline. These items prove their interest in using the computer to learn more about technology and their interest to take more classes in technology. The table below shows the students' interests in each discipline of the STEM by percentage.

Students’ Interests	S	T	E	M
I enjoy this class.	70%	100%	70%	30%
I like to find answers to questions by doing experiments.	85%	70%	72%	25%
I get to do experiments in this class.	100%	30%	80%	20%
Being a scientist, technologist, engineer, or mathematician would be exciting.	35%	25%	40%	10%
This subject is difficult for me.	25%	10%	30%	90%
I like to use the book to learn about this subject.	30%	5%	10%	80%
This subject is useful in everyday life.	89%	84%	92%	26%
This subject helps make our lives better.	92%	96%	95%	40%
I want to take more classes in this subject.	75%	100%	70%	28%
I like to use computers to learn about this subject.	90%	100%	95%	10%
I like to work in a small group in this class.	100%	100%	100%	100%

Table 11: Students' interests in STEM disciplines by percentage.

Student responses about enjoying the class indicate that all of them enjoy technology classes and 70% enjoy science and engineering classes while only 30% who enjoyed the math classes. STEM education influenced students’ in shaping their career. 40% of students would like to be engineers, 35% wanted to be scientists, 25% prefer to be technologists, and 10% wanted to be mathematicians. Around 90% of students claimed that they do not feel comfortable with the mathematics subjects. The usefulness of each subject differs I the students; 92% respond for engineering, 89% in science, 84% of technology, and 26% for mathematics. All the students expressed the desire to take more classes in technology, 75% for science, 70% for engineering, and 28% of technology. All the students agreed that used computers as a tool in learning about technology, 95% used computers to learn about engineering, 90% to learn about science, and 10% used it to learn about mathematics. All the students also agreed that they feel more comfortable to work collaboratively in the STEM subjects.

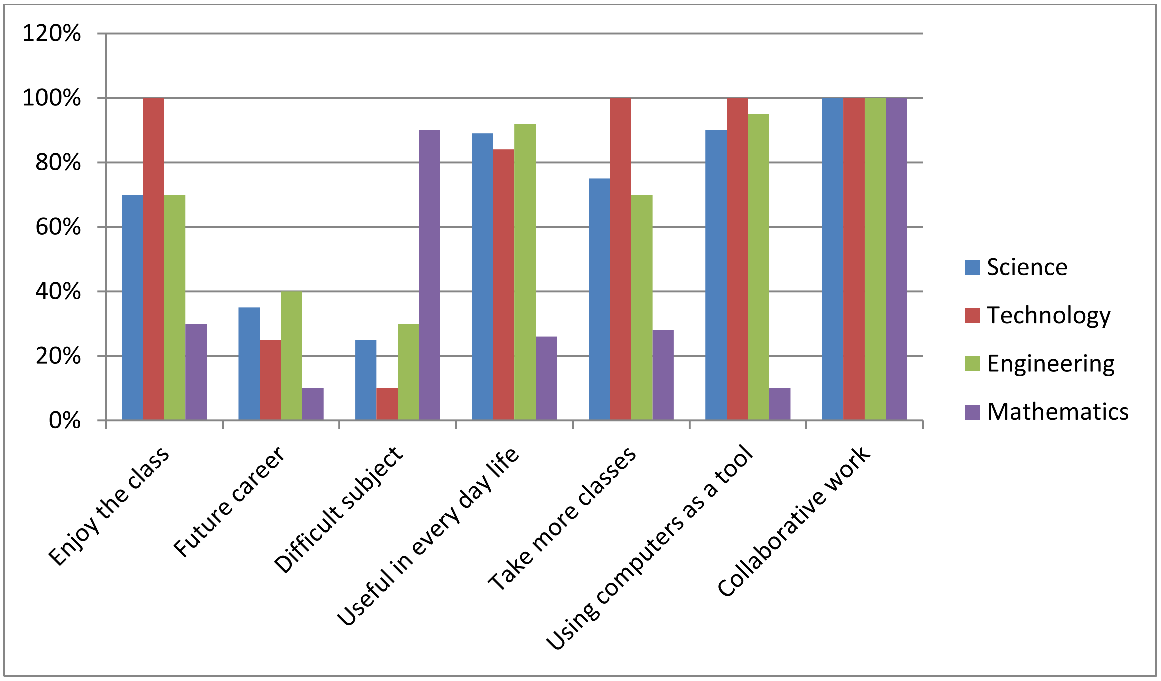

Figure 8 : Students' perceptions of each discipline by percentage

4.3 Summary of The Results.

The most interesting finding from the results in the teachers' practices and perceptions is that the science and engineering teachers have the highest score in their responses about the use of PBL strategy in their daily practices than the mathematics and technology teachers. However, the results in the self-direction skills were different; the technology teachers got the highest score, then the science teachers came in the second rank, followed by the engineering teachers, science teachers, and mathematics teachers.

The results of the students' achievements corroborate the success of the robotics module. Most of the students got higher scores in the presentation of the project and the written exam while the lowest achievement was in the internal design review sample. Students' perceptions show an increase of their interests towards the science and engineering subjects followed by the technology and the lowest for mathematics.

In the next chapter, these results will be analyzed in detail and discussed in light of the literature reviewed. Then, suitable recommendations will be made followed by conclusions and limitations of the study.

Chapter 5: Discussion, Conclusions, and Implications

The interdisciplinary STEM education is best taught by the PBL strategy as it helps students acquire critical skills. This chapter presents the discussions, conclusion, recommendations, suggestions for further studies, and limitations.

5.0 Discussion

This study set out with the aim of measuring teachers' and students' perceptions of the latter's skills development within Lego-Mindstorm robotics module which is taught as an interdisciplinary STEM curriculum incorporating PBL strategies. As has been stipulated previously, the skills are not easy to measure and need multiple tools (Lai &Viering, 2012). Accordingly, four tools have been used to measure students' developing skills, achievements, and teaching practices over four stages during 10 weeks. As mentioned by Hewlett (2010), there are three types of learning occurred in the PBL models; cognitive learning, content learning, and collaborative learning. The findings presented in chapter 4 are in agreement with previous studies that have highlighted the improvement of the students' cognitive, content, and collaborative skills through the PBL-STEM models (Capraro, Capraro, and Morgan, 2013; Wyss et al., 2012; Asunda, 2012; Hendricks et al., 2012; Toker & Ackerman, 2011). However, there are some gaps occurred in the results will be discussed in this chapter.

It is encouraging in the beginning to compare the pattern of STEM used in the Robotics by the different ways of interdisciplinary STEM that were identified by Dugger and Fellow (2011). The results show that the engineering project (robotics) used for the study fits the third pattern the focus was on the engineering part and is integrated with the other disciplines: math, science, and technology. According to Dugger& Fellow (2011), the third pattern is the most comprehensive way in integrating the four disciplines in a real-world project.

The conceptual framework of the study clearly illustrates the basis of constructivism that provides PBL the process to teach STEM project that requires cognitive, content, and collaborative learning to develop the students' higher-order thinking skills. In light of this, the results will be discussed according to this framework.

5.0.1 Teachers' practices and perceptions

A teachers' questionnaire was used in order to answer the first sub-question in the study regarding teachers' perceptions and practices. The results show that the teachers act as facilitators to enhance students' skills through solving STEM problems by applying PBL-strategy. However the teachers' responses varied according to their specializations.

As shown by previous studies, the main results about cognitive learning in this study focuses on the ill-structured problems and the process of solving these problems that develop students' critical thinking, creativity, and motivation skills (Capraro, Capraro, and Morgan, 2013). In reviewing the representative models of Barrows' PBL taxonomy (Hung, 2011), the types of problem used is called pure-PBL or Hybrid-PBL that is described as being ill-structured problems which the self-led students tried to solve.

A surprising result from this study is that the mathematics teachers seemed to less inform on how to integrate critical thinking and creative skills in their teaching strategies. This is consistent with Broadbear's (2003) theory that teachers have in-depth information about content knowledge, but lack information about pedagogical content knowledge based on Shaulman's idea. In this present study, the mathematics and technology teachers indicated a lack in integrating critical thinking skills and creativity in their practices. The project used the mathematics as tool and the math concepts are heavy for the students. The more the mathematical problems are integrated to the real-life the more the students find it easy. Although technology has been used as a tool for learning, it does not play a major role in inculcating PBL skills. In addition, the strong relationship between engineering and technology has been supported by the National Academy of Engineering (Dugger& Fellow, 2011). Furthermore, there is also an evidential link between science and technology where science aims to seek consistency and understanding of the real-world (NRC, 1996) while technology is the modification of the natural world (ITEA, 2000; 2002; 2007).

The science and engineering teachers' responses in this study showed a higher percentage in integrating critical thinking in their teaching practices. It was also revealed that the science and engineering teachers were more inclined to develop students' creativity and innovations through their practices. This could be compatible with the study of Melchior, Cutter & Deshpande (2009) who mentioned that the majority of students were more interested in learning science and engineering as they are able to reflect, synthesize, and analyze. Another study of lego-robotics stated that the robots are considered to be a useful real-life and complex problem that requires the use of PBL strategy to develop students' skills (Casteldine & Chalmers, 2012).

However, the mathematics teachers remain behind in integrating creativity and innovations in their practices. They need to connect the mathematical practices to the real-life to be more meaningful for the students.

Content learning is the other type of learning that is embedded within PBL and can develop students' integrated knowledge across disciplines, connecting their learning to the real-life, and using technology as a tool. As expected, the findings that emerged confirmed that the science and engineering teachers are integrating the knowledge across discipline more than the mathematics and technology teachers. The mathematics teachers tend to teach theories and rules more than relating learning to the real-life. This is due to that mathematics didn't take a major role in this project and the focus was on the engineering subject In addition, technology teachers face unmotivated students when they teach them concepts related to robotics. This matches with what Broadbear (2013) stated about the pedagogical content knowledge that teachers need to be aware of.

Collaborative learning is the third type of learning within PBL that develops students' collaborative, self-direction, and communication skills. Constructivism, which is the backbone of PBL, shapes the cognitive process where students incorporate new experiences to the existing experiences (Piaget, 1954) and become users of information in a student-centered environment. The results of this study support the idea that robotics is a real-life task built on constructivism. Vygotsky (1978) also emphasized the role of the co-constructed process where the learners interact and collaborate in solving problems.

5.0.2 Students' achievements

The students' scores have been used to address the second sub-question of the study to investigate the extent that using has impacted their achievements. The results verify that PBL strategy influenced students' achievements and increased students' engagement which was the same outcomes found in the study of Mosier, Bradely-Levine & Perkins (2013). Other studies have also expounded the important role of PBL strategy in teaching integrated subjects (Capraro, Capraro, and Morgan, 2013; Mosier et al., 2013; Casteldine & Chalmers, 2012; De Graff & Kolmos, 2003;2007; Du & Kolmos, 2006; Du, 2006; Savin-baden, 2003; Evensen & Hmelo, 2000). However, there are some gaps occurred in this study will be discussed.

The students' scores represent that they applied the collaborative learning which meets the objective of the Ministry of Education in UAE (2010-2020). In addition, they are able to use technology to facilitate their learning process. Previous research has also emphasized the important role of technology in helping students to use knowledge, get deeper into the content, and develop reasoning skills (Wai et al., 2010; Rockland et al., 2010; and Dani & Koeing, 2008). The results show low in students' achievements in the internal design review that is including the cognitive process of the PBL strategy. This part is related to integrating critical thinking skills in the learning process. The results of students' perceptions show that they are able to synthesize, analyze, reasoning, explain, and discuss findings in the science and engineering lessons. However, this was not the case in mathematics classes but they are able to understand the math concepts better when they are connected to the real-life. The scores of the external design that is related to conducting the robotics and applying their learning knowledge to the real-life were high. This means that students are able to connect their learning to the real-life and are able to use the knowledge in term of integration and breaking down. Previous studies mentioned that it allows students to develop essential skills and have the ability to be users of information with the help of technology that is used as a tool to facilitate learning (Chang & Liu, 2011; Chang, Liu, Lee, Chen, Hu, & Lin, 2011; Chang, Shieh, Liu, & Yu, 2012; Liu, Lin, Jian, & Liou, 2012).

5.0.3 Students' perceptions

Analyses of the student survey responses clearly show that students are able to solve and find alternatives to their problems, reflect, synthesize, and connect their learning to the real-life. Similar studies approved that to some extent students are able to solve problems, reflect on their learning, and apply what they have learned to the real-life (Capraro R., Capraro M., and Morgan J., 2013; and Chamers & Casteldine, 2012).In addition, the participating students' career choices have been influenced by learning, interdisciplinary STEM (robotics) through PBL strategy. The same results have been mentioned in previous studies (Wyss et al., 2012; Asunda, 2012; Hendricks et al., 2012; Toker & Ackerman, 2011; Russell et al., 2007; Hunter et al., 2007).

Students were more interested in being scientists and engineers. The second rank was in being technologists and few of them thinking about being mathematicians. Students were very interested in technology, science, and engineering classes. They feel that they can relate what they have learned to the real-life. Most of the students expressed less interest in mathematics classes as they did not feel that they can relate what they have learned to real-life. However, this did not affect the students' skills development as mathematics has a minor, albeit essential role in the robotics curriculum.

5.0.4 Qualitative Results

The qualitative results have been combined with a coded theme arranged according to the three types of learning that were mentioned previously in the conceptual framework of the study.

	Cognitive Learning	Content Learning	Collaborative Learning
Teachers' practices & perceptions	Engineering and science teachers responded that students acquire critical thinking skills as they are able to synthesize, analyze, reflect, and finding reasons to support their claims as these are essential processes used in learning science and engineering.	Science and engineering teachers stated that students are able to use information in terms of integration and breaking down. They are able to connect what they have learned in the real-life and used technology as a tool in the learning process.	STEM teachers stated that students are working collaboratively in groups. Technology teachers mentioned that students are self-directed in using technology. Science and engineering teachers mentioned how students are self-directed learners while math teachers explained that students have a fear of directing themselves.
Students' achievements	The internal design review includes the cognitive process of PBL and solving problems. 50% of students' scored above 80 which indicate that they have problems in the critical	The external design review includes the integrated knowledge to form the robotics in addition to the use of technology. Around 67% of students got above 80	The engineering journal includes students' self-direction, collaboration, and communication. Around 64% of students got above 80 marks. In addition, there is another skill present

	thinking and problem solving processes.	marks. In the presentation, there were 93% who got above 80 marks. They are able to connect their learning to the real-life.	which is not considered in this study, the project management skill.
Students' perceptions	Students respond that they feel difficulty in the mathematics subject in terms of solving the problems as they believe that math is not related to real-life. Students' career choices have been influenced from their experiences in learning robotics. The highest rank was in engineering and science, then technology, and last was in mathematics.	Students were very interested in using technology as a tool in the learning process. They used technology to learn about science, technology and engineering, and rarely used it to learn about mathematics. They felt that engineering, science, and technology are useful in everyday life and that math is not related to the real-life.	All of the students responded that they like to work collaboratively in groups to learn about all the STEM disciplines. They enjoyed learning science, engineering, and technology the most.

Table 12: Students responses as coded themes.

5.1 Implications

The most important implications of this study are summarized in three categories; practical, professional, and research.

5.1.0 Practical Implications

Students acquire critical thinking skills that are essential in learning science and engineering; they are able to synthesize, analyze, reflect on their learning. In addition, they are able to use the information, integrate, break down, connect what they have learned to the real-life, and use technology as a tool. They are working collaboratively and are self-directed learners, especially in using technology.

5.1.1 Professional Implications

The internal design review of the robotics includes the cognitive process of the PBL and solving problems where some of the students' scores are low. This indicates that some of the students have problems in developing the critical thinking and problem solving skills in particular subjects. The external design review in the STEM project includes the integrated knowledge to form the robotics where the students' scores are high. This mention that students are able to use the information and relate it to the real-life. The students' scores in engineering journal that includes students' self-direction, collaboration, and communication skills are high. The students mentioned that they still feel difficulty in solving mathematical problems and in relating their learning to the real-life. Students were very interested in using technology as a tool to learn about engineering and science. However, they were rarely using it in learning mathematics.

5.1.2 Research Implications

The most interesting implication of this study is that more skills came to the fore during this study such as project management, time management, self-development, and motivation. It is significantly important to consider these soft skills for further studies. A follow-up study on the students' interests is also recommended to provide an insight whether their interests remain the same and how this will affect their career choices. Considerably more work will need to be done to determine to what extent the constructivism environment occurs in the different disciplines of STEM. Further research can also be conducted to measure motivation that is considered to be one of the cognitive aspects and has not been measured in this study.

5.2 Conclusions, Recommendations, and Limitations

The present study was designed to determine the teachers' perceptions and practices of using PBL strategy in learning STEM curriculum and how they impact students' achievement. Returning to the main question posed at the beginning of the study, it is stated that students' skills have been enhanced from learning, robotics curriculum which is a STEM topic through the PBL strategy. Problem-based learning is better strategy than the project-based strategy in teaching STEM. According to Barrows' PBL taxonomy, the pure problem-based learning requires students' self-direction in solving ill-structured problems (Hung, 2011). In conducting the robotics project, students solve ill-structured problems that are related to real-life. The three types of learning that occurred in the PBL are cognitive learning, collaborative learning, and content knowledge which proved to enhance students' skills (Du et al., 2009; Kolmos et al., 2009; Ravitz, 2010; Savery, 2006; Darling-Hammond, 1994).

In cognitive learning, the teachers' roles were as facilitators and coaches as they should be in teaching through PBL strategy; however, there are gaps which occurred in integrating critical thinking skills in the teaching. Most teachers face pedagogical challenges in teaching critical thinking. Vygotsky and Guliford (1950) emphasized the importance of developing creativity and critical thinking in students (Beghetto, 2010). Students are able to synthesize, analyze, discuss, explain, and hypothesize in the engineering and science classes. The mathematical lesson classes were less interesting to students and the problems represented are well-structured. Students were hardly engaged in the learning process in mathematics classes. It appears that some students had issues engaging with the learning process in mathematics classes. Students need to connect their learning to the real-life in order to increase students' interests in learning mathematics and make their learning more meaningful.

In content learning, students realized that science is the basis of all the disciplines. They realized that to learn robotics they have to learn about mechanical and electrical engineering. To learn engineering they must have the basics of physical science, which is the backbone of their project. In addition, they feel the importance of using technology as it facilitates their learning and math is the common tool in completing the project.

Critical thinking, creativity, and motivation skills of students are apparent in learning. This is implied in students' demonstrations of these skills in science while failing to do the same in math. Accordingly, it is highly recommended that mathematics teachers should be supported by some professional development programs so they can learn how to integrate these skills in the learning process. Students' scores mentioned that they were achieving well in all stages of the robotics except in the internal design review which is related to the cognitive process. It was clear from the results that students in engaging with the mathematical concepts and were not interested in these lessons as the problems were well-structured and not related to the real-life. In addition, some students were unmotivated and not confident to direct their learning route. Furthermore, the mathematics teachers' role remains essential in shaping the students' route of learning which makes them depend on the teachers even in a constructivism environment. There is a coherent structure in STEM instruction through the common core standards used that serve as the benchmark for accomplishing teaching STEM disciplines through implementing the robotic; however, an additional professional development for teaching STEM is highly recommended. The onus is on teachers to arrange learning experiences that guide students learning to identify the knowledge and skills needed.

Students' worked collaboratively during all the robotics stages which in turn meet the ministry of education of UAE objectives. Students' experience in the robotics curriculum enhanced their career choices positively which has completely matched the results of the study of Hendricks, Alemdar & Ogletree (2012). Another study of lego-robotics stated that the robots is a STEM project and is considered to be a useful real-life and complex problem that requires the use of PBL strategy to develop students' skills (Casteldine & Chalmers, 2012). The results also show that students were digital natives, they were reluctant to direct themselves in the mathematics classes, but were highly engaged in the science, technology, and engineering classes. Furthermore, it is suggested to increase students' awareness about STEM careers through providing information via video interviews with STEM professionals as it was noticed that students' information about STEM careers is limited.

5.3 Limitation

The generalisability of these results is subject to certain limitations. For instance, the presented results are limited due to the small representative sample as the STEM (Robotic) curriculum is considered to be new and there are limited schools offering robotics in the UAE. However, the robotic curriculum enhances students' skills in addition to the growing knowledge base on the power of implementing the project to inspire students to pursue STEM pathways.

The most important limitation lies in the fact that these skills are intertwined in a very complex way and have heavy reliance on the researcher which needs more data to be collected to triangulate the results. It is recommended to apply students' interviews in order to make the results more reliable as the skills are not easy to observe and needs more than one tool to get accurate results.

In addition, using the pre and post test for students such as Liwa test could be a very useful tool to measure the students' skills and their interest in the STEM careers.

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Appendix 1: The Teachers' Questionnaire

To Whom It May Concern

I am doing this research in specialization of Science Education from British University in Dubai. The topic of my research is "Teaching Students Critical Thinking Skills through the Project-based Learning Strategy of STEM projects". The study will develop 21st century teaching and learning tools for local use. As I receive your permission, I will give the science and engineering teachers the 21st century teaching and learning questionnaire.

The information collected from the teachers will be kept confidential and will be used in this research only. If you have queries or require more information regarding this research study, please contact the undersigned. Thank you for your cooperation in this academic endeavor.

Best Regards,

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The 21st Century Teaching and Learning Questionnaire

Adapted from: The 21st Century Teaching and Learning Survey [WVDE-CIS-28].

The questions in this questionnaire are going to ask about your teaching practices that might support students' learning of the following 21st century skills:

- Critical Thinking.
- Collaboration.
- Creativity and Innovation.
- Self-Direction.
- Integrating Content Knowledge (Science, Technology, Engineering, and Mathematics).
- Connection to Real life.
- Using Technology as a tool.

For each of the above you will be asked about your general teaching of these skills, and about a few specific practices you may have used.

There are no correct or incorrect answers and all responses will be kept confidential.

Name:………………………………………………………………………………………

Gender: **Male** ☐ **Female** ☐

School:………………………………………………………………………………………

Teaching Position:………….. **Grade:………..** **Specialization:…………..**

Total Teaching Experience: **0-5** ☐ **6-10** ☐ **11-15** ☐

In service training (Professional development training): **Yes** ☐ No ☐

Part (A): Critical Thinking Skills

In general, critical thinking skills refer to students being able to analyze complex problems, investigate questions for which there are no clear-cut answers, evaluate different points of view or sources of information, and draw appropriate conclusions based on evidence and reasoning.

1. Here are some examples of practices that may help students learn Critical Thinking Skills.

Almost never = **AN** A few times of semester **=TS**1-3 times per month = **TM**
1-3 times per week = **TW**Almost daily = **AD**

In your teaching of your target class, how often have you asked students to do the following?

	AN	TS	TM	TW	AD
g. Compare information from different sources before completing a task or assignment.					
h. Draw their own conclusions based on analysis of numbers, facts, or relevant information?					
i. Summarize or create their own interpretation of what they have read or been taught?					
j. Analyze competing arguments, perspectives or solutions to a problem?					
k. Develop a persuasive argument based on supporting evidence or reasoning?					
l. Try to solve complex problems or answer questions that have no single correct solution or answer?					

2. To what extent do you agree with these statements about your target class?

Strongly disagree = **SD** Disagree = **D** Undecided = **U**Agree = **A**Strongly agree = **SA**

In your teaching of your target class, how often have you asked students to do the following?

	SD	D	U	A	SA
a. I have tried to develop students' critical thinking skills.					
b. Most students have learned critical thinking skills while in my class					
c. I have been able to effectively assess students' critical thinking skills.					

- **How do you integrate the critical thinking standards in your teaching practices?**

Part (B): Collaboration Skills

In general, collaboration skills refer to students being able to work together to solve problems or answer questions, to work effectively and respectfully in teams to accomplish a common goal and to assume shared responsibility for completing a task.

1. **Here are some examples of practices that may help students learn Collaboration Skills.**

Almost never = **AN** A few times of semester **=TS**1-3 times per month = **TM**
1-3 times per week = **TW**Almost daily = **AD**

In your teaching of your target class, how often have you asked students to do the following?

	AN	TS	TM	TW	AD
g. Work in pairs or small groups to complete a task together?					
h. Work with other students to set goals and create a plan for their team?					
i. Create joint products using contributions from each student?					
j. Present their group work to the class, teacher, or others?					
k. Work as a team to incorporate feedback on group tasks or products?					
l. Give feedback to peers or assess other students' work?					

2. **To what extent do you agree with these statements about your target class?**

Strongly disagree = **SD** Disagree = **D** Undecided = **U**Agree = **A**Strongly agree = **SA**

In your teaching of your target class, how often have you asked students to do the following?

	SD	D	U	A	SA
a. I have tried to develop students' collaboration skills.					
b. Most students have learned collaborative skills while in my class					
c. I have been able to effectively assess students' collaborative skills.					

- **What roles do you take in managing the groups?**

Part (C): Communication Skills

In general, communication skills refer to students being able to organize their thoughts, data and findings and share these effectively through a variety of media, as well as orally and in writing.

1. Here are some examples of practices that may help students learn communicationSkills.

Almost never = **AN** A few times of semester **=TS**1-3 times per month = **TM**
1-3 times per week = **TW**Almost daily = **AD**

In your teaching of your target class, how often have you asked students to do the following?

	AN	TS	TM	TW	AD
f. Structure data for use in written products or oral presentations (e.g., creating charts, tables or graphs)?					
g. Convey their ideas using media other than a written paper (e.g., posters, video, blogs, etc.)?					
h. Prepare and deliver an oral presentation to the teacher or others?					
i. Answer questions in front of an audience?					
j. Decide how they will present their work or demonstrate their learning?					

2. To what extent do you agree with these statements about your target class?

Strongly disagree = **SD** Disagree = **D** Undecided = **U**Agree = **A**Strongly agree = **SA**

In your teaching of your target class, how often have you asked students to do the following?

	SD	D	U	A	SA
d. I have tried to develop students’ communication skills.					
e. Most students have learned communication skills while in my class					
f. I have been able to effectively assess students’ communication skills.					

- **How do you think that discussions and reflection incorporated in the PBL lesson?**

Part (D): Creativity and Innovation Skills

In general, creativity and innovation skills refer to students being able to generate and refine solutions to complex problems or tasks based on synthesis, analysis and then continuing or presenting what they have learned in new and original ways.

1. **Here are some examples of practices that may help students learn communicationSkills.**

Almost never = **AN** A few times of semester **=TS**1-3 times per month = **TM**
1-3 times per week = **TW**Almost daily = **AD**

In your teaching of your target class, how often have you asked students to do the following?

	AN	TS	TM	TW	AD
a. Use idea creation techniques such as brainstorming or concept mapping?					
b. Generate their own ideas about how to confront a problem or question?					
c. Test out different ideas and work to improve them?					
d. Invent a solution to a complex, open-ended question or problem?					
e. Create an original product or performance to express their ideas?					

2. **To what extent do you agree with these statements about your target class?**

Strongly disagree = **SD** Disagree = **D** Undecided = **U**Agree = **A**Strongly agree = **SA**

In your teaching of your target class, how often have you asked students to do the following?

	SD	D	U	A	SA
a. I have tried to develop students' creativity and innovation skills.					
b. Most students have learned creativity and innovation skills while in my class					
c. I have been able to effectively assess students' creativity and innovation skills.					

- **What types of problems do you think that can develop students' creativity?**

Part (E): Self-Direction Skills

In general, self-direction skills refer to students being able to take responsibility for their learning by identifying topics to pursue and processes for their own learning and being able to review their own work and respond to feedback.

1. Here are some examples of practices that may help students learn self-directedSkills.

Almost never = **AN** A few times of semester **=TS**1-3 times per month = **TM**
1-3 times per week = **TW**Almost daily = **AD**

In your teaching of your target class, how often have you asked students to do the following?

	AN	TS	TM	TW	AD
h. Take initiative when confronted with a difficult problem or question?					
i. Choose their own topics or learning or questions to pursue?					
j. Plan the steps they will take to accomplish a complex task?					
k. Choose for themselves what examples to study or resources to use?					
l. Monitor their own progress towards completion of a complex task and modify their work accordingly?					
m. Use specific criteria to assess the quality of their work before it is completed?					
n. Use peer, teacher or expert feedback to revise their work?					

2. To what extent do you agree with these statements about your target class?

Strongly disagree = **SD** Disagree = **D** Undecided = **U**Agree = **A**Strongly agree = **SA**

In your teaching of your target class, how often have you asked students to do the following?

	SD	D	U	A	SA
a. I have tried to develop students' self-direction skills.					
b. Most students have learned self-direction skills while in my class					
c. I have been able to effectively assess students' self-direction skills.					

Explain how do you guide, facilitate, or coach students in the learning process in order to be self-directed?

Part (F): Interdisciplinary STEM

In general, interdisciplinary STEM refers to students being able to integrate the content knowledge across disciplines in order to solve authentic problems.

1. Here are some examples of practices that may help students learn self-directedSkills.

Almost never = **AN** A few times of semester **=TS**1-3 times per month = **TM**
1-3 times per week = **TW**Almost daily = **AD**

In your teaching of your target class, how often have you asked students to do the following?

	AN	TS	TM	TW	AD
f. The PBL strategy is helpful to analyze and handling of the STEM problems?					
g. In solving problems, I facilitate the use knowledge from different disciplines?					
h. Plan the steps they will take to integrate knowledge to accomplish a complex task?					
i. Choose for them what disciplines to use in solving real life problems?					
j. Guide them to integrate, classify, and keep track of knowledge they obtained?					

2. To what extent do you agree with these statements about your target class?

Strongly disagree = **SD** Disagree = **D** Undecided = **U**Agree = **A**Strongly agree = **SA**

In your teaching of your target class, how often have you asked students to do the following?

	SD	D	U	A	SA
a. I have tried to develop students' content knowledge.					
b. Most students have learned how to obtain, integrate, and classify knowledge while in my class.					
c. I have been able to effectively assess students' content knowledge.					

- **How is the PBL method is helpful in teaching students integrated knowledge?**

Part (G): Connections Skills

In general, making connections skills refer to students being able to apply what they have learned to real life, local context, and community issues.

1. Here are some examples of practices that may help students learn connectionsSkills.

Almost never = **AN** A few times of semester **=TS**1-3 times per month = **TM**

1-3 times per week = **TW**Almost daily = **AD**

In your teaching of your target class, how often have you asked students to do the following?

	AN	TS	TM	TW	AD
f. Investigate topics or issues that are relevant to their family or community?					
g. Apply what they are learning to local situations, issues or problems?					
h. Talk to one or more members of the community about a class project or activity?					
i. Analyze how different stakeholder groups or community members view an issue?					
j. Respond to a question or task in a way that weighs the concerns of different community members or groups?					

2. To what extent do you agree with these statements about your target class?

Strongly disagree = **SD** Disagree = **D** Undecided = **U**Agree = **A**Strongly agree = **SA**

In your teaching of your target class, how often have you asked students to do the following?

	SD	D	U	A	SA
a. I have tried to develop students' skills in making connections.					
b. Most students have learned to make connections while in my class					
c. I have been able to effectively assess students' skills in making connections.					

- **In your specialization, to what extent students connect their learning to the real life?**

Part (H): Using Technology

In general, using technology as a tool for learning refers to students being able to manage their learning and produce products using appropriate information a communication technologies.

1. Here are some examples of practices that may help students learn use technology as a tool for learning.

Almost never = **AN** A few times of semester **=TS**1-3 times per month = **TM**
1-3 times per week = **TW**Almost daily = **AD**

In your teaching of your target class, how often have you asked students to do the following?

	AN	TS	TM	TW	AD
i. Use technology or the internet for self-instruction (e.g., videos, tutorials, self-instructional websites, etc.)?					
j. Select appropriate technology tools or resources for completing a task?					
k. Evaluate the credibility and relevance of online resources?					
l. Use technology to analyze information (e.g., databases, spreadsheets, graphic programs, etc.)?					
m. Use technology to help them share information (e.g., multi-media presentations using sounds or video, presentation software, blogs, podcasts, etc.)?					
n. Use technology to support team work or collaboration (e.g., shared work spaces, email exchanges, giving and receiving feedback, etc.)?					
o. Use technology to interact directly with experts or members of local/global communities?					
p. Use technology to keep track of their work on extended tasks or assignments?					

2. To what extent do you agree with these statements about your target class?

Strongly disagree = **SD** Disagree = **D** Undecided = **U**Agree = **A**Strongly agree = **SA**

In your teaching of your target class, how often have you asked students to do the following?

	SD	D	U	A	SA
a. I have tried to develop students' skills in using technology as a tool for learning.					
b. Most students have learned to use technology as tool for learning while in my class.					
c. I have been able to effectively assess students' skills in using technology for learning.					

- **To what extent students struggle in using technology as a tool?**

Appendix 2: The Students' Survey

الجامعة البريطانية في دبي
The British University in Dubai

Student Consent Form

Dear Student,

I would like to know if using robotics in the classroom makes students more interested in Science, Technology, Engineering and Mathematics. Helping me with this study will take about 10-15 minutes at the end. If you would like to help me, I will need to ask you some questions about your feelings toward Science, Technology, Engineering and Mathematics. You will be asked to answer a survey at the end of the lesson.

If you decide later that you don't want to be part of my research study, you and your parent/guardian can tell me that by calling, emailing, or writing to me. When I finish my research study, I might talk about what I learned with other people, or write it down so other people can read it, but I will always use your secret identity.

If you would like to help me in my study, please put your name on the bottom of this sheet. I have a copy of this form to give to you to keep, as well as one for your parent/guardian to keep. If you don't want to help me in my study, do not sign this sheet.

Investigator

Areej El-Sayary

Student Informed Consent Form (continued)

VOLUNTARY CONSENT FORM:

I have read and understand the information on the form and I consent to the terms of this study. I understand that the students' responses are completely confidential. I have the right to withdraw at any time. I have received an unsigned copy of this Informed Consent Form to keep in my possession.

Student Name (PLEASE PRINT) ____

Signature ____

Date ____

I certify that I have explained to the above individuals the nature and purpose, the Potential benefits, associated with participants in this research study, and have answered any questions that have been raised.

____________ ______________________________

Date Principal Investigator's Signature

Student Interest Survey: Technology

Instructions: The following statements relate to beliefs and interest in technology.

Mark the column that most closely matches how you feel about each statement.

Beliefs about Technology	**SD**	**D**	**N**	**A**	**SA**
I enjoy technology class					
I like to find answers to questions by doing experiments					
I get to do experiments in my technology class					
Being a technologist would be exciting					
The technology is difficult for me					
I like to use the technology book to learn technology					
Technology is useful in everyday life					
Technologists help make our lives better					
I want to take more technology classes					
I like to use computers to learn about technology					
I like to work in a small group in technology class					

Student Interest Survey: Engineering

Instructions: The following statements relate to beliefs and interests in engineering.

Mark the column that most closely matches how you feel about each statement.

Beliefs about Engineering	**SD**	**D**	**N**	**A**	**SA**
I enjoy engineering class					
I like to find answers to questions by doing experiments					
I get to do experiments in my engineering class					
Being an engineer would be exciting					
Engineering is difficult for me					
I like to use the engineering book to learn engineering					
Engineering is useful in everyday life					
Engineers help make our lives better					
Being an engineer would be a lonely job					
I want to take more engineering classes					
I like to use computers to learn about engineering					
I like to work in a small group in engineering classes					

Student Interest Survey: Math

Instructions: The following statements relate to beliefs and interests in Math.

Mark the column that most closely matches how you feel about each statement.

Beliefs about Mathematics	**SD**	**D**	**N**	**A**	**SA**
I enjoy mathematics class					
I like to find answers to questions by doing experiments					
I get to do experiments in my math class					
Being a mathematician would be exciting					
Math is difficult for me					
I like to use the math book to learn math					
Math is useful in everyday life					
Math help make our lives better					
I want to take more math classes					
I like to use computers to learn about math					
I like to work in a small group in math classes					

Student Interest Survey: Science

Instructions: The following statements relate to beliefs and interests in engineering.

Mark the column that most closely matches how you feel about each statement.

Beliefs about Science	**SD**	**D**	**N**	**A**	**SA**
I enjoy science class					
I like to find answers to questions by doing experiments					
I get to do experiments in my science class					
Being a scientist would be exciting					
Science is difficult for me					
I like to use the science book to learn science					
Science is useful in everyday life					
Science help make our lives better					
I want to take more science classes					
I like to use computers to learn about science					
I like to work in a small group in science classes					

Appendix 3: Summary of the ROBOTCS LEGO MINDSTORM

Teaching ROBOTCS for LEGO MINDSTORMS

Robotics is a STEM subject that is taught in the schools. It is designed in the sense of forming robotics projects and solving ill-structured problems while building the robots. The description of the module is given here and the rubric scale for assessing the students.

It has been predicted that new technology will include science, computer programming, electronic embedded systems, engineering design, and mathematics. Robotics has the ability to teach these concepts. In addition, robotics teaches the 21st century skill sets like time management, resource allocation, teamwork, problem solving, and communications. Robotics does provide opportunities for teachers to place engineering design, scientific process, technological literacy and mathematics in contexts that students find engaging and understandable. For students' STEM understanding to move beyond parroting the teachers' words, ideas, and solutions, and to develop deep understanding, students need the opportunity to struggle with the problem, be able to defend their decisions, and explain their answer in their words.

The module used is the robotics for Lego Mindstorms. The best practice in teaching engineering is to involve real-life tasks in addition to breaking down the problems to solve. The first phase of the STEM project is the self-guided lab experiments. The second phase of the STEM is an open-ended experiments that students learn over 8 weeks. Students learn the software-simulation, hardware for real industrial problems, open-ended problems of integrated knowledge, science, engineering, and mathematical concepts. The hands-on experiments are the product of students' learning that they conduct at the end of the term. These are the students' challenges in designing and building functional engineering system. The three types of learning have been clearly illustrated during this project. Collaborative learning is essential in the process of PBL. Cognitive learning occurred during the learning process and the students' use of knowledge in integrating and breaking down set as a fundamental part of the STEM education. Each lesson in the robotics moved in two parts together; the lecture and the practical.

The type of assessments used in this project is assessment rubrics that were designed to suit different learning types of students. The rubrics used in assessing students is used in "Teaching

Robotoc for Lego Mindstorms" in the Carnegie Mellon Robotics Academy (Shoop, 2009). The rating scales used involve qualitative description of many aspects as well as the four point scale. This method of rubric has a high degree of reliability. It is significantly important to provide students the criteria of the rubrics for achieving clarity. The purpose of providing students these criteria is to act as self-assessment and self-regulation in evaluating their performance. In addition, the rubrics allow teachers to see what is being assessed. The rubrics used in this project are categorized according to the projects' needs. There are four rubrics; the engineering journal rubric, the internal design review rubric, the external design review rubric, and the rubric for the presentation.

The first rubric used is for the engineering journal that is used during the whole term. It is an organizational method that is highly recommended for students. It consists of a folder for each student which contains the students' work, plans, assignments, handouts, and daily notes for constructing the project. The rubric is based on the checklist points. It consists of five points and at each point there are sub-points. First, the journal is graded according to its completeness and organization; all the handouts included syllabus and sheets, homeworks and quizzes, independent notes of daily notes, and group meeting notes. In addition to all the documents that should be organized by dates. Second, points should be deducted for the journals that are damaged, poorly kept, or lost. Third, journals should be ready any time when requested. Fourth, assignments and quizzes that are graded should be kept in the journal. Finally, students' daily notes are evidence of students' work. Accordingly the students self - report that records their effective use of time, better planning, and teamwork should be kept in the journal. Students are provided the criteria for their engineering journals and the teachers assess students' journals according to the checklist by adding and subtracting points then calculating it by percentage.

The second rubric is for the internal design. It is an evaluation to help students to understand the expectations and the preparations needed for the internal design. It is categorized according to a four-point rating scale. It starts by A - Advanced (4), B - Proficient (3), C - Basic (2), and ends with D - Below Basic (1). The content of the internal design includes Problem understanding, Consensus, Timeliness, and Discussion. Each stage of the internal design differs in its percentage. The problem understanding is 40% used to assess the peers' discussions that indicate their familiarity with the problems and their understanding to it, and if the students' designs are oriented to solve the problem and how students show evidence of thought. The consensus is 20% is to assess the group in avoiding unnecessary attachments and are able to consensus. The timeliness is 10% is to assess students' sheets to be completed on time for design and group is present and ready to begin on time.

The third rubric is for the external design. As the internal design rubric, it is an evaluation tool that is used to guide students about the preparations needed for the external design. It is also categorized as the internal design according to the same four-point rating scale. However, the content differs than the internal design as well as its percentage. It includes; timeliness, presentation, project management, progress, and future plan. The timeliness is the first thing to assess in the external design. It is 10% and used to assess that the prototype is fully functional at the time of review and that group are ready to begin on time. The presentation which takes 15% is to assess the group if they are able to focus on the relevance of the robot design and that discussion is professional and proceeds efficiently. The project management (30%) used to see if the development of students' plans in designing the robots and their schedules for future development is practical and workable. The progress that takes 30% of the external design is to see the progression of the project, effective contribution of each member in the group, decision-making process, and the consideration given to all aspects of development. Finally, the future plans that are 15% is to assess the students' description about what aspects of design will be worked next, and their priority tasks to ensure the project will be completed on time.

Finally, the presentation rubric that is used in evaluating students according to their use of technology and the content analysis. As the internal and external design is categorized on the same four-point scales but differ in its content. The students are assessed on their use of technology if the presentation is eye appealing, has clear pictures, organized, complete, and if the speakers are clear and use proper terminology. The content analysis of presentation is evaluated according to its organization, description of the project, and enjoyable to the eyes.

Appendix 4: Rubrics Assessments of The ROBOTCS

Rubrics for Robotics Explorations Assessment

	(4) Advanced - A	(3) Proficient - B	(2) Basic - C	(1) Below Basic - D or E
Build/ Program Test Robot	• Robot is built accurately with no mistakes • Robot is programmed accurately with no errors	• Robot is built with few mistakes • Robot is programmed with few errors	• Robot is built with some mistakes • Robot is programmed with some errors	• Robot is built with some mistakes • Robot is programmed with some errors • Robot is built with many mistakes • Robot is programmed with many errors
Data Analysis/ Scientific Method	• Make reasonable predictions based on prior knowledge • Correctly gather and record all data • Accurately construct a bar graph illustrating results	• Make predictions based on prior knowledge • Correctly gather and record most data • Construct a bar graph illustrating results with few errors	• Predictions are irrational and not based on prior knowledge • Correctly gather and record some data • Construct a bar graph illustrating results with some errors	• No predictions made • Data is not gathered or recorded correctly • Bar graph is inaccurate
Writing an Analytical Paragraph	Paragraph includes: • A topic statement accurately presenting information on probability. • A detailed explanation of how the results of the trial compare with probability calculations. • A concluding statement thoroughly summarizing results of the experiment.	Paragraph includes: • A topic statement accurately presenting information on probability. • An explanation of how the results of the trial compare with probability calculations. • A concluding statement summarizing results of the experiment.	Paragraph includes: • A topic statement presenting some information on probability. • Some explanation of how the results of the trial compare with probability calculations. • A concluding statement summarizing some results of the experiment.	Paragraph includes: • A topic statement that does not present information on probability. • Little explanation of how the results of the trial compare with probability calculations. • A concluding statement that does not summarize results of the experiment.

Rubrics for Engineering Journal Assessment

The Engineering Journal

The Engineering Journal is a highly recommended organizational method for the instructor to keep track of each group's work throughout the multi-week project. It consists of a folder or binder for each individual in the class, which contains the entirety of that student's work for the project. Consolidating each student's work in a single place allows for easy collection of assignments, and gives students responsibility for keeping his or her own material organized.

This gives the instructor the option of collecting students' journals to grade when assignments are due (and even when they're not).

Each student's Engineering Journal contains:

- Class handouts
- Daily logs and notes
- All completed and returned assignments
- Final (turned-in) version of any individual assignments that are due

All material should be kept in chronological order

Alternatively, you may choose to have only one journal per group, or have every student keep a copy of both individual and group assignments. The Engineering Journal is your tool for efficient assessment – customize the requirements to fit the needs of your classroom.

Assessment

- The Journal itself should be graded based on completeness and organization
  - A complete journal should include:
    - All class handouts, including syllabus and assignment sheets
    - All teacher-assigned work (homework, quizzes, etc.)
    - Daily logs, one per day of independent work
    - All major project deliverables (proposal, etc. – group journal keeper only)
    - Group meeting notes (group journal keeper only)
  - All documents in the journal should be organized by date

- Students should be responsible for lost, damaged, or poorly kept Journals
  - Points should be deducted for journals that are:
    - Lost (no credit for assignments that are lost!)
    - Damaged or sloppy (unprofessional!)

- When requested, students should hand in their journals
  - This is the preferred method for collecting work on days assignments are due
    - Penalties apply for groups or individuals who are not prepared

- Journal contents should be graded and returned in the journal
  - Assignments should be graded according to their own rubrics
    - Quizzes and journal hand-ins can be done together for convenience

- Notes and logs are a student's evidence of work done on a daily basis
  - Self- and peer-reported student records are how work habits are tracked
    - Teamwork
    - Effective use of time
    - Good planning and preparation

Rubrics for External Design Review

	(4) Advanced - A	(3) Proficient - B	(2) Basic - C	(1) Below Basic - D or E
Timeliness (10%)	• Prototype is fully functional at the time of review • Group is present and ready to begin on time	• Prototype is semi-functional (has at least one working component) at the time of review • Group is present and ready to begin on time	• Prototype is together, but not functional at the time of review • Group is present but not ready to present	• Prototype is not built or functional at time of review • Not all group members are present, and group is not ready
Presentation (15%)	• Discussion remains professional in tone and direction • Discussion proceeds efficiently due to understanding and articulation of the groups ideas and design • Group is able to focus on relevant aspects of the robot design	• Discussion remains professional in tone and direction • For the most part discussion proceeds efficiently • Group may not focus on relevant aspects of design, but does articulate important issues	• Discussion does not have a professional tone or manner • Discussion does not stay on topic • Students may articulate some ideas of the project, but do not focus on main aspects of robot design	• Little discussion occurs during the presentation • Students show lack of understanding of group ideas and design of robot • Group does not focus discussion
Project Management (30%)	• Development is in line with timeline submitted with proposal • Group member roles and responsibilities are defined and adhered to • Schedule for future development is practical and workable	• Development is mostly in line with timeline submitted with proposal • Group members have roles and responsibilities which were mostly adhered to • Schedule for future development is present and likely practical and workable	• Group member do not abide by timeline that was submitted with proposal • Group members do not adhere to clearly defined set of roles and responsibilities • Future development is present but may not be in schedule or practical and workable	• Timeline is not submitted, or timeline is disregarded during development process • Group members do not clearly define roles • No schedule for future development is created

Rubrics for Internal Design Review

	(4) Advanced - A	(3) Proficient - B	(2) Basic - C	(1) Below Basic - D or E
Timeliness (10%)	• Design Candidate Sheets are completed on time for each design • Design Assessment Criteria sheet is completed on time • Group is present and ready to begin on time	• Design Candidate Sheets are complete but not on time • Design Assessment Criteria sheet is completed but not on time • Group is present and read to begin on time	• Most Design Candidate Sheets are complete • Design Assessment Criteria sheet is mostly complete • Group is present	• Design Candidate Sheets are not completed • Design Assessment Criteria sheet is not completed • Group is not present
Discussion (30%)	• Group follows good meeting and teamwork procedures • Discussion remains professional in tone and direction • Discussion proceeds efficiently • Group is able to focus on the relevant aspects of the robot designs	• Group follows decent meeting and teamwork procedures • Discussion remains professional in tone and direction • For the most part discussion proceeds efficiently • For the most part group focuses on relevant aspect of robot designs	• Group follows few meeting and teamwork procedures • Discussion does not have a professional tone or manner • Discussion does not proceed efficiently • Group rarely focuses on relevant aspects of robot design	• Group does not work as a team • Little discussion occurs • Discussion does not stay on topic • Group does not focus on relevant aspects of robot design

Rubrics for Presentations

	(4) Advanced - A	(3) Proficient - B	(2) Basic - C	(1) Below Basic - D or E
Use of Multimedia Technology	**Excellent use of multimedia technology.** • The presentation was eye appealing. • The pictures were clear. • The sequence of the presentation was well thought out. • Presentation was organized, • Speakers were clear and used proper terminology. • Complete	**Student demonstrated they knew how to use multimedia technology.** • The presentation was eye appealing. • The pictures were clear. • The sequence of the presentation was well thought out. • Complete	**Multimedia technology use needs work.** • The use of multimedia technology was a distraction rather than help. • Incomplete	**Multimedia technology didn't support topic.** • Pictures were not clear and didn't seem to have a purpose. • Incomplete
Content Analysis	**Content was excellent.** • Presentation was organized. • Project was fully described. • I learned something when I listened to the presentation. • Presentation enjoyable to watch.	**Content was good.** • Presentation was organized. • Presentation was organized but needed more practice to be excellent.	**Content of presentation lacked clarity.** • Presentation lacked organization and didn't have a unified theme. • Presenters didn't use proper terminology.	**Content of presentation lacked clarity.** • Presentation lacked organization and didn't have a unified theme. • Presenters didn't use proper terminology.

Appendix 5: Teachers' responses on their classroom practices.

Critical Thinking	Mean	SD
m. Compare information from different sources before completing a task or assignment.	4.06	0.715
n. Draw their own conclusions based on analysis of numbers, facts, or relevant information?	3.81	0.39
o. Summarize or create their own interpretation of what they have read or been taught?	3.62	0.484
p. Analyze competing arguments, perspectives or solutions to a problem?	3.5	1.369
q. Develop a persuasive argument based on supporting evidence or reasoning?	2.87	0.78
r. Try to solve complex problems or answer questions that have no single correct solution or answer?	3.56	0.496
Collaboration		
m. Work in pairs or small groups to complete a task together?	4.56	0.508
n. Work with other students to set goals and create a plan for their team?	4.37	0.484
o. Create joint products using contributions from each student?	3.75	0.75
p. Present their group work to the class, teacher, or others?	4.37	0.484
q. Work as a team to incorporate feedback on group tasks or products?	4.37	0.484
r. Give feedback to peers or assess other students' work?	4.62	0.484
Communication		
k. Data structure for use in written products or oral presentations (e.g., creating charts, tables or graphs)?	4.37	0.484
l. Convey their ideas using media other than a written paper (e.g., posters, video, blogs, etc.)?	4.37	0.484
m. Prepare and deliver an oral presentation to the teacher or others?	3.75	0.75
n. Answer questions in front of an audience?	4.37	0.484
o. Decide how they will present their work or demonstrate their learning?	4.37	0.484
Creativity and innovation		
f. Use idea creation techniques such as brainstorming or concept mapping?	4.43	0.718
g. Generate their own ideas about how to confront a problem or question?	3.81	0.949
h. Test out different ideas and work to improve them?	3.25	0.75
i. Invent a solution to a complex, open-ended question or problem?	3	0.612
j. Creates an original product or performance to express their ideas?	2.37	0.484
Self-direction		
o. Take initiative when confronted with a difficult problem or question?	3.31	0.691
p. Choose their own topics or learning or questions to pursue?	2	0.866

q. Plan the steps they will take to accomplish a complex task?	1.93	0.658
r. Choose for themselves what examples to study or resources to use?	2.37	1.111
s. Monitor their own progress towards completion of a complex task and modify their work accordingly?	2.43	0.998
t. Use specific criteria to assess the quality of their work before it is completed?	3.06	0.658
u. Use peer, teacher or expert feedback to revise their work?	1.5	0.5
Interdisciplinary STEM		
k. The PBL strategy is helpful to analyze and handling of the STEM problems?	3.18	0.806
l. In solving problems, I facilitate the use knowledge from different disciplines?	3.43	0.704
m. Plan the steps they will take to integrate knowledge to accomplish a complex task?	3.37	0.695
n. Choose for them what disciplines to use in solving real life problems?	3.5	0.707
o. Guide them to integrate, classify, and keep track of knowledge they obtained?	3	0.612
Connection		
k. Investigate topics or issues that are relevant to their family or community?	1.62	0.505
l. Apply what they are learning to local situations, issues or problems?	2.12	0.695
m. Talk to one or more members of the community about a class project or activity?	2.5	0.707
n. Analyze how different stakeholder groups or community members view an issue?	2.31	0.681
o. Respond to a question or task in a way that weighs the concerns of different community members or groups?	1.31	0.463
Using Technolog		
q. Use technology or the internet for self-instruction (e.g., videos, tutorials, self-instructional websites, etc.)?	4.68	0.463
r. Select appropriate technology tools or resources for completing a task?	4.56	0.704
s. Evaluate the credibility and relevance of online resources?	4.18	0.881
t. Use technology to analyze information (e.g., databases, spreadsheets, graphic programs, etc.)?	4.5	0.5
u. Use technology to help them share information (e.g., multi-media presentations using sounds or video, presentation software, blogs, podcasts, etc.)?	4.68	0.463
v. Use technology to support team work or collaboration (e.g., shared workspaces, email exchanges, giving and receiving feedback, etc.)?	4.68	0.463
w. Use technology to interact directly with experts or members of local/global communities?	4.5	0.5
x. Use technology to keep track of their work on extended tasks or assignments?	4.5	0.5

Appendix (6): The frequency of teachers' responses.

Critical Thinking	Frequency (%)
d. Develop students' critical thinking skills. e. Students have learned critical thinking skills. f. Assess students' critical thinking skills.	All of the teachers agreed that they tried to develop students' critical thinking skills; they have learned the skills and assess them.
Collaborative skills	**Frequency (%)**
g. Develop students' collaborative skills. h. Students have learned collaborative skills. i. Assess students' collaborative skills.	All of the teachers agreed that they tried to develop students' collaboration skills; they have learned the skills and have been assessed.
Communication Skills	**Frequency (%)**
a. Develop students' communication skills. b. Students have learned communication skills. c. Assess students' communication skills.	All of the teachers agreed that they tried to develop students' communication skills; they have learned the skills and have been assessed.
Creativity Skills	**Frequency (%)**
d. Develop students' creativity skills. e. Students have learned creativity skills.	All of the teachers agreed that they tried to develop students' creativity skills and they have learned the skills.
f. Assess students' creative skills.	45% of teachers were able to assess students' creativity.
Self-direction Skills	**Frequency (%)**
d. Develop students' self-direction skills.	45% agreed
e. Students have learned self-direction skills.	40% agreed
f. Assess students' self-direction skills.	45% agreed
STEM Skills	**Frequency (%)**
d. Develop students' STEM skills.	40% agreed&60% strongly agreed
e. Students have learned STEM skills.	25% agreed&75% strongly agreed
f. Assess students' STEM skills.	25% agreed& 75% strongly agreed
Connection Skills	**Frequency (%)**
d. Develop students' connection skills.	20% disagreed 20% agreed
e. Students have learned connection skills.	20% disagreed 60% agreed
f. Assess students' connection skills.	60% disagreed 40% agreed
Technology Skills	**Frequency (%)**
d. Develop students' Technology skills.	30% agreed, 70% strongly agreed
e. Students have learned Technology skills.	25% agreed, 75% strongly agreed
f. Assess students' Technology skills.	25% agreed, 75% strongly agreed

Appendix 7: Students' responses on their classroom experiences.

Interests in Technology	Mean	SD
I enjoy technology class	4.5	0.5
I like to find answers to questions by doing experiments	4.6	0.48
I get to do experiments in my technology class	4.4	0.5
Being a technologist would be exciting	4.9	0.5
The technology is difficult for me	1.9	0.75
I like to use the technology book to learn technology	2.3	0.65
Technology is useful in everyday life	4	0.31
Technologists help make our lives better	4.9	3.92
I want to take more technology classes	5	0
I like to use computers to learn about technology	5	0
I like to work in a small group in technology class	5	0
Interests in Engineering	Mean	SD
I enjoy engineering class	4.6	0.47
I like to find answers to questions by doing experiments	4.6	0.47
I get to do experiments in my engineering class	4.8	0.37
Being an engineer would be exciting	4.9	0.29
Engineering is difficult for me	2.7	0.76
I like to use the engineering book to learn engineering	2	0.31
Engineering is useful in everyday life	4	0.31
Engineers help make our lives better	4.9	0.23
I want to take more engineering classes	4.6	0.47
I like to use computers to learn about engineering	4.7	0.41
I like to work in a small group in engineering classes	5	0

Interests in Mathematics	Mean	SD
I enjoy mathematics class	2.1	1.26
I like to find answers to questions by doing experiments	3.6	0.47
I get to do experiments in my math class	2.75	0.72
Being a mathematician would be exciting	1.3	0.46
Math is difficult for me	4	1.11
I like to use the math book to learn math	4.8	0.59
Math is useful in everyday life	2.7	0.6
Math help make our lives better	0.8	2.16
I want to take more math classes	2.3	1.17
I like to use computers to learn about math	3.6	0.47
I like to work in a small group in math classes	5	0

Interests in Science	Mean	SD
I enjoy science class	4.5	0.5
I like to find answers to questions by doing experiments	4.8	0.37
I get to do experiments in my science class	5	0
Being a scientist would be exciting	4.6	0.47
Science is difficult for me	2.25	0.68
I like to use the science book to learn science	3.6	0.47
Science is useful in everyday life	4.6	0.59
Science help make our lives better	4.6	0.59
I want to take more science classes	4.7	0.44
I like to use computers to learn about science	4.9	0.19
I like to work in a small group in science classes	5	0