Exploration of STEM Reforms for Developing an Effective Large-scale, Research-based Policy in the UAE

استطلاع إصلاحات STEM

(العلوم والتكنولوجيا والهندسة والرياضيات) لتطوير سياسة فاعلة ذات نطاق واسع ترتكز على الدراسات البحثية في دولة الإمارات العربية المتحدة

by

ELAINE AL QURAAN

A thesis submitted in fulfilment

of the requirements for the degree of

DOCTOR OF PHILOSOPHY IN EDUCATION

at

The British University in Dubai

Professor Sufian A. Forawi

November 2017

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ELAINE AL QURAAN

ABSTRACT

Background: Mathematics, science, engineering, and technology are subjects believed to reflect people's cultural achievements that power the economy and development, and at the same time constitute essential aspects of the lives. Educators admit that it is vitally important that integrated STEM education in K-12 schools aligns with 21st century skills, creates new jobs, increases competition in the global economy, and educates the next generation of STEM professional. The implementation of STEM is at its early stage in UAE and calls for an integrated framework for effective implementation in K-12 education.

Purpose: The purpose of this study was to develop a policy and implementation framework in the UAE by identifying critical elements of an integrated STEM education and key factors related to the implementation of an integrated STEM curriculum in K-12 schools in UAE.

Methods: The researcher employed Exploratory Sequential Mixed Methods for this study. The mixed research methods included both qualitative and quantitative methods. These include document analysis, teacher questionnaire survey, teacher and coordinators' interview surveys, school and district leaders' interview survey, and classroom observations.

Results: The findings of this study proposed the policy recommendation framework for integrated STEM implementation in UAE schools. It can be concluded from the findings that STEM implementation can be categorized into structural and interpersonal implementation dimensions. In addition, Assessment, Connection, Curriculum and Delivery, Leadership, Pedagogical Content Knowledge, Technology and Resources are important factors associated with STEM integration and implementation in UAE schools. The findings also suggested that curriculum, pedagogy, leadership, professional development, and assessment are important elements associated with STEM integration and implementation in UAE schools. The study proposed policy recommendation based on policy planning, leadership, establishing STEM, professional development of teachers, communities and businesses' role, technology and resources, curriculum design and assessments, pedagogy and learning, capacity building and motivation, awareness and promotion, society's adaptations, and exposure and employment.

Implications/Contributions: It was evident that teachers and school leaders are facing many challenges as they struggled to figure out the best ways to plan and implement STEM in UAE. The isolation that they faced as pioneers in implementing these kinds of courses in K-12 education was also evident. Examining of an integrated policy recommendation for STEM framework could help all educational leaders to understand this phenomenon better.

Keywords: STEM, UAE Education, Integration, Implementation, K-12 Education

الخلاصة

خلفية الدراسة: إن مواد التدريس كالعلوم والتكنولوجيا والهندسة والرياضيات (العلوم المتكاملة) يُنظرُ لها كمواد تعكس الإنجازات الثقافية التي من شأنها تقوية الاقتصاد والتنمية وهي نفس الوقت تشكل المظاهر الاساسية لحياة الناس. ويعترف العاملون في مجال التعليم أنه من المهم جدا أن يتوافق نظام العلوم المتكاملة المطبق في المدارس من مرحلة الروضة حتى مرحلة الصف الثاني عشر مع مهارات القرن الثاني والعشرين وكذلك يوفر فرص عمل جديدة ويزيد المنافسة في الاقتصاد العالمي ويرفد الجيل القادم من المهنيين المتخصصين علميا وعمليا. وفي الواقع إن تطبيق نظام العلوم المتكاملة مازال في مراحله الأولى في دولة الامارات العربية المتحدة ويدعو لبناء إطار معرفي يتم تطبيقه بشكل فعال في نظام التعليم من مرحلة الروضة حتى مرحلة الثاني عشر

غرض الدراسة: إن الغرض من هذه الدراسة هو تطوير سياسة وتنفيذ إطار معرفي في دولة الامارات العربية المتحدة من خلال تحديد العناصر الهامة الحاسمة لنظام تعليم العلوم المتكاملة وكذلك تحديد العوامل الرئيسة المتعلقة بتطبيق هذا النظام.

منهج الدراسة: قام الباحث بتوظيف وتطبيق أساليب بحث استكشافية متتابعة متنوعة. وتتضمن هذه الأساليب البحثية كلا الأسلوبين الكمي والنوعي وهي كالآتي: تحليل الوثائق و استبانة للمعلمين ومسوحات مقابلات مع معلمين معلمات ومنسقي ومنسقات مواد تدريسية وكذلك تطبيق مسوحات مقابلات مع مدراء المدارس والمناطق التعليمية وأخيرا مشاهدات صفية.

نتائج الدراسة: إن نتائج هذه الدراسة تقترح سياسة تطبيق موصى بها لإطار نظام العلوم المتكاملة لتطبيقه فعليا في مدارس دولة الإمارات العربية المتحدة. ويمكن الاستنتاج ووفقا للنتائج أن لعملية تطبيق نظام تعليم العلوم المتكاملة بُعدين هما البعد البنائي وبعد العلاقات الشخصية التفاعلية. وبالإضافة الى ذلك فهناك عوامل هامة ترتبط بتنفيذ نظام تعليم العلوم التكاملية في مدارس دولة الامارات العربية المتحدة وهي القياس والتقويم، الترابط والمنهاج الدراسي ،كيفية نقل التعلم للمتعلم ، نمط القيادة التربوية ،المعرفة بالمحتوى والأساليب التربوية ، استخدام التقنية وأخيرا المصادر التعليمية. وكذلك فالنتائج توصي بسياسة للتنفيذ معتمدة على التخطيط ضمن سياسة واضحة وعلى نمط قيادة جيد وعلى تأسيس لنظام العلوم التكاملية وكذلك على التنمية المهنية للمعلمين والمعلمات وكذلك على دور المجتمع والأعمال وعلى التقنية والمصادر وتصميم المناهج ونظام التقييم والامتحانات وعلى التعلم وأساليب التعليم وعلى بناء الكفاءة وأيضا تعتمد على التحفيز والوعي والترويج للنظام وكذلك على مدى تكيف المجتمع مع هذا النظام التعليمي والتعرض المباشر له وممارسته وأخيرا عملية التوظيف.

استنتاجات ومساهمات الدراسة: من الواضح وبعد إجراء هذه الدراسة أن المعلمين والمعلمات والقيادات المدرسية يواجهون تحديات كبيرة حيث أنهم يشقون طريقهم بصعوبة لفهم الطرق الأنجح والأفضل للتخطيط وتطبيق نظام تعليم العلوم المتكاملة في دولة الإمارات العربية المتحدة. ومن الواضح كذلك الانعزالية التي يواجهونها رغم أنه يُعتبروا الآن الرواد لتنفيذ وتطبيق هذه الأنواع من المساقات في النظام التعليمي من مرحلة الروضة الى المرحلة الثانوية.

إن القيام بعملية اختبار وفحص دقيق لسياسة تنفيذ متكاملة وموصى بها لإطار العلوم المتكاملة من شانه مساعدة القيادات التربوية على فهم هذه الظاهرة بشكل أفضل.

الكلمات المفتاحية: العلوم والتكنولوجيا والهندسة والرياضيات (العلوم المتكاملة)، نظام التعليم في دولة الامارات العربية المتحدة، التكامل، التطبيق والتنفيذ، التعليم من مرحلة الروضة حتى مرحلة الصف الثاني عشر.

DEDICATION

I dedicate this thesis to my family, as an appreciation to their constant love and support.

ACKNOWLEDGMENTS

First, I am deeply thankful to Allah for giving me the strength and patience all the way through my educational journey. In addition, I wish to express my gratitude to my Director of Studies, Prof. Sufian Forawi for his tremendous support and brilliant encouragement. Your advice on both research and career have been priceless. It was a great honour to finish this thesis under your supervision.

I wish to acknowledge the amazing support received from my parents, my husband, and my children. The faith you put on me and the undoubted sacrifices you made on my behalf have lit my way throughout this difficult course of my life, I cannot thank you enough for the extraordinary care and guidance. I owe you the greatest degree of gratitude.
To my family and friends, your inspiration and motivational words have carried me throughout this process.

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CHAPTER 1

INTRODUCTION

Science, Technology, Engineering, and Mathematics (STEM) education has become the topic of much debate in educational settings over the past several decades (Herschbach, 2011). Significant amounts of money and resources have been allocated to advance STEM education in various settings. The study of these subjects combined as STEM education occupies the forefront of investigation for many educators, researchers, and decision makers (Belland, Walker, & Kim, 2017 ; Gehrke & Kezar, 2017; Allaire, 2017; Green & Sanderson, 2017; Harris, 2017; Davis & Mason, 2017; Glaze, 2017).

STEM education is under focus of educational reform movements today and is funded extensively at both state and national levels; for instance, in the US (Gonzalez & Kuenzi, 2012). However, there appear to be few standards in place to judge what quality STEM education should look like (Wang, Moore, Roehrig, & Park, 2011). The lack of research evidence to support STEM education policy for its integration and implementation is evident across the literature, and researchers are struggling to provide this evidence quickly in order to justify programs and spending at K-12 levels.

Due to the continuing interest of the STEM topic, numerous in-depth studies have been conducted about different aspects of STEM education. Several papers discussed the essence of STEM education and STEM literacy (Bellard, Walker, & Kim, 2017; Gehrke & Kezar, 2017; Reeve, 2014; Stevenson, 2014; Vasquez, 2014; Zollman, 2012). Other studies have addressed students' perceptions toward integrated STEM (e.g. Faber et al., 2013; Allaire, 2017; Green & Sanderson, 2017; Harris, 2017). In addition, Berlin and White (2012), Koehler et al. (2013), Gouia-Zarrad and Gunn (2017), Hamilton et al. (2017), and Murphy and Mancini-Samuelson

(2012) studied in-service and teachers' preparation for and attitudes toward STEM education. Other authors, such as Ernst and Glennie (2015), Bahrum, Wahid, and Ibrahim (2017), and Stohlmann, Moore, and Roehrig (2012), discussed STEM curriculum and the integration of STEM disciplines. Bybee's (2013) book addresses, in detail, challenges and opportunities in STEM education. As with any educational orientation, there are important reasons for the abundant local and international scientific publications on STEM education. Sanders (2009) described some of the reasons behind the American and international focus on STEM or "STEMmania": "a) Sputnik, the first successful Soviet Union space satellite launched in 1957. This event shocked the American nation and inspired the government to look for solutions to compete with the Soviet's advancements in science; b) The failing of students' test results compared with Asian competitors; c) The published reports and books, such as A Nation at Risk: The Imperative for Educational Reform by Gardner et al. (1983), The Shame of American Education by Skinner (1984), Rising Above the Gathering Storm (National Academy of Sciences 2011), and The World is Flat by Friedman (2007), that condemned the American educational system; and d) Former President Barack Obama's Educate to Innovate campaign speech in 2009 and his commitment to make STEM education a national priority to strengthen America's role as the scientific, technological, engineering and mathematical engine of the world" (White house 2009, para. 4).

All these reasons contributed to international attention recently given to STEM education, which is becoming a major catalyst of educational reform in United Arab Emirates (UAE). In 2012, the Arab Robotics Association conducted the first scientific conference focusing on STEM in Amman, Jordan (Al-Muhaisin & Khaja, 2015). Many papers were presented that stressed the importance of learning integrated STEM in a logical timeline. Also, the presenters discussed how STEM subjects are interdependent and related to students' real-life experiences. Moreover, some papers at the conference focused on the role of schools, teachers, students, and decision makers in developing and growing integrated STEM education. In Saudi Arabia for instance, educational initiatives are aligned with these international and domestic orientations toward integrated STEM education in schools. The Saudi National Strategy for Public Education Development Project aims to develop "curriculum, instructional methods, and the assessment process to improve pedagogy" (Al-Muhaisin & Khaja 2015, p.6). There are many ways to reach such goals, one of which is to integrate STEM disciplines in education and by relating curricula to 21st century skills (Saudi Ministry of Education, 2010).

In 2014, the United Arab Emirates through the Institute of Applied Technology hosted the fifth International Annual Teaching Technology (IAT TEC) conference. International initiatives to teach STEM disciplines were discussed, and new patterns and technology solutions to teach STEM were represented. These solutions have been described as easing and encouraging the educational processes to motivate students to choose STEM careers in the future as their professional path (Al-Muhaisin & Khaja, 2015). It is from such forum that many ideas to build STEM capacity and develop programs in the Middle East are discussed and shared.

To complement the UAE government's Vision 2021, the UAE Ministry of Education implemented the educational development programme for mathematics and science as part of improving integrated STEM education (Bahrum, Wahid, & Ibrahim, 2017; Warner & Burton, 2017). The new initiatives were taken to support scientific literacy and to develop math and science curricula. The new curricula are based on McGraw Hill Education's textbooks which were translated and adapted to the Arabic language and culture (Sahoo, 2016). "The UAE Ministry of Education has signed a seven-year deal with the American company McGraw-Hill Education to procure all K-12 maths and science instructional materials in e-book and print formats" (Sahoo 2016, p.1). This initiative has resulted in several movements toward applying

STEM education in UAE. All integrated STEM education initiatives in UAE are so far "exclusive to private educational institutions and have not yet reached public education and government schools" (Sahoo 2016, p.1). The government is however taking logical steps to expand integrated STEM education to public schools, entailing changes that would affect teachers, students, administrators, and curricula in UAE. In UAE, "teachers are qualified to teach their specialty area in K-12 schools after having at least either a) a bachelor's degree in a specific field and education or b) a bachelor's degree in a specific field and a one-year diploma in educational psychology, learning theories, and teaching methods or pedagogies" (Sahoo 2016, p. 1). Likewise, "UAE mathematics teachers are not automatically qualified to teach integrated STEM disciplines" (Sahoo 2016, p. 1), which aligns with Bennett and Ruchti's (2014) statement about teachers regarding content: "Many teachers are not content experts within each of these disciplines and bridging these individual fields can be a challenge" (Bennett & Ruchti 2014, p. 17). Since teachers and stakeholders are key players in the educational process, it is important to examine the perspective of teachers' and stakeholders' regarding STEM integration and implementation by discussing on points of STEM pedagogical content knowledge, thoughts, attitudes, needs, and obstacles that can challenge them to successfully implement integrated STEM education in their classrooms.

1.1 Context of the Research Study

Mathematics and science teachers at all levels of education have been issued a call for change in STEM education by the Obama administration through the Educate to Innovate initiative. In the report from the President's Council of Advisors on Science and Technology Policy (Prepare and Inspire: K-12 2010) four main priorities were identified: "a) ensuring a STEM-capable citizenry, b) building a STEM-proficient workforce, c) cultivating future STEM experts, and 4d closing the achievement and participation gap. In meeting this call, K -

12 schools are struggling with what is STEM education?" (Prepare and Inspire: K-12 2010, p.1). Similarly, higher education struggles with preparing future practitioners on how to teach STEM education. Society needs and demands more STEM career minded people (Carnevale, Smith & Strohl, 2010). STEM education is an important topic at all levels of education where virtually all involved parties are caught up in the movement. Many studies have suggested changes in the way schools teach science, technology, engineering, and mathematical concepts.

It has been noted by Peter Diamandis and others that we are living in exponential times (Diamandis 2010). By this statement, Diamandis implies that at no time in our past has information ever been generated at the pace of today. The video, *The Information Age – We Are Living in Exponential Times*, based on research concerning the progression of information technology states, "It is estimated that the amount of data created doubles every two years" (Diamandis 2010, p.2). "Some of the most in-demand jobs did not exist five years ago," (Diamandis 2010, p.3) and "What this means for education is that we are preparing students for jobs that do not exist yet, using technologies that have not been invented to solve problems that we don't even know are problems yet" (Fisch, McLeo & Brenman 2013, p.5). When looking at data from the U. S. Department of Labour, one can glean that upwards of 80% of jobs in the next decade will require a large degree of technical skills and most of the fastest growing occupations will require significant mathematical and/or science preparation (Fastest Growing Occupations, 2012). These occupations are in STEM fields. Some of these high demand occupations of STEM are: "Information security analysts, Operations research analysts, Statisticians, Biomedical engineers, Petroleum engineers, Computer systems analysts, Software developers, applications, Mathematicians, Software developers, Computer user support specialists, Web developers, Civil engineers, Biological science teachers, Environmental science and protection technicians, including health etc" (U.S. Bureau of Labour Statistics 2017, p.1).

Some STEM jobs will require as little as an associate's degree with the average educational attainment level being a bachelor's degree. By the year 2022, the United States Department of Labour projects that they would need 9,900 more petroleum engineers, 67,100 more architectural and engineering managers, 50,900 more computer and information systems managers, 2,900 more natural sciences managers, 200 more astronomers, 2,100 more physicists, 4,100 more computer and information research scientists, 6,100 more computer hardware engineers, 800 more mathematicians, 6,100 more aerospace engineers, 1,900 more nuclear engineers, 82,800 more software developers, 1, 500 chemical engineers, 20,900 more computer network architects and 5,000 more Engineering teachers (U.S. Bureau of Labour Statistics 2017). The Connecticut Department of Labour (2012) has predicted that 75% of the fastest growing careers in Connecticut will require knowledge in the STEM field. In fact, five of the occupations in the highest demand cluster for Connecticut include four occupations related directly to STEM degrees: Aerospace, Bioscience, Maritime, and Metal Manufacturing (The Connecticut Department of Labour, 2012).

Groups like the National Science Foundation (NSF) have been conducting research on alternate methods of teaching STEM content and looking at why some schools have better performance in STEM disciplines than others (NSF, 2016; James & Singer, 2016). Regardless of whether changes in how the STEM disciplines are currently taught occur or not, the fact remains that ultimately schools must produce students that can enter the workforce and face the challenges of rapidly changing information and technology (NSF 2016; James & Singer 2016). This context is equally true for both developing and developed countries and perfectly fit for United Arab Emirates (NSF 2016).

Another cause for changes in STEM education is the difference in the way today's students are motivated (Chittum et al. 2017). The millennial generation is different from any previous generation. Students leave STEM fields for a number of reasons with the leading attrition factors being lack of motivation, teaching techniques, study skills, rigid course sequencing, poor grades, uninspiring introductory courses, poor advising, and deficiencies in mathematics (Grimm 2005; Matthews 2012; Gilmer 2007; Hanover Research 2011; Lichtenstein et al. 2007; Chittum et al. 2017). A lack of student engagement in STEM activities results in lower motivation in STEM learning, lower academic achievement, and reduced efficacy in the use of metacognitive strategies (Chittum et al. 2017). This impacts the developmental processes of STEM identities, which relate to self-concept and self-efficacy, particularly for women and minorities. Ultimately, these factors influence students' interest in STEM activity and education and the decision whether or not to pursue post -secondary education STEM disciplines. According to Pink (2011), organisations need to focus on three things to improve motivation at work: autonomy, mastery, and purpose. Autonomy relates to when and how a task is performed, how a task is completed, and with whom a person works. Mastery allows people to become better at something that have relevance to them. Pink (2011) states that you need to assign tasks that allow employees to extend themselves without being overly difficult while "creating an environment where mastery is possible" (p.52). The author implies that work needs to fulfil a "person's natural desire to contribute to a cause greater and more enduring than themselves" (p.52). This means that the work needs to be relevant (Pink 2011). The employee that Pink is investigating relative to his theories of motivation will likely soon be an American school graduate and a member of the millennial generation. While it is recognised that schools are different from the workplace, Pink's theories on motivation have implications for schools. Students of today are a product of the information age and the exponential times that have resulted in them rapidly adapting to new technology. Nowadays, students are able to master technology far better than most of the previous generations (Cavanaugh, Giapponi & Golden 2016). However, as stated above, U.S. students' performance compared to their peers is not favourable. As a result, schools are looking for different ways to motivate students and using the technology that students use has become more common in instructional practice. Some schools are implementing Pink's notions related to motivation in staff development (Singh 2016). From this author's perspective as a veteran classroom teacher, students are not motivated by the same things and in the same way that students of the past were motivated. Ken O'Conner states that grades are not motivators of students and many of the ways we traditionally have attempted to motivate students do not work (O'Connor 2011). Such a conclusion presupposes that new ways of student motivation will need to be discovered. It is logical to turn to the work of Pink for guidance, in motivating students, since they will be filling the jobs on which Pink's research focuses.

Data related to STEM careers and jobs is the final area of consideration which the researcher will explore related to changes in STEM education. It can be shown that "the United States is not producing enough STEM graduates to fill the growing need for STEM related jobs. According to the U.S. Department of Commerce, in 2010, there were 7.6 million STEM workers in the United States representing approximately 5.5% of the workforce" (U.S. Department of Commerce 2012, p.1). In addition, "STEM occupations are projected to grow by 17% over the decade beginning in 2008, compared with about 9.8% growth for non-STEM occupations" (Langdon et al. 2011, p.61). The need for STEM jobs in world`s economy is widespread. Georgetown University's Centre on Education and the Workforce found that the cluster of STEM occupations is forecast to provide 2.8 million jobs through 2018 and is made up of "1.2 million new jobs and 1.6 million replacement openings" (Carnevale, Smith & Strohl 2010, p.5). In the Monthly Labour Review, it is stated that over the decade beginning in 2009 there would be a need to add one million more STEM professionals to the American workforce (Lacey & Wright 2009). In the report, *Rising above the gathering storm, revisited: Rapidly approaching category 5,* the National Academies *Gathering Storm* committee concluded that “innovation would be largely driven from advances in science and engineering and the future economy will be dependent upon new innovation to create jobs” (p.62). The report goes on to state that only 4% of the workforce is made up of scientists and engineers, but they will create 96% of future new jobs (Augustine et al. 2010). This means that STEM careers produce more jobs than other fields. These statistics show the demand for people that have STEM skills. It will fall to educational institutions of all levels to cultivate and develop students to fill these needed roles. STEM careers have one advantage however; STEM careers generally pay better than other jobs. In the article, *STEM: Good jobs now and for the future*, it states that “STEM workers command higher wages, earning 26 % more than their non-STEM counterparts” (Langdon et al. 2011, p.4). In fact, “STEM degree holders enjoy higher earnings regardless of whether they work in STEM or non-STEM occupations” (Langdon et al. 2011, p.4). Given the higher-paying nature and importance of STEM jobs to economic growth, the report argues that education is needed at all levels to target these individuals and provide opportunities to experience STEM. One of the proposed ways to address this challenge is through STEM education in K-12 schools.

The rapid change in information and technology, poor performance in math and science by students, different motivation of employees (and possibly students), and the shortage of students going into STEM jobs, are related to the STEM education movement as seen in current educational practice of UAE schools in K-12 education. UAE public and private schools have a desire to implement STEM curriculum in an effective manner and there is a push from many stakeholders to create and implement STEM curriculum (National Research Council, 2011). Some institutes like, Institute of Applied Technology, have campus-wide STEM initiatives and plans to address the shortage of students with STEM degrees and to fill STEM jobs in the future (Al-Muhaisin & Khaja, 2015). STEM education is seen as a way to address these problems in both public and private schools in UAE (Margheri 2016; Pasha-Zaidi & Afari, 2016) and, hence, this study is intended to address the gaps and the quality issues by understanding STEM advancement, mainly in areas such as stakeholders planning for interconnectedness between sectors and partnership with community and other sectors curriculum and level of integration, STEM job skills and competencies, teachers preparation and professional development, delivery, and workforce demands.

1.2 Statement of the Problem

The current situation is that STEM is taught as extra-curricular subject or after school activity or as a STEM club in most of the public and private schools. For instance, Sahin, Ayar, and Adiguzel (2014) completed a study in a charter school located in Southeast of US. The focused on STEM-associated activities that were as a result of after-school programs; they looked into the related outcomes on the learning of students. The research was founded on a case study that was qualitative to comprehend the opinions and views of the students pertinent to the respective activities and their learning trajectories (Sahin, Ayar, & Adiguzel, 2014). Informal and formal observations, field notes, and semi-structured interviews were utilized in gleaning information. The results depicted that the activities stressed on collaborative and open-ended scientific explorations on STEM fields and offered an arena through which the learners demonstrated their skills. The current position of STEM education in UAE schools is similar to the other developing countries and relies on the integration between Science and Mathematics. Some schools make alignment in the learning outcomes in the four disciplines and provide project-based learning once per term. Currently, STEM is not part of the assessment system, however, its science, technology, maths, and engineering concepts are used with success criteria to guide students while working mainly to assess three pillars which are 21st century competencies, design process, and project based learning.

Overall, the difficulty with answering the call for STEM education reform is that currently there is little consensus about what constitutes STEM education (Pitt, 2009). There is no concrete example of a practical STEM curriculum that had been implemented in public and private schools. There is a gap in knowledge between conceptualisations of what integrated STEM curriculum is in a public and private K-12 schools and what factors the implementation of STEM curriculum should contain (Margheri, 2016; Pasha-Zaidi & Afari, 2016). Using a mixed method research design, the current study sought to learn what experts identified as critical elements of successful integrated STEM curriculum development in the context of design-based education, project-based education, and subject integration in UAE schools.

While the optimal implementation of STEM in K-12 schools is the long-range goal, currently there is no literature and understanding of how STEM education is defined and how schools are currently implementing integrated STEM curricula. In fact, a single definition of STEM education might be inappropriate. Rather to achieve long-range success, "broad tactical definitions of STEM and STEM education might need to be constructed" (Ostler 2012, p.19). Ostler (2012) believes that, "If STEM education programs are to be successful, educators need to develop a long-range tactical understanding of STEM content and STEM education regardless of their own localised definition" (p.10)

Another theme that surfaced in the literature related to STEM education is the need for curricular support structures if a STEM curriculum is to function successfully in schools. Since the study focused on identifying critical elements of successful integrated STEM curriculum development, curricular support structures would likely need to be explored/identified as a part of the research.

As a result, to address these needs, the purpose of this study is to identify the international common models of effective instructional practices and policies of the STEM education. Second, the study identified what STEM teachers and stakeholders believe are the critical elements by which definitions of integrated STEM education are generated. Third, the study identified factors, based on expert opinion, that suggest how best to implement an integrated STEM curriculum in public and private high schools.

1.3 Significance of the Research Study

The study has the potential to change the direction of STEM education reforms in UAE by providing a focus on the integration aspect of the STEM disciplines. Many authors (Merrill 2009; Sanders, 2012) believe that STEM is more than each individual STEM discipline being taught one course at a time, and the study will at the very least provide talking points for future educational decisions related to STEM education. This researcher is interested in pursuing further research into STEM education after this study concludes, and it is believed that numerous follow-up studies can be conducted in the future related to current STEM programs based upon the findings from this study. STEM programs can be evaluated against the findings in this study to determine if necessary key components for integrated STEM education are present in current educational settings. This research will allow school leaders to decide where and how to best allocate resources to foster integrated STEM environments. Ultimately, it is hoped that the study will play a role in helping bring cohesion to the profession through the structured process of inquiry to determine the key points related to STEM education in UAE.

The findings of this study add to current literature pertaining to preparing teachers in UAE for STEM instruction and integration, which is valuable in the sense that STEM content will be increasingly used throughout the K-12 curriculum as USA begin to adopt and implement the Next Generation Science Standards (Achieve Inc., 2013). Embedded within the Next Generation Science Standards is an emphasis on building STEM knowledge and skills; thus, it becomes imperative to accommodate for this shift in content by taking steps to ensure that the teachers who are being prepared today are equipped to handle the rigors of STEM-based curricula of tomorrow. Yet, because STEM-based initiatives are so new, a lack of significant research on pre-service teacher STEM preparation exists. Thus, this study adds to the foundational platform for current and future research studies on teacher preparation for STEM integration.

1.4 Purpose and Questions of the Research Study

The purpose of this study was to develop a policy and implementation framework in the UAE by identifying critical elements of an integrated STEM education and key factors related to the implementation of an integrated STEM curriculum in K-12 schools in UAE. For the purposes of this study, a general definition of integrated STEM education includes "an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems" (Moore et al., 2014, p.38) –with the goal to be a more holistic approach engaging learners in a more meaningful and relevant context (Moore et al. 2014). *The Committee on Integrated STEM Education* (NAE & NRC, 2014) noted they were reluctant to provide a strict definition to not limit experimentation or creativity in a field still needing further research and practice. Wang et al. (2011) explained that integration can be thought of as a cross-disciplinary approach or sometimes referred to as an interdisciplinary approach. They maintained that "cross-disciplinary" and "interdisciplinary" are familiar educational terms that have been around for many years. Wang et al. (2011) suggested that this approach to teaching is applied to make subjects more relevant for students, as it would look in the "real world" and that rather than isolating subjects and fragmenting information, subjects are merged to make connections between the disciplines. According to Roehrig et al. (2012), many times interdisciplinary units begin with a problem or project where students must apply knowledge from several different disciplines to solve the problem. Thus, this technique presents many challenges to traditional or silo teaching approaches and can be a complex, and sometimes-problematic way to look at curricula (Roehrig et al., 2012).

Because of the nature of STEM education and its "newness" in UAE schools as a combined field, if it is asked from STEM practitioners it is likely that one will get a wide range of key components of an integrated STEM definition and factors that influence implementation of an integrated STEM curriculum. By analysing the collected data, the study results can be utilised, at least regionally, to begin conversations about if and what schools are currently doing is considered integrated STEM and how they can utilised in UAE context. By attempting to learn what resources, staffing, structure changes, etc. are necessary for a successful integrated STEM implementation, the study results can influence conversations about best practices in STEM education and whether STEM disciplines are integrated or not.

The research questions for this study were broad and open ended in nature to facilitate discussion and idea generation related to integrated STEM education in K-12 schools in UAE. The goal of this study was to describe the category of integrated STEM education and to develop integrated STEM education themes related to international common models of effective instructional practices and policies of the STEM education and "expert" practitioner's experiences. These themes were used to identify what STEM experts believe to be the critical elements by which definitions of integrated STEM education are generated and to identify critical factors that suggest how best to implement an integrated STEM curriculum in public and private high schools. Below are three broader questions that were addressed through the mixed research process.

RQ1: What are the international common models of effective instructional practices and policies of the STEM education?

RQ2: What are the factors associated with STEM integration and implementation in UAE schools?

RQ3: In the light of the proposed policy, what are stakeholders' knowledge and perception about STEM future implementation?

1.5 Definition of Terms

The following definitions have been used throughout the study and are presented to the reader for clarification.

Integrated STEM education*:* "An approach that explores teaching and learning between two or more of the STEM subject areas and/or between a STEM subject and one or more other school subjects" (Sanders 2009, p.2).

Project-based learning: "A multidisciplinary approach combining design-oriented project-organised education and problem-oriented organised project-education" (Dym et al. 2005, p. 109).

Design-oriented project-organised education*:* "Deals with know how: the practical problems of constructing and designing on the basis of a synthesis of knowledge from many disciplines" (Dym et al. 2005, p. 109).

Problem-oriented project-organised education*:* "Deals with know why: the solution of theoretical problems through the use of any relevant knowledge, whatever discipline the knowledge derives from" (Dym et al. 2005, p. 109).

Design-based education*:* "Education in a full range of real-life activities and using a hands-on approach to teaching" (Kelley, 2012, p.4).

1.6 Overview of the Research Study

STEM education benefits UAE's teachers, students and schools in several ways. Not only does an education rich in science, technology, engineering, and mathematics better arm a student with vital concepts and skills that can be applied to a variety of educational areas, it also opens doors to good paying, increasingly abundant jobs. The study has the potential to change the direction of STEM education by providing a focus on the integration aspect of the STEM disciplines. Many authors (Merrill, 2009; Sanders, 2012) believe that STEM is more than each individual STEM discipline being taught one course at a time, and the study will at the very least provide talking points for future educational decisions related to STEM education. This researcher is interested in pursuing further research into STEM education after this study concludes, and it is believed that numerous follow-up studies can be conducted in the future related to current STEM programs based upon the findings from this qualitative research. STEM programs can be evaluated against the findings in this study to determine if necessary key components for integrated STEM education are present in current educational settings. This further research will allow school leaders to decide where and how to best allocate resources to foster integrated STEM environments. Ultimately, the study will play a role in helping bring cohesion to the profession through the structured process of inquiry to determine the key points related to STEM education in UAE.

STEM education is an important topic in today's educational discussions in UAE education. Whether considering rapidly changing technology, student performance, motivation, or economic reasons, there is a national need to develop more people interested in STEM in UAE who will pursue STEM fields. The ambiguous nature of STEM education in UAE as it stands today confounds the problems associated with fulfilling this need. Numerous definitions of STEM have been put forth by different practitioners and there is little consensus among STEM professional, educators, or policy makers about how to improve STEM education to address the outlined need for more STEM career professionals.

This study has addressed this problem by identifying critical elements of an integrated STEM education definition and key factors related to the implementation of an integrated STEM curriculum. This has been accomplished through a mixed research design. The following review of literature (Chapter 2) continues to point out the need for a study of this nature and discussed the literature review. Chapter 3 describes the study methodology in greater detail. Chapter 4 details the results of the study. Chapter 5 contains addresses discussion and conclusions related to the study.

CHAPTER 2

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

The purpose of this study was to develop a policy and implementation framework in the UAE by identifying critical elements of an integrated STEM education and by identifying key factors related to the implementation of an integrated STEM curriculum in K-12 schools in UAE. The previous chapter of the study presents the overview of the study. This chapter is divided into two parts, theoretical framework and the literature review. Theoretical framework part includes description and discussion of the major theories and models comprising the theoretical framework of the current study. It includes Integrative Theory for Drake and Burns (2004), Institutional Theory by DiMaggio and Powell's (1991), the Socioscientific Issues (SSI) Theory of Science Education by Zeidler et al. (2002), Vygtosky's Sociocultural/Social Development Theory (1962), the evidence-based management in the educational field, and finally Postmodernity and Global Economy Theory.

The literature review is associated with the pertinent research studies to the main constructs of the study. It includes presentation and discussion of the knowledge and implementation of STEM field was conducted prior for this research study. The review of literature provides insights about the previous studies related to the purpose, gaps in the line of the research, the significance of the study, methodology and research process, and specific major areas of research. First area includes the review that focused on the historical perspectives, characteristics, and aspects of research examining STEM education. The second area focuses on review of science education, knowledge-based economy in UAE, UAE education system and its reforms that encompasses the historical milestones, and program models and frameworks.

According to Abend (2008), the strategies that guide the development of an effective and appropriate theoretical framework demands that the researcher examines the title and research problem of the dissertation, brainstorms on the core variables, and followed by an extensive review of extant literature. Besides, the researcher is required to list the various variables and constructs and conduct a review of other theories. Additionally, it is noteworthy that the research discusses the propositions and assumptions of the respective theory and relates them to the current study (Abend, 2008). Basing the researcher's arguments on Abend's (2008) strategies, it is explicit that the theoretical framework does not necessarily link to the study questions and its respective justification. However, it is prudent to depict that the research should provide a leeway towards the development of a novel theoretical framework cognizant of the STEM education in the UAE.

2.1 Theoretical Framework

A review of previous research in STEM field demonstrates a diverse array of frameworks, models, and perspectives. To project our glance into the probable theories among varied possibilities, the following proposed theoretical framework will be adopted for this thesis, and would be further discussed in the light of this study. The theories discussed are the Integrative Theory from Drake and Burns (2004), Institutional Theory by DiMaggio and Powell's (1991), the Socioscientific Issues (SSI) Theory of Science Education by Zeidler et al. (2002), Vygtosky's Sociocultural/Social Development Theory (1962), the Evidence-Based Management in the Educational Field and Postmodernity and Global Economy Theory.

STEM policy is an essential component in the current education system in the UAE. As such, it is important to devise a theoretical framework, which delves into the current reviews of literatures to showcase how the STEM policy can be effectively integrated in the study institutions. Effective formulation of an appropriate theoretical framework demands that the relevant theories should be explicated and linked together to exhibit how the topic under investigation is studied and aligned to the UAE context. To develop a large scale research-based STEM policy and implementation framework in line with the UAE, several theories should be elucidated and interlinked to provide a guideline for the study. Indicatively, the integration theory proposed by Drake and Burns (2004) is selected because of its focus on curriculum assimilation. Provided that the researcher had an interest in the education system and, in particular the STEM policy, it is crucial to justify the incorporation of this theory. Indeed, the conceptions of multidisciplinary, trans-disciplinary, and interdisciplinary link with the scope of STEM policy, which seeks to provide relevant knowledge and skills with regard to science, technology, engineering, and maths.

Linking integration and institutional theories demand an in-depth look into the context in which the STEM policy is implemented. According to Whittaker and Montgomery (2014), institutional theory calls for transformation of three levels of the education system including the faculty, students, and the institution. In so doing, the changes will make it easier for the proponents of the integrative theory to implement the STEM policy framework. With regard to the socio scientific issues theory, Leshner (2015) ascertains that an option to a smooth implementation of the STEM framework is to provide genuine and respectful dialogues between the scientists, in this case, the policymakers, and the society. Zeidler et al. (2015) depict this notion in the aspect of a science education movement termed as Science, Education, and Society where the respective shareholders engage in dialogues regarding science and its effects on the society and how the society will impact science. Notably, these theories link with each other in an attempt to align the STEM policy framework and its implementation in the UAE context.

Further, the evidence-based management theory postulated in the 1990s advocates for decisions that are articulated with the evidence collected with regard to the context (UAE), shareholders, and the broader aspect of ethical considerations. As depicted from the earlier paragraphs, it is clear that the integration, institutional, and socio scientific issues theories should be backed with actual information to bolster the establishment of a functional STEM policy framework for the UAE. The evidence-based management theory, in this regard, provides a comprehensive outlook of the education system and its organisation to bring about the required information for a smooth implementation of STEM. The researcher seeks to attain organisational objectives, ensure valid learning, and provide a continued improvement of the education system; elements that are evinced in the evidence-based management theory as connoted by Rousseau (2006).

According to the theory of sociocultural development hypothesised by Vygtosky (1962), knowledge construction is the core component to foster understanding, interpretation, and social interaction. Therefore, the relevant theories elucidated in the previous context align appropriately with the notion of understanding, interpreting, and interaction; for instance, the integration theory requires all these elements so that there is a sense of knowledge construction within the realm of the UAE education. Ideally, for effective implementation of STEM policy framework within the UAE context there is a need to incorporate the social constructs of learning. In essence, these concepts are indoctrinated through the incorporation of Vygtosky's sociocultural development theory.

For the purposes of the theory of post modernity and global economy, Anderson, Cissna and Arnett (1994) indicate that the diversity exhibited in an inclusive education system, for instance STEM demands for harmony among the learners. In fact, there should be no confusion among the learners; thence, the vitality of categorically delving deep into the policy framework before its implementation. Here, the researcher seeks to establish a consensus on STEM implantation, a notion that calls for an extensive theoretical framework, which encompasses varied theories that provide details about the innumerable aspects required. Contextually, the theoretical framework for the current study is expansive as it incorporates relevant theories that make it possible for the exploration of the study topic and implementation of the framework suggested.

Figure 1: Current Study's Integrated Framework for STEM Reform Policy in UAE

2.1.1 Integrative Theory

Integrative Theory or Curriculum Integration means many things to different people. Because of this, it is important to clearly define the term prior to beginning any study involving integration. To develop a definition that aligns most closely to the broad body of research in the field, the theoretical works of Beane (1997), Bybee (2013), Drake (2012; see also Drake & Burns 2004), Fogarty (2009), and Jacobs (1997; 2010) have been reviewed to determine the differences and commonalities amongst them. While not all components of the theorists' viewpoints align perfectly, for the purposes of this study, curriculum integration is defined, collectively, as an educational approach where students study an integrated or interdisciplinary theme or topic and its related issues in the context of multiple disciplines (Beane; Bybee; Drake; Fogarty; Jacobs). Additionally, Chernus and Fowler (2010) identified four key elements of curriculum integration that must also be present for a learning experience to be defined as truly interdisciplinary:

- Content for the learning experience must be derived from two or more disciplines.
- There must be a shared purpose for the learning experience from the disciplines involved.
- Well-defined objectives must be derived from the appropriate content standards.
- The learning experience must be grounded in a real-world context.

Beane's perspective would refute aspects of this combined definition because his work focuses on drawing the distinction between integrated curriculum and interdisciplinary curriculum.

The educational climate of leadership and growth in today's world is driven by standards and accountability (Drake & Burns 2004). Students are held accountable for more information, which they have to filter, process, and store. For students to meet with success in applying an enormous amount of information, they must be able to make connections (Drake & Burns 2004). Researchers and education reformers, including those involved in STEM education have suggested that one way to meet and satisfy the standards is through integration (Drake & Burns 2004; Humphrey 2003; Moonesar & Mourtada 2015). There are three different integrative approaches: multidisciplinary, transdisciplinary, and interdisciplinary. It suggests that an interdisciplinary approach to STEM education is an efficient and significant way to advance understanding and learning across subject areas.

Multidisciplinary integration, which focuses primarily on the disciplines, involves the organisation of curriculum and instruction from two or more disciplines around a particular theme (Drake & Burns 2004). There are many different ways to create a multidisciplinary curriculum. Researchers have suggested that instruction may be organised and taught from an issue common to the disciplines instead of from a disjointed perspective (Drake & Burns 2004). In education, multidisciplinary integration is often used by classroom teachers to team- teach. Education reformers and teachers are arguing for bringing together contributions and relationships from more than one discipline, and concur that a multidisciplinary approach provides learners with a better understanding of a topic, theme, or how to solve a problem (Moonesar & Mourtada 2015). For instance, the education shareholders in Poland have used educational robots to implement STEM education in the primary schools (Smyrnova-Trybulska, Morze, Kommers, Zuziak, & Gladun, 2016). In the study completed by Smyrnova-Trybulska et al. (2016), there is emphasis that students should be well-prepared with STEM-associated skills, particularly, in the elementary levels. Ideally, workshops utilising kits to establish and program robots have been evinced as a novel form of interdisciplinary education of youth and children. The researchers contend that robotic classes will impact the development of science-technical, social competence, and math literacy (Smyrnova-Trybulska et al., 2016).

Transdisciplinary integration involves "the organisation of curriculum and instruction around students' questioning, where concepts and skills are developed in real-life context" (Drake & Burns 2010, p.4). While multidisciplinary and interdisciplinary integration involves the merging of two or more disciplines to bring an understanding of a topic, an idea, or to solve a problem, transdisciplinary integration goes beyond discipline boundaries to support and enrich learning. Learning is not compartmentalised but rather explored within the content and context of the inquiry such that, unifying issues and topics are through discipline connections (Drake & Burns 2010). Thus, it is important to understand that how subjects are integrated makes the approaches differ. Transdisciplinary integration is presented in ways such as Understanding by Design, 21st Century Skills and Knowledge (ISTE standards, 2007), and project and problem-based learning. However, since the terms interdisciplinary and transdisciplinary mean interactive and holistic respectively, it is appropriate to denote that the approaches applied in transdisciplinary can as well be applicable to the notion of interdisciplinary (Elias, 2006).

2.1.2 Institutional Theory

Aligned with calls for a focus on institutional factors, recent efforts of STEM integration require transformation on the institutional level. Those transformations require transformation at three levels: student, faculty, and institution (Whittaker & Montgomery 2014). An example of the institutional model is depicted by Rawlings (2011) as a framework design to implement systemic changes in the undergraduate STEM learning and teaching to bolster change in STEM education. According to Rawlings (2011), the model demands for identification of core levels including agents, mechanisms, and structures to sustain it. In this context, the main structure is pedagogy, the varied practices implemented by faculty members to train students, support, and guide their learning. Further, it is notable that to institutionalise and successfully enact the usage of evidence-based training methodologies two more concepts are necessary including support or scaffolding for the students and faculty and cultural change to foster alteration of the learning practices (Rawlings, 2011).

Parsons and Priola (2013) cited Meyerson and Tompkins (2007) who, drawing on DiMaggio and Powell's (1991) terminology, describe "institutional entrepreneurs" as "those who can expose the contradictions between their identities, ideology and interests and the dominant logic of their organisations" (p. 582). In her proposed framework and methodology for designing more inclusive academic organisations, Sturm (2006) defines "organisational catalysts as individuals who operate at the convergence of different domains and levels of activity. [They act as information entrepreneurs leveraging] knowledge, ongoing strategic relationships, and accountability across systems. This role places individuals with knowledge, influence, and credibility in positions where they can mobilise institutional change". (p. 287)

Institutional change requires support from the entire department, school, and institution (Wieman et al. 2010). Effective methods of institutional change include the empowerment of STEM faculty and administrative decision makers, organisational structure changes, clear career progression paths, female faculty, policies that support work-life-family balance, consistent progress reports, and the establishment of clear indicators of success (Sidlauskiene & Butasova 2013).

Along with institutional characteristics, institutional change at the departmental level has been found to positively impact the climate in the school. Changes in institutional culture require attention to the inclusion and support of diverse faculty, and faculty development that focuses on diversity (Thomas, Bystydzienski & Desai 2014). McClelland and Holland (2014) completed a study that "You, Me, and Her," which delved into the perceptions of the leaders' responsibilities towards augmenting gender diversity in varied STEM departments. Semi-structured interviews were conducted among 31 STEM chairs of departments and deans of public universities. Both quantitative and qualitative techniques were used to examine the information. Through distinctions of either high or low responsibility, several themes were evaluated to determine qualitative features and their respective frequencies. The chairs that showcased high responsibility ascertained change in their institutions and named male colleagues as responsible for diversity. Nevertheless, those that exhibited low responsibility described female faculty to be responsible and characterised women's choices and attitudes as obstacles to fostering gender equity with regard to STEM. First, mentoring of historically marginalised faculty members is one way to include diverse faculty in the department culture and improve bias literacy among existing faculty (Monroe et al. 2008; Thomas et al., 2014).

Second, faculty development should be implemented and assessed as part of an institutional agenda that focuses on equity and diversity with an emphasis on systemic change (Whittaker & Montgomery 2014). One example of this change is bias literacy, or the ability to identify personal biases, and create a plan of action to reduce those biases for faculty and the institution (Carnes et al. 2012).

Instituting bias literacy programs at the college level has a positive impact on departmental equity, leading to an increased involvement in activities that promote gender equity (Carnes et al. 2012; Charleston et al. 2014). Finally, it is important that higher education institutions have policies in place that support female faculty and administrators (Minerick et al. 2009; Monroe et al. 2008). For example, Monroe et al. (2008) ascertain that overt favouritism has led to less obvious inequities, which are deeply entrenched. Despite the increased number of females in authority positions, discrimination has remained through devaluation of gender. Therefore, it is important to have policies in place that support alternative tenure tracks for faculty members who take time off to have a family (Monroe et al. 2008). These efforts are important for the student environment as well addressing the institution at each level will reduce the effects opportunity cost of new changes. The notion of diversity in the context of STEM requires that all people are included in the policy framework; is important that all the individuals with disabilities both male and female are incorporated into the suggested education framework to ensure achievement rights as denoted in the varied agreements and the UAE constitution. To attain this diversity, gender equality must be guaranteed; for instance, Smith, Handley, Zale, Rushing, and Potvin (2015) there is a need for heterogeneity in the higher education sector since majority of the ranks in almost all faculties across the world are men, particularly in STEM fields. In this regard, gender diversity should be stressed pertinent to STEM faculties to enhance innovations through acquisition of knowledge and skills on science education.

Gaad (2011) showcased the reforms instituted in the UAE education system including the need to develop a “School for All,” which was implemented in line with the UAE Federal Law, amended law and the UN Convention. According to Gaad (2011) the Federal law indicates the formal realisation of the various rights of the people with disabilities and gives an elaborate outline regulating the social, welfare, educational, health, economic, cultural, and professional services and rights. Notably, the inclusion of disabled individuals in formal education commenced in 1980s when the UAE Ministry of Education (MOE) showcased organised efforts towards including disabled learners. Ideally, the MOE conducted an in-depth survey that saw the need for augmented services with regard to the mainstream schools; here, the incidences of kids having special needs in the classroom, especially language and speech disorders as well as learning disabilities were detected (Gaad, 2011). Additionally, in search of diversity in the classroom, Gadd (2011) notes that the UAE ratified the CRPD to confirm its commitment towards the rights of the disabled persons. In perspective, the CRPD articulates that nations should implement the conception of diversity by granting the SEN students an opportunity to access inclusive and appropriate education.

According to Li, Ernst, and Williams (2015), STEM educators are focusing on the ways through which they can make the institutions inclusive for all the learners including those students having limited English proficiency and categorical disabilities. It is evidenced that low rates of graduation are witnessed among the SEN students; for instance, Li, Ernst, and Williams (2015) ascertain that not more than 9% of students in the undergraduate studies report majors in the engineering subject and that nearly 6% indicate either computer or science-related areas. Referencing the aspect of global development and discovery, efficiency of STEM education is a vital component cognizant of the welfare and wealth of individuals. STEM education allows learners to be equipped with real life experience, which prepares them in adapting to life and making informed decisions about work and life in line with augmented technology.

Nonetheless, many UAE students living with disabilities face systemic barriers towards engaging in STEM activities; hence, less likely to engage in STEM careers or majors (Li, Ernst, & Williams, 2015). Therefore, it is important to devise a STEM policy framework, which is inclusive because equitable access prospectively bolsters the underrepresented students to select STEM majors and then settle on STEM careers.

These institutional changes seek not only to improve the experiences, retention, and performance of teachers and administrators in STEM but also institutional equity. As a result, reaching critical mass, changing discourses, and revising policy also results in improved retention, performance, and comfort for students but does so by affecting change at the sources of inequity. Institutional changes within an organisation require that the practices are identified; identification precedes any recommendations for change that can improve equity through institutional transformation. To extend the research on the institutional changes found to affect the institutional STEM practices, this study also seeks to identify the institutional roots of challenges for teachers and leaders in order to make recommendations for institutional transformation.

2.1.3 Socio Scientific Issues (SSI)

Alan Leshner (2015), the former CEO of the American Association for the Advancement of Science, argued that the gap between the opinions of scientists and the general population regarding the policies about science-related issues cannot be closed simply by having a citizenry that trusts scientists or that understands science concepts. He contends that those things are “compromised whenever information confronts people’s personal, religious, or political views, and whenever scientific facts provoke fear or make people feel that they have no control over a situation. The only recourse is to have genuine, respectful dialogues with people” (p. 459). In education, spaces for such a dialogue have been recommended since the 1970s with the advent of a science education movement called Science, Technology, and Society (STS) (Zeidler et al. 2005). STS education provided opportunities for students to engage in dialogues about science and its impact on society as well as society's impact on science. From STS education another movement, referred to as Socioscientific Issues Science (SSI), emerged as a way to prepare future citizens to engage in conversations regarding policy decisions impacted by science and technology.

Socioscientific issues are open-ended, controversial issues informed by both science and societal factors such as politics, economics, and ethics, which are deliberated by both scientists and the general public (Kolsto 2001; Sadler 2004; Sadler 2011). When using socioscientific issues in the classrooms, the goal is to empower students "to consider how science-based issues reflect, in part, moral principles and elements of virtue that encompass their own lives, as well as the physical and social world around them" (Zeidler et al. 2005, p.44). Sadler, Barab, and Scott (2007) argued that, in order to fully engage with socioscientific issues, students should have opportunities to apply and practice reasoning skills, which include recognising complexity, multiple perspectives, ongoing inquiry, and scepticism.

Socioscientific issues are scientific issues that require public input, as opposed to those discussed only in the scientific community (Kolsto 2001). Sadler (2004) identifies socioscientific issues as those that have scientific and social factors at their core, and he argues that science and society are not separate matters. In fact, all science is tied to the society from which it originates, but the term *socioscientific issues* is used to describe those topics that "display a unique degree of societal interest, effect, and consequence" (p. 513). These issues are open-ended, controversial social issues that are informed by science but also impacted by politics, economics, and ethics (Sadler 2011). Examples of socioscientific issues are the human impact on "global warming, genetically modified foods, cloning, cell research, alternative fuels, and conservation efforts for endangered species" (Sadler 2011 p.10). For example, students learning about the carbon cycle can improve their content understanding by applying the information to a socioscientific unit regarding the impact humans have on global warming.

Socioscientific issues place special focus on the psychological and epistemological growth of students. In a foundational definition, Zeidler et al. (2002), defined Socioscientific issues as a movement that incorporated all the goals of STS education "while also considering the ethical dimensions of science, the moral reasoning of the child, and the emotional development of the student" (p. 344). Sadler and Zeidler (2005) later specified that while SSI focuses on the effect of science and technology on society, it does not consider the "moral and ethical implications that underlies these issues". In contrast, "the socioscientific issue movement arises from a conceptual framework that unifies the development of moral and epistemological orientations of students and considers the role of emotions and character as key components of science education" (p. 113). Pedretti and Nazir (2011) identify SSI as a *value-centred current* of STS that challenges the idea that science is value free. For example, the issue of fracking understood through a Science Technology and Society lens considers the science and technology of fracking and how it impacts people. But from a socioscientific issue perspective, all of those elements would be considered along with the ethical issues of engaging in fracking. Students would learn about and discuss the ethics of providing natural gas to heat homes against the negative impacts of fracking, such as the accidental release of natural gas into the atmosphere and the contamination of drinking water. Engaging in exercises that require students to consider the decision to conduct, fracking allows them to develop the skills needed to consider multi-faceted issues. Additionally, it involves them in opportunities for true agency to address those issues, and to understand that the choices regarding the use of science and technology are anything but value free.

It is most important to acknowledge that application of socioscientific issues and dialogue alone are not enough to establish a critical pedagogy. In order to make that connection, the curriculum must also require students and teachers to take action. Santos (2009) argues that a Freirean perspective must be applied in science education in order for both poor and rich students to engage in transformative practices that apply science and technology to equality and social justice.

The idea of adopting controversial topics such as integrated STEM in teaching has been recognised internationally (Trend 2009; Levinson 2006; Zeidler & Keefer 2003; Topçu et al. 2011; Lin et al. 2012; Liu et al. 2012; Liu 2011; Manzo 2001; Marlowe & Page 2005; Zeidler & Nichols 2009; Zeidler et al. 2009). Ideally, relevant models for pedagogy, which act as vehicles for science instruction, in general and contemporary issues, in particular, are not incorporated in science classrooms (Kelley & Knowles, 2016). The selection of opportunities that enhance students' skills of argumentation, recognition of scientific issues and evidence based decision making must necessarily be included and planned for carefully.

The new reformed curriculum proposed in Abu Dhabi likewise aims to invest in catalysing new channels of thinking into the fabric of the society in order to accelerate and sustain scientific progress in a competitive and viable globe (Moonesar & Mourtada 2015). Therefore, particular attention was given to consider the significance of SSIs in fostering scientific citizenship amongst youths in the Emirate of Abu Dhabi (Moonesar & Mourtada 2015). Therefore, the SSI seems to fit one of the lags of the conceptual framework of this study by contributing possible explanation and evaluation of those societal values and knowledge may be exhibited by participants from the science field or the other STEM fields as deemed connected.

2.2 Literature Review

This section provides a comprehensive definition of STEM, offer a discussion of a wealth of reasons to consider STEM in K-12. Additionally, it will address best practices in STEM initiative including program structure, curricula, implementation, professional development and sustainability and lastly will stipulate various STEM model programs that evidenced success and harnessed expertise.

According to Treffinger and Isaksen (2005) and Lai and Viering (2012), the teaching of the integrated subjects of Science, Technology, Engineering and Maths (STEM) has gained momentum in the last decades. An interdisciplinary technique, according to Khadri (2014), incorporates rigorous application of academic conceptions that are entwined with real-world lessons, which students apply in science, engineering, technology, and mathematics in line with community, school, work, and the globalised enterprises making STEM a core tool to compete in the transnational novel economy. The conception of STEM, likewise, strives to cultivate a STEM-proficient workforce. This is fundamentally crucial to examine the changes that have been brought about to motivate nationwide reforms. As a result of these features, generating a set of channels between science academia on one hand and business, government and civil society on the other will contribute greatly in speeding up the prospective rhythm to produce excellence and transfer international knowledge networks (Bear et al. 2005; Kolodner et al. 2003; Frees & Bouckaert 2014).

STEM education includes every field under the umbrella of Science, Technology, Engineering and Math. The acronym was coined by the National Science Foundation (NSF 2003) to refer to programming dealing with science, technology, engineering, and mathematics (Lai & Viering 2012) It is a “slogan” that the education society in the United States has embraced to be interpreted to mean science or math and seldom does it refer to technology or engineering (Bybee 2010). Though these definitions are not necessarily incompatible with each other, multiple interpretations have created confusion among many educators (Hendricks et al. 2012; Dugger & Fellow 2011; Roehrig et al. 2012).

Through numerous iterations and automated alerts, word searches were used to collect data available up to 2017. Searches included the following words and phrases: K-12 education, Education in UAE, science and math education in UAE, UAE, STEM; Science, Technology, Engineering, and Math; STEM education; and technology education. An extensive review was conducted on past and current available literature related to the study purpose. Dating up to August-September 2017, over 100 resources were reviewed. References were selected from peer-reviewed journals articles, dissertations, primary sources, and other scholarly resources. Given the quantity of references reviewed and cited in the study, the researcher found a limited amount of research conducted within the past five years. As such, the research is not limited to the past five years due to the importance of the historical significance of each area and the limited amount of research about the integration of STEM curriculum into K-12 education. The reference management tools, citation manager, and collaboration features were used extensively throughout the research collection period. Proquest and EBSCOHost are the two main online databases used in the collection of resources and references. The journal index and abstracts links to ERIC, Emerald Journals, ScienceDirect, GoogleScholar, Oxford Journals, and Sage Journals were used when additional information was needed on a specific area or limited research was available.

2.2.1 Concepts/Definitions of STEM

According to Vasquez, Sneider, and Comer (2013) in the book *STEM Lesson Essentials*, STEM is an interdisciplinary approach to teaching science, technology, engineering and math through real world learning experiences. According to Dugger (2010), “[STEM] may be defined as the integration of science, technology, engineering, and mathematics into a new cross-disciplinary subject in schools" (p. 2). This, however, may be an idealised definition because even though some research supports the cross-disciplinary approach as being more relevant and meaningful for students, there appear to be few schools that put this into practice (Wang et al. 2011). Contrary to Dugger's definition, Sanders (2009) pointed out that the National Science Foundation (NSF), where the term STEM originated, used it to refer to the four separate fields, and noted "It will take a lot more than a four-letter word to bring them all together" (p. 21). Hence, the term STEM was officially created by the National Science Foundation in an effort to encompass all education related programs. Since each of the STEM disciplines are no longer viewed as individual subjects but instead an inclusive field of study, there is a focus on preparing students to grow and thrive in a 21st century world. Prior to this time the acronym Science, Mathematics, Engineering and Technology (SMET) was used. Judith Ramalay, who at that time was the Director of the NSF's Education and Human Resources Division, stated "I always thought it was terrible," regarding the SMET initials. "It made me think of many things, but none of them had to do with science and technology" (Crayton 2010, p.55). After much discussion on the acronym's negative association with the word "smut," the acronym was eventually changed to STEM (Dugger and Fellow 2011). Because of this, many individuals may mistake STEM as being a completely new initiative, when in fact, the components of STEM have been in existence for at least two decades.

2.2.3 STEM Education: Conflicts, Challenges, and Rationale

Expanding on the organisational structure detailed in the history of STEM education section and outlined in the statement of the problem, the conflicts, challenges, and rationale for STEM education will be explored in more detail.

In the literature, “there is little consensus among practitioners about what STEM education means, and sometimes conflicts exist between the STEM disciplines” (Pitt, 2009, p.21). In the article “*Blurring the Boundaries – STEM Education and Education for Sustainable Development”,* Pitt (2009) argues that “STEM in an educational context is problematic” (p.21). For some, “STEM education is seen as pre-vocational learning or training to encourage the pursuit of STEM careers” (p.22). Others view STEM education as a different way to learn, where boundaries between subjects blur and students are encouraged to develop transferable knowledge and skills (Pitt, 2009). In the article, *STEM, STEM Education, STEMmania,* Sanders (2009) is sceptical when the term STEM is used to imply something new and exciting. He goes on to state that most current STEM practices appear to be basically status quo educational practices that have existed for a century (Sanders 2009).

When discussing STEM education, Pitt (2009) states that: “There is little consensus as to what it is, how it can be taught in schools, whether it needs to be taught as a discrete subject or whether it should be an approach to teaching the component subjects, what progression in STEM education is, and how STEM learning can be assessed. Some people define any activity that involves any of science, technology, engineering, or mathematics as a STEM activity; others argue that intrinsic to the concept is some linking of two or more of the component areas of learning, and that real STEM must be more than the sum of its parts” (p. 41).

According to de la Paz and Cluff (2009), the concept of STEM originated in the 1990’s at the National Science Foundation (NSF) when it started funding the development of instruction that integrated mathematics, science, and technology. Bybee (2010) states that “STEM” has been used to label any policy, program or practice that involves any or all of the STEM disciplines. He goes on to say that a recent survey on the perceptions of STEM indicates that professionals in STEM fields often do not understand what is meant by the STEM acronym (Bybee 2010).

STEM education is often viewed as dominated by the mathematics and science discipline considerations and with technology and engineering considerations playing a lesser role (Kelley 2012). In fact, during the Mathematics/Science/Technology (MST) movement when math and science educators started to use the term MST in their vernacular, Foster (1994) claimed that MST looked less like a coordinated effort between mathematics, science, and technology and more like technology education wishing that it was a coordinated effort. Kelley (2012) states that many speculated that technology would become a stepchild to math and science. He warns that as engineering education struggles to enter the K-12 educational system, it must attempt to define itself so that engineering education will not face the unclear purpose and division within its practitioners that technology education faced in the past and currently still does. This is affirmed by in the article *The Time is Now: Are We Ready for Our Role?* where the authors argue that engineering education must form partnerships that allow all involved parties at all levels in the educational process to feel like they “win” (Haghighi et al. 2008). The need for an equal partnership between the STEM curricular areas is affirmed by authors de la Paz and Cluff (2009). They state, it is important “to seek to understand the importance of ensuring that the (T and E) are equal partners within STEM in order to adequately prepare the next generation workforce and produce valued contributors to our communities and society” (de la Paz & Cluff 2009, p.2).

STEM education faces many challenges in its implementation. Katzenmeyer and Lawrenz (2006) performed research in the area of STEM program evaluation. They argue that “there are not enough well qualified evaluators for STEM education projects and programs and that there is a severe lack of instruments with validity and reliability to measure the outcomes of STEM education interventions, teacher knowledge and skills, classroom practices, and student understanding of STEM content" (Katzenmeyer & Lawrenz 2006, p.63).

STEM Problem-Based Learning (PBL) has been defined as having "a well-defined outcome with an ill-defined task within an interdisciplinary framework" (Capraro, Capraro & Morgan 2013, p.14). This is problematic, as "ill-defined tasks can be complex and messy by nature and are challenging for students to initially accomplish at high level" (Torp & Sage 2002, p.22).

The article, "*STEM Education: Proceed with Caution"*, points out many challenges with STEM education including: "(a) the unchallengeable curriculum (the rigidity and resilience of the school curriculum structure when proposing reform); (b) lack of clarity of the movement (there does not seem to be any clarity about what STEM education might look like in schools in terms of how the STEM subjects should relate to each other); (c) vocational vs. general education (explicit vocational approach in the STEM agenda, mainly related to science and engineering); and (d) dominance of mathematics and science over technology and engineering" (Williams 2011, p.61). Williams (2011) also argues, when examining projects developed to help teachers implement STEM activities into their classrooms, that the projects do not actually integrate science, technology, engineering and mathematics. Rather, these projects include parts of a few disciplines and primarily serve to advance the goals of mathematics and science.

There is a large body of literature that provides rationale for an integrated STEM educational approach. Sanders, a strong proponent of an integrated STEM education approach states, "there is sufficient evidence with regard to achievement, interest, and motivation benefits associated with new integrated STEM instructional approaches to warrant further implementation and investigation of those new approaches" (Sanders 2009, p. 22). Sanders explains that veteran teachers understand the importance of creating classrooms that are interesting and motivating to improve learning for students. He states: “It follows, therefore, that integrated STEM instruction, implemented throughout the P-12 curriculum, has potential for greatly increasing the percentage of students who become interested in STEM subjects and STEM fields. There is a distinct possibility that STEM literacy for all may pay greater dividends in the long run than STEM preparedness for college entrance examinations” (Sanders 2009, pp. 22-23).

Research shows students in STEM-focused high schools outperformed their peers at institutions where STEM disciplines were not integrated (Scott 2012). Scott’s research on the performance of STEM focused schools shows that high school students in STEM focused schools had much higher rates of passing mathematics and English than students that attended other schools. Additionally, Scott found that all STEM focused schools in the study that participated in state testing performed better than the state average in mathematics and English (Scott 2012).

Proponents of integrated STEM education claim that “countries across the globe are not producing enough STEM graduates because there is a lack of social and economic incentives for pursuing STEM careers, and that increases in STEM courses taken in high school have not sparked interest in post-secondary STEM” (Stearns et al., 2013, p.52). The authors argue that “improvement in the quality and integration of STEM education should be the focus of national attention because increasing high school students’ STEM course load in high school has been shown to be insufficient and STEM courses should focus learning on creative exploration, projects, problem solving, and innovation rather than rote memorization of current curriculum” (Stearns et al., 2012, p. 1).

Marshall (2010) stated “STEM education must engage students in understanding and experiencing the human consequences of innovation and its essential value in advancing the human condition” and suggests that to do this, “we must immerse students in disciplinary and interdisciplinary thinking, creative problem solving, and innovative system and process design” (p. 51). Building a stimulating curriculum that “links across all STEM subjects is important to teachers and students alike” (Pitt, 2009, p.11). Pitt believes that STEM learning has an intrinsic educational value and as such deserves a place in general education much the way that people agree that physical education is valuable in itself even though very few students become professional athletes (Pitt, 2009).

The concept of integrated STEM education faces many challenges. There is little consensus as to what integrated STEM looks like and how to implement it (Belland et al. 2017; Gehrke & Kezar 2017; National Research Council, 2013; Pinnell et al. 2013; Eger 2013). School curricula and institutions can be inflexible and resistant to change for a multitude of reasons. The individual disciplines of STEM are often at odds, with one discipline attempting to have more influence than another discipline (National Research Council, 2013; Pinnell et al., 2013; Turner 2013; Tanenbaum, 2016). However, with integrated STEM having the promise of more student engagement, higher student achievement, and possibly generating more individuals who show interest in and aptitude for STEM careers, it is important to try to meet the challenges and conflicts that hinder the successful integration of STEM education (Stohlmann et al., 2012; Gonzalez & Kuenzi, 2012; Ralston, Hieb & Rivoli, 2012).

2.2.4 Curricular Support Structures for STEM Education

Curricular support structures will be necessary to facilitate the development of an integrated STEM curriculum. The literature identifies many curricular support structures that can improve STEM education when present, or hinder STEM education when not present. These curricular supports in schools are essential to support integrated STEM.

STEM libraries more important characteristics include: (a) highlighting existing STEM resources; (b) emphasising STEM in book orders; (c) providing placement and career training; (d) participating in career fairs; (e) keeping up with technology; (f) speaking to science clubs and student organisations; (g) increasing parent and community involvement; (h) inviting guest speakers; and (i) having book talks (Duff 2012; Tchangalova 2009). Tchangalova (2009) argues that a major professional competency that librarians should exhibit is supporting cooperation and collaboration. This is borne out in Duff's (2012) article, *10 Steps to Creating a Cutting-Edge STEM School Library,* where the author states that we must understand that for students to enter STEM career fields they must first become proficient in STEM classrooms. She argues that access to a STEM library is important and that librarians must share STEM content and STEM information with their patrons.

Counselling is another area of traditional student support that can be modified to support STEM education. Schmidt et al. (2012) stated that counsellors affect the career choices that students make and are the gatekeepers for STEM coursework. The Museus et al. report (2011) shows that minority students are underrepresented and "often do not believe that STEM courses are relevant to their backgrounds, and that counsellors and other educators need to ensure minority students are exposed to STEM opportunities early in the educational process" (p.51). Counselling can be an effective support for STEM education as practitioners discuss class choices and career options with students (Museus et al. 2011; Schmidt et al. 2012).

Professional development and collaboration for counsellors is essential and counsellors should improve their willingness/ability to counsel students toward STEM fields for STEM to grow. Counsellors should endeavour to broaden their STEM knowledge base by reviewing theory related to age appropriate student career development, exploring specific career fields of study, and sharing relevant STEM information with students and parents (Schmidt et al. 2012). Turner and Lapan (2005) argue that in middle school, students develop the skills that will influence STEM related course selection in high school and whether they take a STEM focused program of study. Therefore, since counsellors have the power to persuade/dissuade student from STEM fields, professional development is important to inform counsellors about STEM fields and curriculum. Strategies to improve counselling for STEM education through professional development include: (a) ensuring that counsellors have access to current career facts and skills requirements for STEM careers; (b) devoting time toward self-evaluation of a counsellor's partiality toward one career area over another; and (c) promoting career linking opportunities (Schmidt et al. 2012).

School leadership has also been identified as an element of school culture that supports STEM learning. School leadership is responsible for change and consequently must support the implementation of integrated STEM education (National Academy of Engineering 2014). "Principals must be strategic, focused on instruction and inclusive of others in the leadership work" (National Research Council 2013, p. 24). Administrators must provide instructional guidance for an integrated STEM curriculum and need to understand the challenges that an integrated STEM curriculum poses as well as understand the tools teachers will use to advance instruction (National Academy of Engineering 2014). It is also believed that for integrated STEM education to be successful, the administration and other school leaders must understand integrated STEM education and what strategies (pedagogical and other) that can be utilised to ensure a successful program implementation (National Academy of Engineering 2014; National Research Council 2013).

The theme of professional development as a mechanism to support STEM education continues throughout the literature. Many authors call for STEM teachers to develop professionally in order to support and improve STEM education (Mason et al. 2012; Page et al. 2013; Reynolds et al. 2013; Zollman et al. 2012). The Research Experience for Teachers (RET) project "funded by the National Science Foundation" supports "the active involvement of K-12 teachers in STEM" areas including incorporating computer and information science in research projects "to bring knowledge of engineering, computer science, and technological innovation into their classrooms" (p.62). One of the goals of RET is professional development of teachers to build collaborative partnerships that "help them translate their research experiences and new knowledge into classroom activities" (Pop, Dixon & Grove 2010, p.127).

Two RET projects that have strong STEM teacher professional development components are "*Enrichment Experiences in Engineering (E^3) for Teachers Summer Research Program: An Examination of Mixed-Method Evaluation Findings on High School Teacher Implementation of Engineering Content in High School STEM Classrooms"* (Page et al. 2013, p.21) from Texas A & M university, and from the University of Texas at Arlington: "*STEM High School Teaching Enhancement Through Collaborative Engineering Research on Extreme Winds"* (Reynolds et al. 2013, p.49). Both of these projects have an emphasis on teachers having a hands-on research experience where they develop inquiry based engineering projects for their classrooms. Teachers learn about engineering career opportunities for students and develop an overall engineering career awareness. They are encouraged to participate in active sharing of the knowledge gained in the professional development experience. These programs and others like them support high quality professional development for teachers interested in STEM education with the overall goal of making them better teachers in the STEM disciplines (Eger 2013; Arabian Business Consultants for Development 2017).

The theme of collaboration as part of STEM teacher professional development is important in Fulton and Britton's (2011) assessment of STEM teachers in Professional Learning Communities (PLCs). This study which was completed in the fall of 2010 was a two year analysis funded by the National Science Foundation. There were five types of research included in the synthesis that were identified using variations of the search string "professional learning community". The research synthesised included: empirical research studies published since 1995 in peer journals and dissertations, research-based articles in other journals and conference proceedings (Eger 2013).

The researchers found that participating in learning teams allows STEM teachers to successfully engage in discussion about the subjects that they teach. The authors found that teachers in STEM PLCs understood "mathematics and science better and felt more prepared to teach their subjects" (Fulton & Britton 2011, p.2). STEM PLCs cause instruction to change because teachers use more "research-based methods for teaching; teachers pay more attention to students' reasoning and understanding, and use more diverse modes of engaging students in problem solving" (Fulton & Britton 2011, p.6).

Another area of curriculum support for STEM education is the arts. In the article, *The Prospect of an A in STEM Education,* Michael Daugherty (2013) argues that art is essential to STEM education. Daugherty (2013) believes that by inserting an "A" for "Arts" in STEM education and making it "STEAM" education, educators can energise creativity and innovation in STEM education.

In his blog, Dr. Robert Root-Bernstein of Michigan State University (2011) points out that the arts do not make science or technology more aesthetic, rather they often make it possible. Instances where the arts directly led to the technology that Root-Bernstein cites include: "(a) electronic display screens consisting of red, green, and blue pixels which originated from the innovation and collaboration of post-impressionist painters like Seurat; (b) computer chips that are made using the classic art process of etching, silk screen painting and photolithography; and (c) in medicine where the stitches that permit a surgeon to correct an aneurysm or carry out a heart transplant were invented by American Nobel laureate Alexis Carrel, who took his knowledge of lace making into the operating room" (2011, p.34).

In a personal interview with Dr. Nealy Grandgenett, Professor and Haddix Community Chair of STEM Education at the University of Nebraska at Omaha, he stated as part of the Nebraska Robotics Expo there is now a creative visual arts competition. This allows the participants to take part in the creative and aesthetic bits of the engineering design process. Daugherty (2013) argues that it may be in the interest of the STEM movement to consider additional learning goals specifically related to creativity as it pertains to innovation. Both Pink (2005), who sees the society changing from the Information Age to a "Conceptual Age" of inventiveness, innovation, and creativity, and Robert Root-Bernstein (2011), who states that successful innovators in science and technology are artistic, would agree. In summation, as society changes to a more conceptual age, we are encouraged and urged to strengthen creativity because successful innovators in science and technology tend to be artistic people (Daugherty 2013; Pink 2005; Root-Bernstein 2011).

There are many student service and curricular areas that can support the successful integration of STEM education in the school setting. Counsellors and librarians play a vital role in students choosing STEM classes and providing them the resources to be successful. Curricular areas including the arts can be vital support structures of students in STEM classes by allowing them to develop the creativity to solve the complex problems integrated STEM education presents (Daugherty 2013).

2.2.5 Curricular STEM Projects

Following the curricular supports that are important for successful integrated STEM education, various STEM education projects that highlight integrated STEM and how those integrated STEM education projects serve students will now be discussed. In literature, there are two categories of STEM education projects: Curricular and Extra-curricular. Curricular in terms of this review means directly tied to a regular school curriculum during the regular school day. To align with the conceptual framework of the study, the selected curricular projects highlighted in the literature review were explicitly selected for their subject integrative nature. Extra-curricular means a project that is outside of the regular school curriculum (Daugherty 2013). Again, to align with the conceptual framework of the study, the extra-curricular projects cited in the review of literature were chosen specifically for their relationship to design-based education. Extra-curricular projects can be sponsored by a formal school structure or another club or organisation. One commonality of nearly all STEM education projects whether they are curricular or extra-curricular, is that there is a hands-on, inquiry based approach to students learning the STEM content. Often the engineering design process (or similar) is used as the overarching structure for the educational process (Berkeihiser & Ray 2013; MacEwan 2013; Riechert & Post 2010; Taylor & Hutton 2013; Teo 2012; Worker & Mahacek 2013; Zhe et al. 2010).

The project *Think 3d! Training Spatial Thinking Fundamental to STEM Education,* correlates spatial learning with STEM learning success. The study consisted of 52 fourth grade students from three classrooms in a rural New Hampshire K-12 school. The method was an experimental design with two experimental classrooms receiving the intervention of completing spatial assessments while participating in the program, and a third classroom serving as the control group. The third classroom took part in the program after completing the spatial assessment. The authors claim that spatial learning is lacking in K-12 school (Taylor & Hutton 2013). In this STEM implementation, students use origami and pop-up paper engineering to strengthen visuospatial thinking. Results show that the program shows promise for improving spatial thinking and engagement in the content (Taylor & Hutton 2013).

Interdisciplinary approaches to STEM projects inspire both students and teachers (Berkeihiser & Ray 2013). In Berkeihiser's and Ray's project which connected calculus students to engineering Computer Aided Design (CAD) students, students use experience from both disciplines to explore the same problem from different perspectives. Each group of students learns a little about how the other discipline functions and the benefits of a multidisciplinary approach to a problem (Berkeihiser & Ray 2013).

In *Skeletons to Bridges & Other STEM Enrichment Exercises for High School Biology,* the authors connect STEM concepts to biology, which is done less often than with other sciences (Riechert & Post 2010). In this project, three different examples of connecting engineering to biology were identified. First, "From Skeletons as Bridges" had students compare mammal skeletons to bridges in a hands-on activity. Students were introduced to the "principles of bridge construction by investigating tension, compression, and bending as they apply to bridges and other engineering structures as well as to animal bones and spinal columns" (p.2). Second, in "Sound Communication, Animal & Engineered Speakers," students discuss sound and how it is formed and then compare that to how animals communicate compared to human and mechanical means of producing sound (computers, speakers, etc.). Third, in "Aerodynamics and Dispersal," students explore "drag with respect to mass and cross sectional area of objects" (p.3). Students make a helicopter out of paper and try to build one that will stay aloft the longest. Their final design is compared to seed and flight dispersal characteristics of the propeller-like seeds produced by maple, ash, and sycamore trees (Riechert

& Post 2010). The authors report that these unorthodox STEM projects engaged students, encouraged them to think about the world from multidisciplinary perspectives, and made STEM learning more interesting (Berkeihiser & Ray 2013; Riechert & Post 2010; Taylor & Hutton 2013).

2.2.6 Non-Curricular STEM Projects

Similar to curricular-based STEM projects, extra-curricular STEM projects are numerous and important to the learning process. Falk and Dierking (2010) argue that 95% of all learning takes place outside of formal school settings through venues such as places like museums, organised programs, hobbies, television, and other sources. According to the National Research Council (NRC 2013), the strengths of programs outside of the school day are evident in technology and engineering education, where students solve engineering design challenges using their hands and minds. In the same way that the numerous curricular STEM projects were handled, this Falk and Dierking chose to focus on extra-curricular STEM projects that were related to design-based education which is one of the prongs of the study's conceptual framework.

In *Getting Intentional about STEM Learning*, MacEwan (2013) outlines an afterschool project where students in K-12 school worked in enrichment clubs with each having its own STEM theme. The goal of these clubs was for students to use critical thinking and problem solving skills to understand broad STEM concepts. MacEwan (2013) spends a lot of time discussing the nature of professional development for the instructors, which utilises the same hands-on, inquiry-based activities as those used with the students. Ultimately, the project wanted students and staff to recognise STEM as a common factor in many activities that they already enjoy and to realise that STEM does not have to be intimidating (MacEwan 2013).

The 4-H Youth Development Program has been engaging youth outside of the formal school setting to reach their fullest potential since 1902 (Worker & Mahacek 2013). One project that 4-H sees, as part of its STEM mission mandate, is “4-H Junk Drawer Robotics”. In this project, students are given a drawer of parts and tools to utilise in solving a problem. There are three levels of students’ progress (To Learn, To Do, and To Make) through which mimic the engineering design process. The author suggests that by infusing science into engineering and technology a synergy exists in situations where students are engaged and have fun learning (Worker & Mahacek 2013).

The EUREKA STEM project at the University of Nebraska at Omaha (UNO) has been providing STEM education opportunities in the summer for minority girls beginning in grade seven for the last three years with grant funding by Girls, Inc. of Omaha, NE. This extra-curricular project focuses on underrepresented segments of the population related to STEM careers, namely minorities and women (National Research Council 2013). The girls were on the UNO campus all day for approximately three weeks and engaged in career talks with local women in STEM fields and STEM curriculum led by UNO faculty/staff and other certified teachers. The participants were divided into two groups, “Rookies” and “Vets”, that received STEM content including: hands-on STEM kits, robotics, rocketry, mathematics, chemistry, life sciences, engineering, high altitude Ballooning for the Rookies; and robotic programming, e-Portfolios, physics, math logic, advanced chemistry, advanced life science, biomechanics, and neurology for the Vets (Squires & Mitchell 2015).

STEM is contagious. Every day there would be someone very disengaged at the beginning of the lesson, but became much more interested as the session continued and they saw their friends creating, building, experimenting, etc. By the end of a STEM activity, the girls were all participating and far exceeding the expectations they had built for themselves at the beginning of the lesson (Squires & Mitchell 2015).

These design-based (extra-curricular) STEM projects serve the same goals as the subject integrative (curricular) STEM projects; that is, to engage students in thinking about the world from a multidisciplinary perspective, and to make STEM learning more interesting (MacEwan 2013; Worker & Mahacek 2013). The diverse nature of STEM projects, whether they are curricular or extracurricular, shows that integrated STEM education has the potential to address many of the issues related to STEM education and careers in our society today. The cited STEM projects, as well as many others, give researchers glimpses into what seems to work and what further research needs to be conducted to continue improvements to the implementation of integrated STEM education.

2.2.7 Engineering and Technology Education in K-12

Technology education is a practical subject with hands-on instructional methods often used. A large portion of America's economy now and in the future requires highly skilled and middle-skilled vocational workers. Holzer and Lerman (2007) remarked about this connection between education and industry in a report on jobs and education: "Without initiatives that do better to link the emerging occupational requirements with the education and training obtained by current and future workers, employers will have to import workers, alter their production strategies, and/or alter their production strategy in ways that eliminate potentially good jobs" (p. 26).

In the updated report "*Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5"* (National Academy of Sciences 2011), the authors state that since their first report in 2005 "*Rising Above the Gathering Storm: Energising and Employing America for a Brighter Economic Future*" much has changed. In a world of even greater challenges and economic turmoil, the United States' competitive position is slipping. In the 2005 report, 20 specific actions were drafted to help America remain competitive in the global environment (National Academies 2007), which includes strengthening the public education system, still a necessary priority.

In the original *Gathering Storm* report, it concluded that quality jobs are a fundamental measurement of competitiveness and that progress in science and technology advancements will result in the majority of newly created jobs (National Academies 2007). Economic studies in recent years reveal that more than half of the increase in Gross Domestic Product (GDP) is due to progress in technological innovation. Not only has technology created a large quantity of quality jobs, but is has also allowed for people around the world to compete for many of the same jobs, no longer limited by the boundaries of great distances. Americans must be preparing for the educational rigor of quality careers as well as maintaining their skills. However, the rising generation in the United States is less educated than the previous ones for the first time in the country's history, and probably the same will be their overall health and standard of living (National Academy of Sciences 2010).

Though little attention has been given to engineering education in the K-12 education system in America, its prominence is growing and being integrated into K-12 engineering and technology education in many schools. Several different engineering curricula and programs are being implemented around the country. The authors of "*Engineering in K-12 Education: Understanding the Status and Improving the Prospects"* stated: "The presence of engineering in K-12 classrooms is an important category, not because of the number of students impacted, which is still small relative to other school subjects, but because of the implications of engineering education for the future of STEM education more broadly. Specifically, as elaborated in the full report, K-12 engineering education may improve student learning and achievement in science and mathematics; increase awareness of engineering and the work of engineers; boost youth interest in pursuing engineering as a career; and increase the technological literacy of all students" (Katehi et al., 2009, p. 1)

Not only is engineering education in K-12 viewed as critical in terms of recruiting and educating future engineers, but also in boosting educational achievement in all STEM disciplines and technological literacy. Although science, math, and technology education have a long history and established standards of K-12 education, little has been established yet for engineering education (Katehi et al., 2009). Miaoulis (2010) addressed how engineering is a missing component from the general curriculum of K-12 education. He traced this back to when public education curriculum was first established in 1893 by the president of Harvard University, Charles Elliott. At that time, there was not a great deal of technology to learn, and what did exist, most children learned by working at home on the farm. In the mid-1990s, K-12 engineering curricula was being developed, though not widely recognised at the time. Miaoulis noted that *Project Lead the Way* was the first to offer a high school course sequence in engineering targeted at students becoming future engineers. In 2000 in Massachusetts, the Board of Education voted to include new technology and engineering standards to transform Technology Education. Since then, there has been a movement to introduce engineering into the technology curriculum and standards nationwide. This helped capture the attention of the National Science Foundation which started funding development of engineering education curriculum for K-12 education. However, launching K-12 engineering curricula nationwide met many challenges, though engineering provides an intersection between math, science, and innovation. While the quantity of future engineers will decline if this is not changed, most people do not know what engineers really do and many misconceptions remain across the United States (Miaoulis, 2010).

Lewis (2004) noted how technology education has continuously been questioned of its validity as a legitimate school subject, but also points out that this has been true of other subjects initially. The author specifically examined the trend of pre-engineering as the most recent movement in ETE and how it is a categorical change from the working class leanings of industrial arts education of the past toward more professional academic traditions emphasising engineering design. He also pointed out this is a calculated sociological move in hope of making the subject more acceptable to academics who run schools as well as parents and children who have focused their attention on higher education pathways and professional careers (Lewis, 2004).

According to Williams (2010), curriculum agendas that propose a link between technology and other areas rarely seem to favour technology. In general, integrative approaches have promoted reform in science and math and accomplished little to advance the goals of technology education. In the United Kingdom and the United States, projects in STEM education have been developed and grown in influence as engineering has been added to the mix. This is driven by a desire to improve science and math education and to increase the quantity of people pursuing careers in STEM fields and STEM literacy. However, this theory of improving science and math education by integrating it with engineering and technology has not yet been proven. Many rationales have been proposed for integrating engineering in technology education that are similar to those presented for other STEM initiatives (Williams, 2010).

Reid and Feldhaus (2007) wrote about the need for K-12 engineering education in the context of the movement toward a more comprehensive and integrated STEM education. In their study they stated that engineering education is on the stage when it can choose different directions. The issues delineated above are all related to pro-active strategic visioning, strategic planning, education and the use of new and innovative technologies to attract the next generation of leaders within the field; and the field is growing increasingly deep and wide. (Reid & Feldhaus, 2007, p. 5)

The creation of a "feeder system" from K-12 education to higher education STEM fields is needed (Reid & Feldhaus 2007). Recently the *American Society for Engineering Education (ASEE)* promoted an initiative to improve K-12 ETE. They noted, "One of the strongest indicators of a student who will successfully navigate the 'pipeline' to college is [a] rigorous high school curriculum that has been specifically mapped during a consultation with high school counsellors, parents/guardians and the high school student…" (Reid & Feldhaus 2007, p. 6). The implementation of engineering curricula into K-12 education is increasing rapidly around the United States, often being integrated with ETE (Reid & Feldhaus 2007). Moore et al. (2014) noted that "effective practices in integrating engineering into STEM teaching involve complex problem solving, problem-based learning, and cooperative learning, in combination with significant hands-on opportunities and curriculum that identifies social or cultural connections between the student and scientific/mathematical content" (p. 36). Engineering may provide a basis for integrated STEM education, but STEM teaching continues to need improvement (Moore et al. 2014).

The PCAST (2010) defined STEM education to include, for K-12, "mathematics, biology, chemistry, and physics . . . other critical subjects, such as computer science, engineering, environmental science and geology" (p. 9). The same report advocated two important concepts as a brief description of the entire report: students must be well-prepared within STEM subjects foundationally and able to use that information in their lives and education; and, other leaders must encourage and inspire all students to study STEM coursework in school and to become excited about employment in STEM fields (PCAST 2010).

The National Science Education Standards (NSES; NRC 1996), called for a shift in science teaching and learning. Traditionally science classrooms were teacher-centred, which was considered to be a less effective methodology (Johnson, Kahle & Fargo 2007). The NSES advocated that classrooms become student-centred and it is reasonable for teachers to utilise varied instructional strategies, which included inquiry "as a way to engage students in science contextually embedded in the real world" (NRC 1996, p.4). Additionally, the NSES were developed by a variety of science stakeholders who stated "all students are capable of full participation and of making meaningful contributions in science classes" (NRC 1996, p. 4). In an inquiry-based classroom, students are engaged in the fundamentals of scientific literacy and can "actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills" (NRC 1996, p. 2). Effective instruction as encouraged in the NSES includes "inquiry into authentic questions generated from student experiences" (NRC 1996, p. 31).

The PCAST (2010) advocated K-12 students be prepared and inspired for STEM education. To prepare students schools must focus on high standards and meaningful assessments. Inspired students, according to PCAST (2010), are engaged in "exciting experiences . . . that reveal to them the satisfaction of solving a problem, discovering a pattern or category on one's own, becoming insatiably curious ..., or designing and creating an invention" (p. 20). Furthermore, from these experiences, students need to be able to envision themselves as "scientist, technologist, engineer, or mathematician" (p. 20).

With the focus on quality K-12 education at the federal level, student achievement on the National Assessment of Educational Progress (NAEP) science test was one indicator examined. This test in 2005 indicated grade 4 students' average was higher than in 1996; grade 8 students' average remained the same; grade 12 students' average declined (Grigg, Lauko & Brockway 2006). Not only did the grade 12 students' average decline but the percentages of students scoring at the basic, proficient and advanced levels all declined as compared to the 1996 NAEP science test but most troubling was the number of students who scored below basic increased (Matthews 2007). The NAEP for reading and mathematics in 2008 in both 4th and 8th grades indicated improved academic achievement; however, grade 12 students exhibited no significant difference compared to 1973 and 2004 scores (Rampey, Dion & Donahue 2009). These assessments indicated that in science, only 29% of the grade 12 students scored proficient (Grigg et al. 2006) and in mathematics, 35% of the grade 12 students scored proficient (Rampey et al. 2009).

Legislators and policymakers have determined that, to support and improve STEM education, specifically in mathematics and science, for public schools, improved K-12 teaching is needed (Gonzalez & Kuenzi 2012). Additionally, PCAST (2010) stated teachers "are arguably the single most important component of education that can be influenced by policy" (p. 58). Previous studies support the concept that an effective teacher in a classroom has a marked impact on student learning (Fishman et al. 2003; Johnson, Kahle & Fargo 2007; Nye, Konstantopoulos & Hedges 2004; Rivkin, Hanushek & Kain 2005; Wright, Horn & Sanders 1997).

Additionally, teacher effectiveness is centred upon two concepts: teacher pedagogical knowledge and teacher content knowledge (Shulman 1986). Pedagogy, in general, refers to teachers' knowledge of teaching and learning, specifically, the processes or practices involved coupled with a deep understanding of ways to formulate and represent the subject to make it comprehensible for students (Koehler & Mishra 2009; Shulman 1986). Pedagogy is a broad understanding of various theories, including cognitive, developmental, and social, of learning and how these theories are applicable for students in a classroom (Koehler & Mishra 2009). Supporting the idea that pedagogy is a broad construct, Zhang (2008) stated pedagogy referred to a non-subject specific, underlying concept that "addresses how students learn more than the learning itself' (p. 91). Moreover, Govindasamy (2001) expressed that the good practices of teaching are guided by broad pedagogical principles or theories. In contrast, instructional practices or instructional methodology, are what teachers do in a classroom to create effective learning environments for students (Graves, Gersten & Haager 2004). An instructional method, such as the use of investigations, may be implemented differently from classroom to classroom, depending upon the pedagogical construct (e.g., discovery learning or direct instruction) the teacher employs with the instructional practice (Magnusson, Krajcik & Borko 1999).

2.2.8 Evidence to Support Integrated STEM Education

After discussing what characteristics integrated STEM appears to exhibit, evidentiary support for integrated STEM education in the existing literature will be reported and analysed. This includes benefits to students, increased knowledge/conceptual learning, increased interest/motivation, and curriculum goals for schools.

In the "National Academy of Engineering" report, "*STEM integration in K-12 education: Status, prospects, and an agenda for research"* (2014), *"*Margaret Honey chair of the committee" that produced the report, stated that the committee does not produce an unequivocal endorsement for integrated STEM, but notes that there is a very exciting potential for using the connections that come naturally between the STEM disciplines to help students.

Scott (2012) performed a comparative case study method to create a holistic description for each of 10 selected STEM schools. The schools were chosen using a criterion-based selection method with the primary criteria for selection being: 1) the school was specifically intended as a STEM school, and 2) the school was designed to improve all students' understanding of the STEM disciplines rather than be focused only on advanced or gifted students. The results of this comparative case study found that students, they researched in STEM schools, outperformed their peers at other high schools on end of course finals and achieved higher proficiency on state tests (Scott 2012).

Evidence in the literature shows that integrated STEM has the potential to increase knowledge and conceptual learning. The National Academy Report, *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research* (2014), found that the integration of "STEM concepts and methods has the ability to lead to increased conceptual learning in the STEM disciplines. Some caution is advised because of the small number of studies with small sample sizes, but the authors of the report see potentially promising findings" (p.34).

Pfeiffer, Overstreet, and Park (2010) argue that well-orchestrated Problem-Based Learning (PBL) activities improve learning. Pfeiffer et al. (2010) further argue that "when school curriculum is focused on STEM PBLs, PBL projects improve student understanding by helping students to make the connections between content taught in other classes" (p.50).

Sherrod, Dwyer, and Narayan (2009) claim that integrating mathematics into the science curriculum will not only improve student's understanding of mathematics, but also will demonstrate how math can be used. Wilhelm and Walters (2006) found that when mathematics is integrated into science, the curriculum is complementary, causing student learning in both mathematics and science to be enhanced.

Reviewing literature found that integrated STEM increases student interest, including minority student interest. Alpaslan Sahin (2013) looked at STEM clubs from a multi-school charter system in Texas. The study employed a survey design that was administered to a multi-charter school system with 36 campuses to investigate after-school programs where all fourth through twelfth graders were expected to complete a science fair project and were encouraged to participate STEM-related clubs. Sahin (2013) found that students who participated in STEM clubs chose STEM majors at a higher rate than those who did not participate in STEM clubs. The findings also showed that students in STEM clubs performed better and went on to post-secondary education at a higher rate than the students that did not participate in STEM clubs.

Hayden et al. (2011) reported on an iQUEST program that serves "seventh and eighth-grade science classrooms with high percentages of Hispanic students" (p.4). The project is geared toward girls and minorities who are underrepresented in STEM fields. The iQuest project found that its summer camps at California State University San Marcos which included integrated STEM content increased student interest and improved student attitudes toward science and technology.

The report by the "National Academy of Engineering", "*Engineering in K-12 education: Understanding the status and improving the prospects",* (2009) recommended that STEM disciplines should not be treated as "silos" rather they should be integrated and that "engineering could serve as a motivating context to integrate the STEM disciplines" (p.25). One of the believed benefits of integrated STEM education is that students can solve real-world problems and make connections to STEM fields that can increase interest in STEM fields (Brown et al. 2011).

DeJarnette (2012) looked at literature related to current initiatives and research regarding early exposure for students to STEM initiatives in the kindergarten grades and concluded that the interactive Problem-Based Learning activities found within an integrated STEM curriculum are innovative and exciting for students. She believes integrated STEM will create motivation for students to take advanced mathematics and science courses as well as consider STEM careers.

The EUREKA project at the University of Nebraska Omaha also showed evidence that integrated STEM content can increase motivation. Anecdotal evidence from this project showed that the minority female participants of the project had increased interest and motivation to learn STEM concepts (Squires & Mitchell 2015). Survey data for the project bore this out when students were asked if they liked doing science, mathematics, engineering, and technology activities. Responses to these questions largely showed positive gains for both the "Rookies" and "Vets" from pre-test to post-test. However, the Rookies showed no change toward mathematics motivation and the Vets showed no change toward technology motivation. Overall, no categories showed a negative influence on motivation related to STEM activities (Squires & Mitchell 2015).

The "National Academy of Engineering" report, "*STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research"* (2014) has outlined several goals for students that integrated STEM education should address. The first goal is STEM literacy, which includes awareness of the roles of STEM fields in society, familiarity with the basic principles of each STEM area, and a basic level of understanding of how to apply each discipline. The report sets other goals as: (a) developing 21st century competencies, (b) preparing a STEM ready workforce, (c) increasing interest and engagement in STEM fields, and (d) the ability to demonstrate connections between STEM disciplines (National Academy of Engineering, (2014). This report advocates more integration of STEM curricular areas in the K-12 education system by teaching STEM using real world problems and issues, which can enhance motivation for learning and improving student achievement. Sanders (2009) argues that there is enough evidence relating to student achievement, interest and motivation associated with integrated STEM to encourage more implementation and research into integrated STEM education.

There is much evidence to support the concept of integrated STEM education. The need for increased interest in and need for more individuals entering STEM careers, the benefits to students in terms of improving motivation, interest, and conceptual knowledge, and the goals of integrated STEM education for students have been well documented. The evidence shows that integrated STEM can address some of the issues facing the American education system today. Yet, the need for further research to specifically look at student achievement and how to best implement integrated STEM education remains.

2.2.9 The Need for Interdisciplinary STEM Education

There is an increased emphasis on improving science, mathematics, engineering, and technology (STEM) education in the K-12 curriculum in schools at global level. Several reports have linked the increased emphasis to concerns that include national and global competitiveness. An indicator forecasts that a growing number of jobs at all levels will require knowledge of STEM (NRC 2012 2013; National Science Board 2010; PCAST 2010), the need to increase jobs for women, and concerns about teacher quality in STEM teaching.

National and global competitiveness is one justification for an increased emphasis on STEM teaching and learning. Literature reminds us that the United States secured a prominent place in science, technology, and engineering innovations after World War II and held its place until the 1990s (Jacobs 2010). However, at the college level, "the United States is losing its technology and engineering leadership to other countries in the world" (Bybee 2010, p.2). Countries such as India and China are investing heavily in STEM education disciplines. They are preparing students for various levels of education with the knowledge and skills required to be college and career ready, and to be globally competitive (Jacobs 2010). Accordingly, the United States, now more than ever, has concerns about maintaining its place globally. Consequently, they are developing and integrating approaches in STEM education practices to increase the numbers of scientists, engineers, and mathematicians to keep the nation at the forefront of research and innovations. A more comprehensive perspective on "STEM integration is featured in Vasquez et al.'s work (2013), where different forms of boundary crossing are displayed along a continuum of increasing levels of integration, with progression along the continuum involving greater interconnection and inter-dependence among the disciplines" (p.9) (See Table 1).

Table 1: "Increasing levels of integration (adapted from Vasquez et al. 2013)"

Form of integration	Features
1. "Disciplinary"	"Concepts and skills are learned separately in each discipline"
2. "Multidisciplinary"	"Concepts and skills are learned separately in each discipline but within a common theme"
3. "Interdisciplinary"	"Closely liked concepts and skills are learned from two or more disciplines with the aim of deepening knowledge and skills"
4. "Transdisciplinary"	"Knowledge and skills are learned from two or more disciplines are applied to real-world problems and projects thus helping to shape the learning Experience"

Over the past few years, more and more documents published in the US have shown greater "interdisciplinary and transdisciplinary STEM integration" (English 2016, p.22). According to the 2014 STEM Task Force Report, for instance, STEM education goes beyond integrating these disciplines for the sake of convenience; such integration includes learning from problems derived from real-world situations and interconnects the four disciplines by way of "cohesive and active teaching and learning approaches" (p.21). Additionally, he stated that "cannot and should not be taught in isolation, just as they do not exist in isolation in the real world or the workforce" (as cited in English 2016, p.9).

Integrated instruction occurs when ideas taken from multiple disciplines are employed. Integrated STEM education programs give the same level of attention to goals and standards at least two of the four STEM disciplines (Laboy-Rush 2011). Almost all integrated STEM models considered effective in enabling students to develop problem-solving skills and acquire information for themselves by creating “artefacts” (Laboy-Rush 2011). According to Satchwell and Loepp (2002), this process is carried out through “open-ended, hands-on activities” focusing on a thematic topic delivering key STEM ideas (as cited in Laboy-Rush 2011, p. 3). Students should be included in attempts to define and optimise solutions to problems drawn from real life (Laboy-Rush 2011).

Integrated STEM programs are normally created by teachers based on common concepts derived from national standards, which include “the National Council of Teachers of Mathematics (NCTM) Focal Points, the National Science and Engineering Standards (NSES) by the National Research Council (NRC), the Technology Literacy Standards from the International Technology and Engineering Education Association (ITEEA)” (Laboy-Rush 2011, p. 4). According to Satchwell and Loepp, the best programs incorporate concepts most likely to encourage interest among students through real-world problems based on STEM standards (as cited in Laboy-Rush 2011).

According to the most recent report card from National Assessment of Educational Progress in science (NAEP 2011), there has not been any significant change in the average scores over 2011and 2007 among United States students in grade 4 and grade 8 who participated in Trends in International Mathematics and Science Study (TIMSS). The average science score for grade 8 in 1995 was 513; in 2007 it was 520 compared to 525 in 2011. Although the “average science score for grade 8 was 12 score points higher in 2011” (p.29), performance on *International Benchmarks* shows no significant increase in science achievement scores of fourth and eighth graders from 1996 through 2011. The vast majority of students still fail to reach adequate levels of proficiency. These analyses provide empirical cross-national evidence of how important it is to invest in teaching strategies for improving national standings.

Additionally, scores on the 2010 Maryland School Assessment (MSA) report show that "students receiving free and reduced lunch, special education students" (NRC 2013, P.55), limited English proficient students, and African American students achieve at the lowest level among all subgroups. These scores have fuelled some reform efforts by national organisations, such as the American Association for the Advancement of Science (AAAS) and the National Research Council (NRC). Reformers have attempted to correct deficiencies in education by developing goals and standards to promote science education and literacy across the nation (standards for education are statements about purposes). Through the development of goals and norms, educators focus on appropriate curriculum and staff development activities to meet the objective of science education, advance science literacy and bridge the gap between liberal arts and the sciences (NRC 2012 2013).

According to NRC (2012 2013), the purposes of STEM education are synonymous with "the goal of science education, which is to guide and improve science literacy" (p.67). Additionally, "NRC maintained that STEM education reflects the types of intellectual preparation needed for the nation's growth and development in our increasingly science and technology-driven world" (NRC 2013, p.54). The National Academy of Sciences (2011) explains that research shows that the implementation of these resources holds promise for preparing United States students to compete and prosper globally and, therefore, should be the focus of education at all levels.

Women who enter education must develop professional-level pedagogical skills to teach effectively. Therefore, according to Beede et al. (2011), increasing STEM literacy through initiatives such as teacher professional development must be a focus of today's education reform efforts for teachers to have experiences that engage them in high-quality STEM instruction. According to Lichtenberg, Woock, and Wright (2008), today's students will create the next generation of technological advances; they must be prepared by qualified teachers to enter college or the workforce ready to compete in the current global market (Lichtenberg, Woock, & Wright, 2008).

Moreover, the need for STEM education in the literature is premised on and related to the issue that the United States is not adequately preparing teachers, students, and practitioners in STEM disciplines to be college and workforce ready to compete in global arenas (Custer, Daugherty, & Meyer, 2009). The author of the book, *Rising Above the Gathering Storm* (National Academies Press, 2010) also notes issues, such as the lack of teacher quality, among the major elements contributing to the inadequate education of many students in K-12, and lack of qualified candidates for employment in STEM fields (Lantz, 2009; NRC, 2011).

Further, the notion that teacher in STEM education is likely compounded by issues such as the lack of clearly defined goals for STEM education, curriculum unaligned in STEM education, and the lack of professional development for teachers in STEM teaching. It is not surprising that these prevailing issues have fuelled a number of reform efforts by national organisations, such as the National Academy of Sciences (NAF), the National Academy of Engineering (NAE), and the Institute of Medicine to revisit the 2005 study on *Energising and Empowering America for a Better Future*. Through revised studies, the development and passage of the bipartisan America COMPETES Act and the actions of several state initiatives, STEM education continues to gain momentum in K-12 public schools, colleges, and universities across the United States (Lantz 2009). In fact, as a result, of the momentum, included in the vision of STEM education is the goal to prepare students to enter college and the workforce ready to compete in global arenas by professionally developing teachers to deliver STEM curricula and including STEM- related disciplines in their instructional methodologies (NRC, 2011; Bybee, 2010).

According to NSF, NRC, and the NAE, the goal and standards of STEM education ensure that students gain the knowledge needed to understand how to manage natural resources, make meaningful decisions, and function in the world as responsible citizens (NSF & NRC 2011). Drawing on research findings from fields such as "neuroscience, cognitive science, social psychology, and human development" (p.34), the United States government affirms that literacy in the STEM disciplines is the driving force of technological advancement for the infrastructure needed to secure economic success in a competitive and innovative world (Watt, Richardson, & Pietsch, 2007). To meet the expectations of STEM education and prepare students to function successfully in the workforce, the United States Common Core policy is taking instruction in this direction (CCSS, 2012).

2.2.9.1 Reform Efforts to Improve STEM teaching in the K-12 Curriculum: The Common Core

The fact that many jobs in the next five years will be STEM jobs, progress in STEM education is crucial. It is important to know how the use of the Common Core will improve the curriculum. The Common Core State Standards (CCSS) are "a set of standards developed for reforming United States education" (p.6). The Common Core "is not a curriculum; rather the standards define the knowledge and skills students in kindergarten to grade 12 need to master each year to be prepared for college and the world of work" (CCSS 2012, p.23). The standards are driven by goals intended to engage students in rigorous content, robust, and relevant, real world, experiences through higher-order thinking skills (HOTS). It is important to understand that the Common Core standards are designed to prepare students to compete in a global economy and that the benchmarks of the Common Core are like the international benchmarked standards (TIMSS; PIRLS). Accordingly, in this section, the Common Core is discussed with regard to HOTS, which is an interdisciplinary STEM teaching characteristic.

In an endeavour to improve STEM teaching, and to help science teachers attain interdisciplinary instructional skills through experience, reformers in science education have developed new education standards that are rich in content and practice. The Next Generation Science Standards (Moonesar & Mourtada 2015; NRC 2011) are connected to the CCSS and are based on research. The Next Generation Science Standards are intended to be taught within context, allow the synthesis of concepts across disciplines, and to change the way science is taught (Moonesar & Mourtada 2015). Accordingly, reform efforts have focused on integrative approaches to STEM teaching. Interdisciplinary STEM education has emerged as an approach that integrates multiple concepts in two or more disciplines to solve a problem, offer deeper understanding, and build upon existing knowledge. Research informs us that an interdisciplinary approach engages teachers in a variety of teaching perspectives. This approach, allows for increased knowledge and a deeper understanding of the methodologies and skills required to promote learning and engagement in the classroom (Common Core State Standards 2012). Although an interdisciplinary approach to teaching and learning is not new (Mansilla 2006; Jacobs 1997), the approach is gaining renewed interest not only because of the need for quality education to meet the needs of state and federal mandates, but also because the real world is interdisciplinary (Moonesar & Mourtada 2015; NCTE 1996). Students can gain deeper understanding and learning when the curricula reflect real life experiences, which are multi-faceted rather than compartmentalised into individual subjects (NCTE 1996). Using an interdisciplinary approach is one educational method for meeting the standards of the Common

Core. The experiences gained as a result of the interdisciplinary teaching and the knowledge and skills learned has promise for preparing students for work, to problem-solve, and to compete globally (CCSS 2012; Humphrey 2003).

Central to meeting the goals of the Common Core, are questions such as what are the best ways of teaching to achieve the standards? According to *CoreStandards.org***,** one-way teachers can address the objectives of the Common Core Standards is through ongoing teacher learning and teacher collaboration. Teachers will need to work together to determine the best ways to engage students, to ensure concepts are understood, and to make sense of real-world issues. According to research, society depends on students viewing the world from more than one perspective; they must be able to incorporate concepts from more than one discipline ordinarily taught separately, think critically, and solve difficult problems (Davies, McNulty & Maddox 2011). These concerns and issues create a need for changes in the initial approach to preparation and professional development of teachers.

2.2.9.2 Change in Professional Development Approach

Changes in the approach to professional development have evolved over time and reflect teachers' as well as policy makers' concerns and issues about its usefulness. Some studies have shown that professional development is often ineffective at changing teachers' instructional practices, which would lead to increased interest of students in learning (Darling-Hammond et al. 2009). Often, teachers were provided a one-time workshop about a concept, but this approach has proven to be ineffective. The challenge is how to create opportunities for teachers to change (Yoon et al. 2007). Today, with the new era of accountability, it is not just about providing professional development; it is about providing effective professional development that has promise for changing teacher instructional practices and improving student achievement (Yoon et al. 2007). In light of the need for change in teacher practice, professional development district leaders and designers of professional development need to know how teachers learn new skills. Also, it is necessary to provide careful planning, and timely, precise feedback to ensure that the planned program responds to the educators' needs (Mizell 2010). In this study, an attempt was made to ascertain science teachers' needs as a basis for designing and implementing an interdisciplinary approach to STEM instruction.

The current review of research on professional development indicates that effective professional development brings about changes through learning experiences and that a teacher learns partly by doing. Most importantly, it is noted that well planned, intensive professional development has an effect on student achievement and the development of behaviours such as problem-solving skills (Guskey 2002; Mizell 2010). Further, The National Staff Development Council (NSDC 2013) has emphasised that effective professional development must be results-driven or related to process, standards embedded or related to content, and job-embedded or related to context.

2.2.9.3 Characteristics of Professional Development

Literature tells us that for professional development to be effective in bringing about a change in teacher instructional practices, it must have certain characteristics. Guskey (2002), Whitehurst (2002), Ferraro (2000), Darling-Hammond et al. (2009), and NSDC (2013) agree that certain characteristics of effective professional development can influence change in teacher instructional practices. These features include supportive, job-embedded instructional-focus (coherence in the planning), active learning focus (collaborative), and on-going professional development (Guskey 2002; NSDC 2013). Professional development, when guided by these characteristics, engages teachers in practices and learning opportunities that have the promise to bring about changes in teachers' thinking. These experiences have the potential to cause a change in teachers' instructional practice methods by altering instructional strategies (Borko 2004; Guskey 2002; Mizell 2010; Spillane, Reiser & Reimer 2002).

Regarding support, research shows that support is an essential characteristic "of learners of all ages" (Chew, Jones & Turner 2008, p.45). Research shows that once support for teachers is established, teachers are motivated to commit to the learning process (Flores 2005; Guskey 2002; NSDC 2013). Teachers are encouraged when their particular learning needs are addressed and are committed to "professional development opportunities that are job-embedded and are on-going" (Flores 2005, p.15). Also, teachers are motivated to learn when the personal and vocational needs are considered not only in the school, but also at the district level (Flores 2005; Guskey 2002; NSDC 2013).

Regarding job-embedded experiences in subject matter, effective professional development experiences are reflected in a teacher's instructional practice method when learning is connected to practices in the classroom and integrated activities supports the purpose (Putnam & Borko 2000). Researchers noted that job-embedded professional development engages teachers in rigorous day-to-day instructional practices and responsibilities. For example, when teachers see the connection between a learning experience and their daily responsibilities, or when the professional development address their needs, learning and integration of instructional practices into daily instruction is almost seamless (Hammond-Darling et al. 2009). Such a notion connotes "a direct connection between a teacher's work in the classroom and the professional development the teacher receives" (Garet et al. 2001, p.6). Capps and Crawford (2009) conducted critical research reviews on 14 inquiry-based professional development programs to determine whether professional development supports teachers in enhancing their knowledge and changing their practice methods. According to the outcomes, professional development that immerses teachers in an intense inquiry program showed promise to increase teacher knowledge, prepare teachers to implement proven research-based instruction, and lead teachers to change their instructional practices (Capp & Crawford 2009).

Regarding coherence in planning, active professional development brings a change in teacher practice methods when the alignment of the professional development with reform efforts is realised (Garet et al. 2001). Coherence, which is the alignment of state standards, curriculum, and district goals, is essential to the quality of instruction (Garet et al. 2001). Aspects of coherence might include the alignment with the "teacher's goal, alignment with changes in standards, alignment with assessments and curriculum materials that reflect the reforms" (Moonesar & Mourtada 2015, p.38). These criteria of what constitutes effective professional development as defined by Moonesar and Mourtada (2015) are not independent of one another and are not void of challenges and barriers.

Regarding active learning, effective professional development experiences are reflected in a teacher's instructional practices when the application of ideas and strategies presented in the professional learning experience is observed in the classroom. Active learning is a dynamic process, which involves learning by doing. The process allows for cognitive, physical, and emotional engagement. Examples of active learning activities include problem-solving, teacher collaboration and discussion, joint planning, observing other teachers, being observed by other teachers, and coming up with possible interventions and solutions (Garet et al. 2001; Roth et al. 2011). Research shows that active learning is collaborative because it emphasises both active and interactive learning experiences (Garet et al. 2001). Further, Guskey (2002) refers to the practices of active learning as effective and should be ongoing because it engages teachers with other colleagues beyond the classroom setting. It also allows teaching time "to share and solve problems, exchange ideas and viewpoints, and work together toward solutions" (p.50). Research shows that teachers value opportunities to work together, to connect not only physically, but also cognitively and to learn from each other (Goddard, Goddard & Tschannen-Moran 2007). Research shows that "the more time teachers spend engaged in implementing successful professional development programs, the more likely their teaching practices will change and result in positive outcomes for students" (Porter et al. 2003, p.5).

Pertaining to teachers' own instructional practices, a teacher who demonstrates a transformation in pedagogy is one who applied experiences from professional development in their instructional planning and practices, looks through the lens of traditional practice and understands the need for a shift in their own practice, and is reflective of what is learned (Heller et al. 2012; Spillane, Reiser & Reimer 2002).

Concerning ongoing professional development, to enhance personal growth, teaching skills, and contribute to the teaching methodologies that will influence student achievement, the duration of contact hours spent on activities, and ongoing professional development is significant. One of the benefits mentioned in the literature is continuous professional development; this process allows teachers to learn new strategies and seek support during the implementation phase to address challenges (NSDC 2013).

Given that effective professional development has unique characteristics and is at the centre of improvement for changing teacher practice methods (NSDC 2013), this study explored the idea of designing a professional development experience that gives teachers' competence in using interdisciplinary approaches to deliver the STEM curriculum. This research hinges on the view that implementing the characteristics of professional development as effective practices hold promise to deepen teachers' understanding of content and pedagogy, resulting in a change of beliefs and attitudes toward teaching and learning. Specifically, since we are seeking to improve teachers' instructional practices in STEM teaching and learning, the design of STEM professional development for STEM teaching and learning, in addition to the characteristics of effective professional development, must be informed by the nature of STEM. (For further reading see appendix 13)

2.2.9.5 Characteristics of an Interdisciplinary Approach

In this section of the literature review, the characteristics of an interdisciplinary approach to teaching and learning are described as beneficial and advantageous to student learning. Boix-Mansilla (2010) described an interdisciplinary approach as purposeful, grounded in the disciplines and integrative. In teaching, the practice is to think purposefully about the concept, interpret it and integrate it across multiple disciplines to systematically provide a deeper and richer understanding of the issues being investigated (Boix-Mansilla 2010). The approach does not replace disciplinary teaching; rather, it is nourished by the content and skills of other subjects (Boix-Mansilla 2010; Jacobs et al. 2005; Drake & Burns 2004). According to Heidi Hayes-Jacobs, author of "Interdisciplinary Curriculum Design and Implementation (1989)", "the act of linking and finding connections among more than one knowledge domain provides a deeper conceptual understanding of the features, characteristics, and dimensions within those domains" (p.23). A change in the way teaching and learning are executed in the classroom is what this professional development design is seeking to accomplish. The professional development design of this study is to provide experiences for teachers who will influence teaching and student learning outcomes. This section of the literature review briefly discusses four distinguishing characteristics of an interdisciplinary approach and indicates that this approach is clearly relevant to the integration of STEM disciplines.

Characteristics of an interdisciplinary approach are described as the ability to develop thinking around more than one concept. It is the ability to integrate knowledge from learning to produce new information that would otherwise be unlikely through a single discipline (Spelt et al. 2009). Another characteristic of an interdisciplinary approach is an in-depth exploration of other disciplines and understanding the relationships among concepts. Rather than teaching the subjects as separate disciplines, an interdisciplinary approach integrates ideas into a cohesive learning paradigm based on real world applications (NRC 2011; Lin et al. 2012). The approach is concerned with solving complex problems that rely on multiple perspectives and methods. Studies are explored using skills and techniques from academic disciplines to inform topics, themes, or problems under investigation. As a testimony to the effectiveness of interdisciplinary teaching and learning, Romance and Vitale (2012) conducted a study in grades K-5. The researchers used the framework "hands-on investigations, reading, journaling/writing, propositional concept maps, application activities, prior knowledge, and cumulative review for planning and integration" (p.24). At the end of the study, Romance and Vitale (2012) reported that interdisciplinary instructional approaches for linking science and reading comprehension resulted in increased "student achievement in science and reading comprehension" (p.7).

Mastering the processes involved in learning about a topic, theme, or problem, mastering the content, concepts, facts, generalisation, and principles have increased students' motivation to inquire into other disciplines (Boix-Mansilla 2010). Martinello and Cook (2000) contended that the construct "*habits of the mind*" is a beneficial learning practice for focusing the mind, asking questions, searching for an understanding of the unknown, and for merging disciplines in meaningful ways that create learning experiences. As an example of this construct, studies by Howes, Hamilton, and Zaskoda (2003) on linking science and literature through technology, reported that middle school students created learning experiences through their interest, critical thinking, and collaborative work. Twenty-two students used principles, theories, and generalisations from different content areas "to gain a better understanding of their field of interest" (p.21). This approach to learning illustrates that students used patterns of learning behaviours to lead to desired outcomes. According to Martinello and Cook (2000), this approach to education is considered interdisciplinary thinking and engaging ways of the mind, which is essential to preparing students for thinking beyond individual disciplines and for exploring interdisciplinary practices, concepts, and contexts (Howes, Hamilton & Zaskoda 2003).

Another defining characteristic of an interdisciplinary approach discussed in the review of the literature is accommodating student diversity by providing for differentiation of student investigation, presentation, and reporting techniques. Howes, Hamilton, and Zaskoda (2003) conducted another study in the same middle school using the same twenty-two students and reported that students developed their individual web page using creativity and websites relevant to the topic of choice. Students applied their learning to think of novel ways to express their understanding. For example, a student focused on trees and linked each figure (picture) to a website about the particular species of tree. Researchers reported that students gained experience during the five-week project as they designed personal pages, asked questions; revised plans based on class discussions, and added details and researched content-related websites. Researchers further reported that students chose to work in isolation; a concern that prompted the further observation and research into ways to encourage a more collaborative atmosphere (Howes, Hamilton, & Zaskoda, 2003). Although student collaboration was not evident in the study, Howes, Hamilton, and Zaskoda (2003) have maintained that the lessons learned, especially the interdisciplinary approach clearly justifies the study because many students do not get enough practice to explore concepts in other disciplines.

One rationale noted in the literature for interdisciplinary teaching and learning is that the 21st century calls for new skills, knowledge, and ways of thinking that prepare students to be competitive and successful in a changing and uncertain world (Kuhlthau, 2010). The approaches to interdisciplinary teaching give students reasons to learn skills and knowledge, to explore, and to discover new and interesting things. However, many studies confirm that it is the teacher within the classroom that must master the content, understand the process of presenting the content, and be experts in a range of teaching methods and approaches (Danielson, 2014). According to Morrison (2006), interdisciplinary teaching methods have the promise to equip students from all levels of formal schooling to acquire the skills and knowledge to apply new learning methods to challenging situations, and to make connections and applications across concepts of other disciplines. An interdisciplinary approach may provide explicit links for students to make connections between what happens in their lives in school and apart from school (NCTM, 1989). The goal of STEM education is to develop critical thinkers and problem solvers (NCTM, 1989). For this reason, the approaches and guidelines for interdisciplinary teaching are an ideal strategy for achieving the goal of STEM education.

The second rationale for interdisciplinary teaching is that many topics are relevant to current issues in our world that are not discussed in school. This is largely because of the breadth and depth of the content covered in the curriculum that must be taught to students within the daily schedule in preparation for state-mandated tests. These hindrances prevent teachers from teaching in-depth and from making connections across disciplines and to real-life. The interdisciplinary approach in teaching enables students to see connections between subject areas and topics in other disciplines while maintaining the fidelity of the curriculum (The National Council of Teachers of English NCTE, 1996). The professional development in this project will equip teachers for the use of the interdisciplinary approach to strengthening skills that students encounter in one context, but practice in another.

A third rationale for interdisciplinary teaching is that districts and school systems are seeking alternative ways to improve student learning and to raise test scores without "teaching-to-the-test." Interdisciplinary teaching organises the comprehensive interdisciplinary unit plans that focus on particular topics, problems, or themes. Research shows that when teachers use an interdisciplinary approach to teaching, students are motivated to ask questions, collect data, sort, observe, predict, measure, and critically develop an understanding of scientific concepts. Student learning is deeper and more enduring; students develop and demonstrate the ability to use the principles of science concepts; they develop ways of thinking about other disciplines or subjects to create new understanding and make applications to other situations such as societal issues, education issues, environmental issues, global issues; and, they learn how to construct their knowledge of the world through assimilation and accommodation (Jones, 2010).

2.2.9.6 Professional Development for Interdisciplinary STEM

Although some studies of professional development for interdisciplinary STEM have shown "positive results for student achievement, others have shown no effect" (NRC 2013, p.1). However, researchers in education argue that "effective practices for interdisciplinary STEM professional development are closely related to effective practices in education" (NRC 2013, p.2). According to the literature, effective professional development helps to change teachers' instructional practices and develops competencies in content as a way of improving the quality of teaching (NRC 2013; McLaughlin & Talbert 2006). Studies show and further suggests that effective interdisciplinary STEM professional development should have three key features: "(1) focus on developing teachers' capabilities and knowledge to teach content and subject matter; (2) address teachers' classroom work and the problems they encounter in their school settings; and (3) provide multiple and sustained opportunities for teacher learning over a substantial time interval" (NRC 2013, p.5).

The literature also suggests that teacher professional development for an interdisciplinary STEM approach should continue as a need-based professional development, moving from initial preparation to induction into practice (NRC 2013). The literature informs us that teacher professional development for an interdisciplinary approach is not enough; administrative school-based support is also necessary to allow teachers to engage in collaboration and interaction with other colleagues (NRC 2013).

A key strategy for advancing integrated STEM education and technology and engineering education includes developing teachers' professional knowledge and motivation to teach this type of curriculum. High quality STEM instruction requires up-to-date content knowledge and specific pedagogical content knowledge in various related fields (Moore et al. 2014). STEM teacher professional development focused on strategies that help increase student mathematical and scientific learning may also be invaluable to making a significant difference in student learning and STEM career interest. Professional development helping STEM teachers design and teach integrated STEM curriculum can provide more engaging student learning experiences as well (Avery 2013).

Research on professional development identified several effective characteristics of implementing teacher training including: focusing on subject matter knowledge; more than 40 hours of training with at least a year of follow up; linking teacher's previous knowledge and skills; actively engaging teachers in the training sessions; and having teams of educators from the same schools attend together (Loveless 2013; Wilson 2009). A similar set of effective features of professional development is recommended in a meta-analysis by the *Council of Chief State School Officers* including: a focus on content knowledge; active methods of learning; participation with a team of colleagues from the same school; coherence to state content standards; sufficient time for training and follow up activities; and evaluation of teacher knowledge, classroom practices, student achievement, and quality of implementation (Blank & de las Alas 2009). This meta-analysis (Blank & de las Alas 2009) also determined that the best programs included at least 100 hours of training through a variety of contexts and methods. The TRAILS professional development workshop aims to incorporate all of these effective strategies to some degree, including the two-week intensive summer training (approximately 70 hours) with follow up meetings, teacher support, an online professional learning community, and evaluation and research through the following academic year, providing additional hours of development.

Though there are many challenges with implementing an integrated STEM education model, research has shown teacher professional development benefited classroom practices in many ways and helped teachers overcome challenges (Avery 2013). A study on teacher professional development for design-based learning by Bamberger and Cahill (2013), guided pedagogical strategies for teaching design, and shared multiple models of design strategies fostering creativity. Denson, Kelley, and Wicklein (2009) noted that technology education teachers identified that they needed training on subject integration and how to incorporate suitable levels of science and math. Technology teachers also felt they needed additional engineering curriculum resources and support in using engineering design (Denson et al. 2009). In another study that followed STEM teachers after professional development, researchers identified that when STEM teachers were not as confident in teaching a design-based curriculum, student learning and accomplishment were affected (Stohlmann et al. 2012). Project Lead the Way teachers with varied backgrounds felt more comfortable with specific parts of the curriculum for which they were more prepared (Stohlmann et al. 2012). In a meta-analysis study on secondary school technology and engineering education professional development, Daugherty and Custer (2014) recommended, "There is a need to think and work integrative across the STEM disciplines within the professional development environment, but also keeping in mind and addressing teachers' unique disciplinary needs" (p. 272). The authors also discussed how much of the content of pre-engineering professional development centred on technology, but also included scientific inquiry, mathematical reasoning, and engineering design. All of these content areas will be emphasised in the TRAILS professional development workshop.

Professional development needs to promote a deep understanding of subject content and pedagogical content knowledge to teach integrated STEM education effectively (Avery 2013). Teachers in K-12 education must obtain the skills to help students learn effectively in the context of the engineering design process, design-based challenges, and project-based instruction. Educators can also learn more about STEM careers, such as what engineers do, to inspire and encourage students in pursuing careers in STEM fields (Avery 2013). Stohlmann et al. (2012) emphasised the importance of STEM teachers attending professional development, partnering with a nearby university, time to collaborate with teachers, and curriculum training to implement effective integrated STEM education. Avery (2013) described the content of a summer professional development workshop for teachers preparing to teach integrated STEM curriculum: "The focus of the summer workshop was to (a) model how an engineering design challenge was performed in the class, (b) provide teachers practice with how to solve design problems, (c) teach the teachers how to infuse engineering design into high school programs, (d) study curriculum models, and (e) learn how to assess engineering design" (p. 58).

A spring workshop was presented before the summer of professional development, introducing general STEM education content. The summer workshop significantly focused on learning and implementing the engineering design process, using engineering challenges, and how to assess engineering design (Avery 2013).

Furthermore, when directing a STEM professional development program, Avery (2013) emphasised how it is imperative to provide a supportive learning environment for teachers. Teachers mentioned several salient points about this program in particular including “showing respect for what teachers do and teach, and providing the necessary support for teachers to sustain what they learn through STEM PD” (Avery 2013, p. 63). When creating STEM professional development, it is vital to contemplate the wide range of knowledge, background, and experiences of the teachers coming from unique educational environments. The delivery of STEM education requires a wide range of knowledge especially when using engineering design to make connections among subject areas in real world context (Avery 2013).

In another study investigating student learning in middle school science classes incorporating engineering design modules, teachers participated in a professional development course to gain engineering content knowledge and integrated technology implementation to support science and math learning (Cantrell et al. 2006). Teachers developed three modules in the course to use in their middle school classrooms, which included lesson plans, web-based simulations, and assessments. Cantrell et al. indicated that they developed engineering design modules, which built on the work of other researchers who created successful curriculum integrating engineering into science courses using engineering design challenges that have effectively engaged middle school students. The authors also emphasised that “Engineering design activities are a powerful strategy for the integration of science, mathematics, and technology, and for engaging a broad population of students” (Cantrell et al. 2006, p. 302). Teachers were paid a stipend to enrol in a three credit-hour graduate course for professional development. The course emphasised engineering content, how to create engineering design modules, assessment strategies, and using scientific inquiry pedagogy. In addition, teachers were specifically taught the thinking processes and teaching approaches for implementing the engineering design process (Cantrell et al. 2006).

Teachers typically avoid instruction on content areas they do not strongly comprehend. This can be a substantial problem for pre-college engineering education and teaching the process of engineering design and inquiry. Teaching engineering design may be particularly difficult because there is no one correct answer but multiple solutions to an ill-structured and open-ended problem. Teachers need to be comfortable teaching the process of engineering design and evaluating the quality of students' solutions to problems appropriately using a level of engineering analysis. However, many teachers lack the necessary experience and knowledge to do this effectively (Brophy et al. 2008). Brophy et al. (2008) noted "preparing teachers to blend engineering education into the curriculum requires identifying and understanding better the unique interaction of pedagogical knowledge, domain knowledge, and the combination of the two, often referred to as pedagogical content knowledge…" (p. 381). Teachers can have a significant impact on student interest in STEM careers, and some outreach efforts have targeted teacher readiness to implement engineering curriculum.

Teacher professional development activities help to prepare teachers for implementing additional content and instructional methods, often focusing on specific lessons or activities (Brophy et al. 2008). However, teachers also need assistance in how to blend this new content and methods with existing curriculum. Sustaining changes requires a community of teachers with a similar commitment and a supportive cohort environment. A one week professional development workshop may assist teachers in getting started but ongoing support and development is needed to sustain teachers in attaining competency to adopt and design engineering curriculum (Brophy et al. 2008).

Furthermore, science educators need to learn the knowledge and skills required for teaching science through employing the engineering design process (Capobianco & Rupp 2014). The Next Generation Science Standards heavily emphasise the integration of engineering design and practices with scientific inquiry and practices. Equipping teachers with the foundation and skills to implement the engineering design process to teach science is a huge task and requires professional development of high quality. Teachers need preparation in planning for and teaching (pedagogical approaches and practices) the engineering design process and design-based science curriculum (Capobianco & Rupp 2014). In their study, teachers attended a two-week intensive summer professional development workshop that focused on "innovative, design- and standards-based curriculum accompanied by design-informed science instructional methods" (Capobianco & Rupp 2014, p. 260). After the summer professional development, teachers participated in supplementary support sessions scheduled during academic year of implementation and related research activities.

Donna (2012) presented a framework for teacher professional development promoting engineering design as a pedagogy to integrate STEM subjects. Donna emphasised how professional development is more impactful when it is job-embedded, sustained over time, and provides professional learning communities (PLCs). In this professional development, the teachers followed an engineering design model incorporating prior knowledge and learned how to collaborate making connections between content areas while working through an engineering design challenge. Donna presents a professional development model with six sequential phases: Explore prior knowledge related to engineering and relationships between domains, Develop basic knowledge of engineering, Engage in a cooperative engineering design activity, Reflect on an activity as learners and STEM educators, Extend knowledge and connections between domains, Continue work within Professional Learning Communities (p. 3).

This professional development model focused on building both the teacher's content knowledge along with pedagogical content knowledge. Teachers learned about technology, engineering, and the engineering design process, including how to implement it in the classroom in a cooperative learning approach–engineering design pedagogy. Teachers also spent time reflecting on the connections between engineering and math, science, and technology concepts and subjects (Donna 2012). Donna also emphasised that professional development experiences are not one time events, but ongoing and that PLCs can help further collaboration and learning among teachers.

Roehrig et al. (2012) investigated secondary teachers' implementation of STEM integration during an extended year-long professional development program. The professional development operated from two underlying STEM integration models– *content* and *context integration*–allowing for more implementation flexibility (Roehrig et al. 2012). Content integration "focuses on the merging of the content fields into a single curricular activity or unit to highlight 'big ideas' from multiple content areas" (Roehrig et al. 2012, p. 35). Teachers worked through a series of activities with direct experiences employing engineering design. This provided a context for teachers to teach from each STEM discipline and show how all these subjects were needed to solve a problem (Wang et al. 2011).

In the second model, "Context integration primarily focuses on the content of one discipline and uses contexts from others to make the content more relevant" (Roehrig et al. 2012, p. 35). For instance, a math teacher might choose a unit that uses statistics to perform a safety analysis for a company, but then the context would allow for the engineering design process to be utilised to design solutions for the business. This type of example is a type of model-eliciting activity (MEA), a broad set of engineering and math problems. MEAs "are complex problem-centred, team-oriented activities that are situated in realistic, meaningful contexts that require students to design approaches to solving a task" (Roehrig et al. 2012, p. 35). With MEAs students develop mathematical models, then test it with sample data, and revise the model to solve a particular problem in an iterative process–a form of engineering design (Roehrig et al. 2012).

In this five-day professional development module (extended over several months) on 6-12 grade STEM integration, engineering and the engineering design process drove the majority of models for the integration of STEM for science and math courses (Roehrig et al. 2012; Wang et al. 2011). Between each professional development day, teachers met four times in professional learning communities organised by school teams to reflect on previous training sessions and to plan how they would execute the integrated STEM activities (Roehrig et al. 2012). Though K-12 STEM teachers are participating in many professional development programs across the country, some possible differences in study results of integrated STEM education could be influenced by the difference in teacher preparation (Valtorta & Berland 2015).

TRAILS professional development aims to equip teachers with both content and pedagogical content and context knowledge to implement integrated STEM lessons. Though teachers will experience an exemplar lesson and develop some of their own lessons during the two-week summer professional development workshop, online resources, a community of practice, on-going follow-up and support during the school year will also be critical to teacher growth and student academic achievement. Research has revealed that professional development which is sustained and job-embedded focusing on developing teacher content and pedagogical knowledge is critical for improving instruction and student achievement, the ultimate aim (Althauser 2015).

2.2.9.7 Empirical Studies and Interdisciplinary Approaches

There is little theorising about how interdisciplinary teaching might encourage learning (Vess 2000). Nonetheless, the benefits for both teachers and students have been building on a substantial foundation of observed evidence across diverse disciplines (Vess 2000; Spelt et al. 2009; Spalding 2002). The literature reports that the primary outcome of interdisciplinary integration is "*boundary-crossing skills*" (Spelt et al. 2009). "*Boundary-crossing skills*" are the ability to analyse and synthesise knowledge of different disciplines, while coping with the complexities of the concepts (Spelt et al. 2009). Simply stated a "*boundary-crossing skill*" is the ability to integrate knowledge from two or more disciplines to produce a thought process that might not have been possible or that might not provide advance understanding through a single discipline (Boix-Mansilla 2000).

To show a benefit of integration during a collaboration of disciplines, Silverman and Clay (2009) conducted a study of self-contained seventh-grade ESL students from an urban setting identified as lagging behind in mathematics. Silverman and Clay (2009) was interested in showing that mathematics was more than following procedures; mathematics is a tool to solve and understand real-world problems. A science teacher commented on the inability of students to calculate percentages and to use math skills in science. According to the report, after collaboration with teachers in social studies, language arts, and intentionally planning to include science and mathematics concepts in an integrated project, achievement improved for most of the seventh graders in mathematics, science, and social studies. Students reported that linking the concepts across disciplines enabled them to develop conceptual understanding rather than memorization. The teacher said that her conception of mathematics shifted when she observed and realised that students could invent mathematical procedures to solve and interpret problems as a result of their exposure to an interdisciplinary teaching approach (Silverman & Clay 2009).

As noted earlier, reviewed scientific literature reveals that interdisciplinary instruction is based on the constructivist approach, which includes student-centred learning, intentional student engagement, and students constructing individual understanding. Constructivist instructors see themselves as facilitators rather than as transmitters of knowledge (Fortin, Long & Lord 2002). As a result, students who are part of a classroom where teachers are practicing interdisciplinary teaching should exhibit a higher degree of understanding of concepts in STEM disciplines and acquire skills in knowledge integration. Additionally, research indicates that constructivist instructors view their students as active participants who create and interpret knowledge (Fortin, Long & Lord 2002).

2.2.10 International STEM Implementation Frameworks

The United States has long been regarded as a global power. To ensure that legacy remains, it is vitally important that policy makers continue to be aware of the development outside of our country as well. STEM education is not just a priority in the United States. The understanding that STEM is the future is one that extends worldwide (Alyammahi et al. 2016; Allaire 2017; Makhmasi et al. 2012; Green & Sanderson 2017; Harris 2017).

A review of literature revealed that Malaysia is one example of a country identifying STEM education as a priority (Meng, Idris & Eu 2014). Science and mathematics achievement scores in Malaysia are low. Through a survey, researchers found that students had a more positive overall perception of assessments in the STEM field; however, they identified a weakness in the assessment in the area of engineering (Hassan Al Marzouqi & Forster 2011; Gnilka & Novakovic 2017; Gouia-Zarrad & Gunn 2017; Hamilton et al. 2017). Their research suggests that changes need to be made in assessments in order to not only provide a better representation of the skills students need to exhibit in order to have success in a STEM field, but also to drive improved instruction (Chalmers et al. 2017; Perignat & Katz-Buonincontro 2017; Carmichael 2017; Guzey et al. 2017; Bahrum, Wahid & Ibrahim 2017).

In Turkey, researchers investigated the impact of an out of school STEM education program (Baran et al. 2016). The purpose of this study was to improve 6th grade students' perceptions towards STEM fields and careers. Additionally, this STEM education opportunity was offered to disadvantaged students from the areas of Anakra. Researchers involved with this study felt that it was important to provide STEM opportunities to those who may not otherwise be able to experience it.

Thirteen faculty members from various universities in Turkey implemented modules of instruction in STEM fields (Baran et al. 2016). In all, the program ran for 40 hours over three consecutive weekends with forty sixth grade students participated. Modules ran from 9:00am until 5:00pm every day during the program. The program incorporated a number of different hands-on and collaborative activities pertaining to STEM. After each activity, students had a 15-minute window for written evaluation to collect information on their perception of the activities they participated in.

Students acknowledged that they developed handcrafting skills (36%). Many also suggested that they developed cognitive skills such as argumentation, reasoning, thinking, observing, planning, mental skills, and imagining (25%). These skills coincide closely to "21st century skills such as collaboration, critical thinking, communication, and creativity" (Baran et al. 2016, p.41). Eighty-three percent of the students who participated indicated that they believed they would use what they learned in STEM education in their future careers.

Researchers in Australia completed a qualitative study with the purpose of identifying opportunities to connect pedagogical knowledge practice and student outcomes in STEM education (Hudson et al. 2015). This was the beginning of a three-year longitudinal study and this particular paper reported on the findings on “one year-4 class comprised of 19 girls” (p.6).

Teachers wrote about the pedagogical approaches and identified where they could have linked STEM education (Hudson et al. 2015). Teachers were provided with a teacher’s guide and student booklet from the university staff. They were then asked about how those resources benefited their instruction. Interviewers asked teachers about the engagement of their students and their preparedness for follow-up lessons. Students answered similar corresponding questions in their written responses. Both teachers and students identified the student booklet as an effective means of planning, which allowed greater success in understanding the tasks.

2.2.10.1 The Process of Implementing STEM

STEM education requires a commitment to encouraging 21st century skills such as “communication and collaboration”. Mike Borowczak (2015) identifies a process that could be use in assessment to improve these very skills. By using a cloud based assessment tool, potential communication issues and challenges within a group were easily identifiable. Of course, the ability to identify these issues early on in the learning process makes it that much easier to address and correct. Quantifying these struggles with the use of technology in a STEM program will go a long way to enhancing group work and other skills that would benefit a student who intends to pursue a STEM future. Furthermore, becoming more comfortable in this type of setting, due to the improvements made along the way, may encourage more students to participate in more collaborative learning experiences (Borowczak 2015).

A preliminary review of another study demonstrates how the CCSS can be integrated into real world education (Johnson, Dodor & Ball 2015). Family consumer science is a class that is used to explore life skills. It is part of Career Technical Education (CTE). The purpose of this study was to examine how practical it would be to incorporate the CCSS into STEM education. Researchers examined how integrating geometry into family consumer science modules would impact understanding.

Two exploring life skills classes were used for this study (Johnson, Dodor & Ball 2015). The first class would receive their instruction in an integrated math and life skills unit. The other class received their instruction in the two subjects independent of one another. In their research, they found that there was no significant difference between the increases in scores from the pre-tests to the post-tests of the two classes. This indicates that the CCSS can be embedded into STEM programs without negatively affecting mastery of the standards.

A review of literature does acknowledge that literacy can be integrated in STEM education as well. One piece of literature in particular analysed the integration of literacy at the collegiate level (Soules et al. 2014). Colleges have tried to implement information literacy programs in different ways.

When introducing the survey, question, read, recite, review (SQ3R) strategy, researchers found that students in the introductory courses were more accepting of the strategy (Soules et al. 2014). Those students who were in upper level courses did not utilise the strategy to the same extent. Many of the students did not find the reading notebooks associated with the strategy to be beneficial to their studies. However, they openly admitted that they did not work with the notebook systematically as the strategy suggests. A preliminary review of this literature suggests that early exposure to integrated literacy may encourage students to be more accepting and willing to incorporate such strategies. By fostering positive perceptions of information literacy strategies early in middle school and high school, students will be more prepared to utilise these strategies in a way that promotes success later in life (Soules et al. 2014).

Hill (2013) also found value in integrated literacy in STEM education. Hill's approach, however, is slightly different. Rather than incorporate the literacy into STEM projects or curriculum, Hill suggests introducing STEM narratives into literacy courses. Several texts are recommended and reviewed in this literature. Hill also indicates that the text can be introduced in a variety of ways. The inclusion of complex text, charts, symbols, diagrams, and equations all encourage readers to make in-depth analysis of the text, as required by the CCSS (Hill 2013).

2.2.10.2 Integrated STEM Education, Benefits, and Challenges

Integrated curriculum, teaching, and learning are not necessarily new but linked to the ideas of John Dewey, constructivist theory, and the progressive education movement. However, there is now an emphasis on 21st century skills and problem-solving incorporating the STEM disciplines in an interdisciplinary approach (Moore et al. 2014). Curricula in K-12 ETE are being improved to create a more effective integrated STEM education program and advance the flow of scholars into STEM careers (Prevost et al. 2009). Yet STEM education often remains limited to science and math, being mostly taught disconnected from one another with little emphasis given to technology or engineering (Hoachlander & Yanofsky 2011).

In 2009, Sanders explained how integrated STEM education includes "approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects" (p. 21). Outcomes for instruction in one or more other STEM domains must be purposefully and explicitly designed in the curriculum originally developed for a single subject (Sanders 2009; Tran & Nathan 2010). Moore et al. (2014) described integrated STEM education as "an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems" (p. 38), with the goal to be a more holistic approach engaging learners in a more meaningful and relevant context. Integrated STEM curriculum models may include content integration with multiple STEM subject learning objectives, or context integration where the focus lies on the content of primarily a single subject, but other STEM domain contexts are incorporated (Moore et al. 2014).

The task of implementing an effective integrated curriculum is challenging but rewarding. Stohlmann, Moore, and Roehrig (2012) noted that integrated STEM education requires great coordination of people and resources to enable students to develop ideas and solutions for problems in the real world implementing the engineering design process. *The National Academy of Engineering and National Research Council Engineering* advocate that engineering design is an ideal STEM content integrator and as a pedagogical approach provides an authentic learning context to enhance STEM learning (NAE & NRC 2009). Research studies on implementing integrated STEM curriculum have revealed students more actively engaged in learning and increased interest in STEM subjects (Stohlmann et al. 2012). Results from using *WISEngineering,* a web-based scaffolding platform to support the engineering design process, improved math learning in an integrated STEM design-based learning environment, showed significant improvement in math performance on standardised tests and pre/post-tests measuring Common Core math concepts (Chiu et al. 2013). In other research using another scaffolding approach to learning science in a design-based context, students made significant increases in understanding science concepts (Puntambekar & Kolodner 2005). Results also revealed that students benefit from a variety of scaffolding and sequence of support.

Roehrig et al. (2012) identified in a study that the highest quality of STEM integration occurred when math and science teachers co-planned and implemented engineering design units. Moreover, few well-developed strategies or models exist for teachers to follow (Brophy et al. 2008; Wang et al. 2011). Science and math learning results also depend on the integrated STEM approach, and the type of support incorporated into the instruction and context (NAE & NRC 2014). The positive impacts on math and science learning differ. Findings from integrated STEM research should be cautiously interpreted with the small number of studies and varying quality and contexts (NAE & NRC 2014).

Integration of subjects is more than including different subject areas together but of emphasising cross-cutting connections among subjects so they are not so easily separated, known as an interdisciplinary approach. Many investigators emphasise that an interdisciplinary approach is the most effective practice for integrating curriculum, which surrounds a real-world problem rather than a specific subject (Wang et al. 2011).

Moore et al. (2014) emphasised engineering design as an integrator of STEM education by having "students participate in engineering design as a means to develop technologies that require meaningful learning and an application of mathematics and/or science" (p. 38). However, implementation of integrated STEM approaches may vary in terms of how many teachers, classes, or subjects are involved and to what degree subjects are emphasised (Moore et al. 2014). The TRAILS project specifically focuses on pairs of teachers in science and ETE classes. Though, math teachers are also a key piece for an integrated STEM education approach, this study is part of the larger TRAILS grant project focusing on high school science and technology teachers. The type and degree of integration of subjects and their emphasis is to be determined by the teacher team that will decide what is appropriate and feasible for their particular school context. Studies on using the engineering design process in pre-college STEM courses shows mixed results in this approach to teaching math and science, and promoting student interest in STEM careers (Stohlmann et al. 2012). These mixed results could occur because of a multitude of reasons. Though there are many benefits to implementing an integrated STEM curriculum, there are also many challenges. A lack of teacher experience and knowledge remains, as well as extra time to prepare and teach an engineering design-based integrated STEM curriculum (Stohlmann et al. 2012).

Frykholm and Glasson (2005) recommend three principles to guide educators to an integrated approach to teaching which include: 1.) a shift in focus from integration of school subjects being only multidisciplinary, to a focus on connections between subjects where a primary concept or idea provides the centre around which to integrate subjects; 2.) an emphasis on the development of pedagogical context knowledge; and 3.) a teacher education program that promotes learning in discipline specific content knowledge and pedagogical content knowledge. Johnson (2013) noted that: "Integrated STEM education is more than curriculum integration…Specifically, integrated STEM education is an instructional approach, which integrates the teaching of science and mathematics disciplines through the infusion of the practices of scientific inquiry, technological and engineering design, mathematical analysis, and 21st century interdisciplinary themes and skills" (p. 367).

In a study by Valtorta and Berland (2015) on an integrated STEM education approach, the researchers indicated that students were unable to describe the math and science content relationship to their solution. Furthermore, there were few instances where students attempted to integrate math and science content at all. Though teachers explicitly supported new mathematical and scientific concepts, students still failed to integrate the concepts into their design work (Valtorta & Berland 2015).

STEM teachers think prior student knowledge of science and math is important for their success in an integrated STEM context (Wang et al. 2011). The design and implementation of integrated STEM curriculum is also greatly affected by teachers' beliefs and perceptions of STEM integration. Teachers in the study by Wang et al. believed that STEM integration did have a positive effect on students' confidence in learning math and science concepts and interest in STEM careers. Benefits for students connected to well-integrated teaching include prospects for learning in more pertinent and engaging practices, practicing higher level critical thinking skills, advancing their problem-solving skills, and increasing retention in STEM disciplines (Stohlmann et al. 2012).

To provide support for integrated STEM education, more institutions and organisations are partnering with schools. Federal funding has provided professional development training for teachers to implement integrated STEM curriculum. Concern for instructors implementing integrated STEM instruction includes support of teachers, teacher efficacy, teaching practices, and necessary materials (Stohlmann et al. 2012). Most research studies have found benefits to integrated instruction, but also mention that more time is required for teachers to plan and effectively teach this material. Teachers also often have gaps in knowledge in their own content areas while adding addition subjects may create additional gaps and challenges. Furthermore, teacher self-efficacy and content knowledge are important for students to successfully learn. Effective pedagogical practices also factor largely in feelings of self-efficacy, reaffirming the need for teacher support and professional development (Stohlmann et al. 2012).

Most of these practices are embedded in the TRAILS professional development institute and exemplar lessons, which emphasise a blend of engineering design, scientific inquiry, and project, based learning in a community of practice. Teachers are taught to use an inquiry approach to teaching science in a collaborative environment requiring students to question, discuss, predict, reflect, and use a problem-solving approach. Teachers will often play a facilitating role guiding students through the design process and integrating technologies to create and test solutions through various types of assessment. More research on integrated

STEM education should be completed that carefully evaluates best practices specifically in this context (Stohlmann et al. 2012).

The TRAILS professional development model begins by grounding teachers in "conceptual understanding of integrated STEM education by teaching key learning theories, pedagogical approaches, and building awareness of research results of current secondary STEM educational initiatives" (Kelley & Knowles 2016, p.98).

2.2.10.3 Demand of STEMs

The evidence cited by educators who feel STEM education does not need to be emphasised in K-12 education (Charette 2013; Salzman et al. 2013) fails to take into account that it is not just the STEM degree that is important. The skills that students acquire while pursuing the degree are skills that can be extrapolated to work done outside of the classroom (Baran et al. 2016; Jones 2014; Sahin & Top 2015). Additionally, research indicates that proper implementation has a positive impact on teachers' perceptions of the program. Also, research suggests that skills and knowledge acquired throughout instruction of STEM curriculum can positively impact students' performance on Common Core State Standard assessments.

While researchers may argue that the job outlook for STEM graduates is perceived to be better than it actually is, a counterargument can be made regarding the positive impact a STEM program can have on an individual regardless of what occupational field he or she ultimately ends up in. Baran et al. (2016) found that STEM education provides students with skills and knowledge that they will need to be successful later in life. STEM education is a rigorous program that provides students with ample opportunity for collaboration and making real-world connections. Both of these skills are sought after in most job markets around the world (Sahin & Top 2015). Jones (2014) argues that students involved with STEM-based programs are intrinsically motivated to be successful and hold themselves more accountable regarding academic needs and expectations.

Charette (2013) noted that there are differing opinions as to what constitutes as a STEM job. This aligns with her claim that job market statistics can be swayed based on a researcher's interpretation of data collected relating to employment percentages. Furthermore, Salzman et al. (2013) found that many of those STEM graduates had taken job opportunities in other fields, not because of limited opportunity, but because opportunities in other job markets were better paying jobs. This finding may suggest that individuals with a STEM background are at least as equipped, if not more equipped, than those individuals without to compete for quality jobs regardless of which job market it may be in.

2.2.10.4 STEM Skills Jobs

In addition to achievement gaps for minority students, other concerns in the STEM education pipeline, particularly in the K-12 segment include teacher quality, academic achievement gaps of all students, performance in "international assessments Program for International Assessment (PISA)", and "Trends in International Mathematics and Science Studies (TIMSS)", as well as the comparative position of the U.S. in the global STEM education (Gonzalez & Kuenzi 2012; U.S. Department of Commerce 2012). A lack of student engagement in STEM activities results in lower motivation in STEM learning, lower academic achievement, and reduced efficacy in the use of meta-cognitive strategies. This impacts the developmental processes of STEM identities, which relate to self-concept and self-efficacy, particularly for women and minorities. Ultimately, these factors influence students' interest in STEM activity and education and the decision whether or not to pursue post -secondary education STEM disciplines.

In the United States there is substantial concern over the decline in U.S. performance in international measures of learning in science and math such as the Program for International Assessment (PISA) and Trends in International Mathematics and Science Studies (TIMSS) (U.S. Congress Joint Economic Committee 2012; U.S. Department of Commerce b 2012). Education, a crucial link in the STEM pipeline, is an important conduit to skilled STEM workers. Economists, entrepreneurs, legislators, and policy makers decry not only the gaps in STEM skills, but also skills gaps between the workforce and educational outcomes (Bosworth et al. 2013). The implications of poor performance on the PISA test are important because "… as the National Science Foundation (NSF) noted, the PISA tests … 'emphasise students' abilities to apply skills and information learned in school (or from life experiences) to solve problems or make decisions'" (Lehming et al. 2010, p.2). "Disadvantaged students show less engagement, drive, motivation and self-beliefs than advantaged students" (Organisation for Economic Co-operation and Development, n.d., p.5). "There is a need for more effective communication between the education community and business community to determine what students need to know and be able to do to be successful in the workforce" (Kentucky Department of Education 2013, p.1).

2.2.11 Challenges in STEM Implementation

Proper implementation of a new program can help to quell, or at least minimise, the negative perception of a STEM program for educators. Research suggests that professional development can ease the transition into a new program (Sunyoung et al. 2015). These researchers expand upon that by emphasising the importance of relevant and quality professional development. Simply providing professional development opportunities does not guarantee that the implementation of a program will be effective. Instead, unannounced observations and teacher-driven professional development sessions should be used to enhance the quality of STEM education and to alleviate some of the stress that accompanies new educational reform (Sunyoung et al. 2015).

There are several challenges that affect introduction of STEM programs in schools, school districts and cross the states. These same challenges also affect how states introduce STEM in other countries that are striving to have STEM programs. Saudi Arabia is one of the countries that started working on STEM program, and one of the primary challenges is to successfully implement integrated STEM at various levels, be it at elementary, middle, and high school/K-12 levels or tertiary.

Preliminary research related to implementation of STEM programs suggest that teachers and teachers “valued the integration of mathematics, science, and technology education and recognised benefits associated with this approach” (Berlin & White 2012, p,9). However, they also recognised that “the integration and implementation of mathematics, science, and technology is a difficult endeavour with many obstacles and challenges” (Berlin & White 2012, p.9), and some of these perceived obstacles are:

- Funding in K-12 specifically designated for STEM is reported to be insufficient.
- Pre service Teacher preparation and Professional development for STEM teachers is insufficient (more so, in countries trying to develop STEM programs): Based upon a review of teacher education reports related to the integration of science and mathematics, Berlin and White (2012) suggest that teacher preparation and integrated science and mathematics education is laden with obstacles or barriers including theoretical and epistemological differences; content and pedagogical content, and instructional context and its needed knowledge; teacher perceptual context of integration and beliefs; school and administrative structures; assessment practices; and appropriate instructional resources (Frykholm & Glasson 2005; Lehman 1994; Pang & Good 2000; Wicklein & Schell 1995). In the face of these challenges, however, is a consistent vision of the need to implement the integration science and mathematics and prepare teachers to make these connections. This means that teachers will need more

exposure to specific concepts, processes, and skills in STEM that are similar, comparable, corresponding, or synergistic to develop a deeper understanding of content across STEM integration (Berlin & White 2012).

- Lack of STEM education in foundational levels (K-12): Although this is found in some other countries, integrative STEM is not found in Saudi Arabian and UAE school systems. So, even if this is a common category in general, since there's no integrative STEM in Saudi Arabia OR UAE at these stages, it is difficult to discuss it intelligently as we are yet to see or experience integrative STEM at K-12 grade schools. Schools only have Science and Mathematics.
- Teacher Attitude towards STEM: Teacher attitude can be an obstacle when it impedes teacher perception and readiness to function. A study by Berlin and White (2012) found that "the prospective teachers moved more toward a more realistic understanding of integration that it is somewhat difficult to plan, design, and implement integrated STEM due to attitude" (p.2). The lack of positive attitude or familiarisation to STEM integration at any stage can create and bring fear in teachers. This can affect teachers' attitudes and with all likelihood may not want to participate in STEM programs even if it is implemented in the school curriculum. Historically, some teachers resented technology, and that affected their students and their teaching as that was manifested in the generational gap between students' technology use and teacher's rejection of its use for instruction.

Stakeholders bring up an unignorable fact when they address the issue of financial challenges that accompany the implementation of a new program, specifically one in the STEM field. With that being said, there are a number of things that can be done to relieve this concern. Many major corporations are looking to help by awarding grants to participating programs. Companies such as Honda, Toshiba, and Lockheed Martin have all provided generous funding to STEM programs around the country. This demonstrates just how important these major companies feel STEM education is. Of course these are just a few examples of businesses that are involved.

The U.S. Department of Education has also gotten involved by issuing a Dear Colleague Letter to help districts and other stakeholders maximise the federal funding allocated in the field of STEM education (U.S. Department of Education 2016). The letter details how student access to STEM can be increased through other grants made available as a result of a five-year STEM Education strategic plan. The letter also states that schools and local educational agencies (LEAs) are able to leverage funding to do things such as increase access to rigorous STEM work. Some schools are eligible to use title I funding for STEM field trips. Additionally, funding can be awarded to districts for recruiting and training STEM educators to help develop effective STEM pedagogy in the classroom.

Although there are concerns over the effect of an integrated program such as a STEM model (Croft, Roberts & Stenhouse 2016), there is evidence that integrated programs do not negatively impact assessment scores. In one study, researchers integrated geometry into a family consumer science class. One class received their instruction in the two areas independently of one another, while the other class received integrated instruction of the two subjects. The researchers did not find a significant difference in pretest or posttest scores between the two experimental groups (Johnson, Dodor & Ball 2015).

Despite the resistance to change that is common amongst people and the inevitable complications or roadblocks that will arise as a result of STEM implementation, it seems that it is imperative that schools take a hard look in this direction. Science, technology, engineering, and mathematics are a major part of human culture. While it is true that student participation in these programs may not always lead to a career in a STEM field (Charette 2013), the fact remains that they will benefit in other areas as a result of their participation (Baran et al. 2016; Jones 2014; Sahin & Top 2015).

According to the framework for K-12 science education, science, engineering, and technology all need to be understood in order solve many of our most pressing needs and issues in the world today (Quinn, Schweingruber & Keller 2012). Furthermore, the framework emphasises some of the concerns in traditional science education today, which is to say that the standards dictate a wide breadth of the knowledge without much depth. A more organised and coherent approach for science instruction, not unlike what STEM education programs are suggesting, can allow students to strengthen their knowledge, rather than just come away with fragments of information across several areas (Quinn, Schweingruber & Keller 2012).

The committee involved in developing the framework for K-12 science education concluded that science and engineering education should narrow their focus and emphasise deeper meaning within their instruction. They acknowledge that this can be done through crosscutting concepts while allowing students to build and revise their own knowledge through scientific inquiry (Quinn, Schweingruber & Keller 2012). Crosscutting concepts describes the process of highlighting fundamental knowledge or skills across multiple disciplines (Quinn, Schweingruber & Keller 2012). Crosscutting concepts, as described in the framework for K-12 science education is very similar to the process of integrated learning that is a focal point of STEM education (Asunda & Mativo 2015). The integrated learning model has been shown to foster the 21st century skills needed to be successful later in life (Baran et al. 2016).

2.2.12 UAE Education System

The UAE sits on the north-eastern area of the Arabian Peninsula, "bordered by Saudi Arabia to the south and west and by Oman to the east and north" (CIA 2014, p.1). The country is made up of seven emirates: "Abu Dhabi, Dubai, Sharjah, Ajman, Fujeirah, Ras Al Khaimah and Umm Al Quwain" (CIA 2014, p.1). Abu Dhabi is by far the largest emirate, occupying 85% of the UAE landmass. The UAE is unique in the sense that the local native population is a minority. The country has a population of "approximately 4.5 million people, of whom less than 20% are native Emiratis" (p.2). The population is overwhelmingly made up of expatriates from the South Asia region choosing to live and work in this country for limited periods; approximately 8% of expatriates are Westerners (CIA 2014).

Abu Dhabi is an emirate of distinct diversity, terrain, people, traditions and ambitions. It has a rich heritage governed by a deep-rooted respect for its past, which guides the present and is influencing its future. The late leader Sheikh Zayed bin Sultan Al Nahyan was revered by his peers and adored by the people of this country. As UAE's president for 33 years and ruler of Abu Dhabi from 1966, Sheikh Zayed was responsible for unifying the disparate emirates and for the major economic and social advances both in Abu Dhabi and throughout the UAE; his vision laid the foundation for today's modern society (Warner & Burton 2017).

When the UAE was established in 1971, the Emirates had 74 schools, and those choosing to pursue a higher education were obliged to travel overseas. More than 40 years later, the UAE is making progress toward its goal of competing with countries such as China and Singapore, which have all invested heavily in establishing top-tier research universities (Mahani and Molki 2011).

Some number of foreign universities was attracted to the UAE by what they believed to be easy money generation in a wealthy country (Warner & Burton 2017). Consequently, they failed to perform their due diligence regarding setting up a campus in the UAE and proceeded without adequate market research. Knight, Tait and Yorke (2006) alternatively argues that "universities not in the for-profit sector are more typically motivated by the desire to expand their research and knowledge capacity and increase cultural understanding" (p.5).

The National vision in the UAE aims to "make the UAE one of the best countries in the world by the year 2021" (p.3). A need to translate the Vision into reality has been one of the most challenging yet inspiring decisions that map the national priorities on one hand and the strategic planning on the other in order to represent the required actions across all the governmental sectors (Warner & Burton 2017).

The National plan aims for the UAE to achieve a leading position in creating a cohesive society that values the preserved identity and the unique culture and heritage of the Emirates. Ideally, STEM has the potential to permit innovative ways through which the beliefs and values can be preserved; this can be done by learning about cultural identity, thus, leading to the learners preserving their traditions. It also aims to place the UAE in the top destinations that promote and manage entrepreneurship initiatives at various levels and make its nationals active participants in the economy of the country. Furthermore, the Agenda goes all-out to implant an entrepreneurial culture in schools and universities to nurture leadership, innovation, creativity, and ambition. This will ensure that the UAE follows bold steps towards becoming among the best in the world in luxury, happiness and business development (National Research Council 2014).

Education has also become in the heart of the National agenda, Smart systems and devices are the basis for all, projects and research. An emphasis has been put on the development of the holistic model of successful citizens of the future in order to shape their personalities and their future. Given that broader context, policy makers forcefully argue that to ensure human development, analytical experts should understand the policy and an implementation framework for STEM in UAE schools (Tabari 2014).

The education system of UAE is currently going through a period of remarkable educational reforms. Over the last few years, UAE has pursued the policies which are in correspondence with not only its neighbour countries, but the wider Middle East and MENA region as well as most of the countries around the globe. Through UNESCO and OECD, the nation is pursing Global education reforms (GERM) to enhance the quality and access of education in UAE public and private schools. Also, there has been widespread expansion of private and public schools as well as other educational opportunities such as virtual education or distance learning which have also further pushed the efforts towards educational reforms in UAE. The World Bank (2014) has pointed that MENA region has achieved several milestones in their educational reforms including reduce illiteracy, increased focus on science and technology education, increased access to the point of universal education for both male and female thereby reducing gender gap where any gender was outperforming the other, and greater financial investment and support from businesses, industries, and local governments (Warner & Burton 2017).

In pursuit of UAE Vision 2021, Highness Sheikh Mohammed Bin Rashid Al Maktoum, announced mechanism in 2014 to achieving the national agenda. The central objective behind national agenda is establish the first rate education system in UAE through which both private and public will be converted into platforms of small learning environments where both theory and practical is taught. There are eight pillars of this national agenda which are considered as foundations for the future development and reforms of education in UAE. These eight pillars are: "education, healthcare, economy, police and security, housing, infrastructure and government services" (Warner & Burton 2017, p.16). The education, being the most important of these pillars, further includes the indicators, which will monitor the progress of achievements towards national agenda. These eight indicators are:

> "1) To be among the top 20 countries with highest performance in the Program of International Student Assessment (PISA) test, 2) To be among the top 15 countries with highest performance on Trends in International Mathematics and Science Study (TIMSS), 3) To ensure that all schools (public and private) in the UAE have high quality

teachers, 4) To ensure that all schools (public and private) have highly effective leadership, 5) To ensure that 90 percent of students in the ninth grade of public and private schools have a proficiency in Arabic, 6) To increase the high school graduation rate to 98 percent among Emirati students, 7) To provide early years education to 95 percent of children between age 4 and 5 through public and private preschool provisions, and 8) To eliminate the need of Emirati students having to complete a foundation program to qualify them for university entry." (Warner & Burton 2017, p.1)

The educational reforms of UAE are inherent within these above indicators which focus on better preparation of students in schools at all stages of their education, high standards of international scale, greater accountability among teachers and school leaders in the sector, and improved professionalism among teachers. These goals can, therefore, summarized into four categories, which are illustrated in Figure 3 below. These goals are considered the obvious synergies among the above eight indicators for the educational reforms in UAE (Warner & Burton 2017).

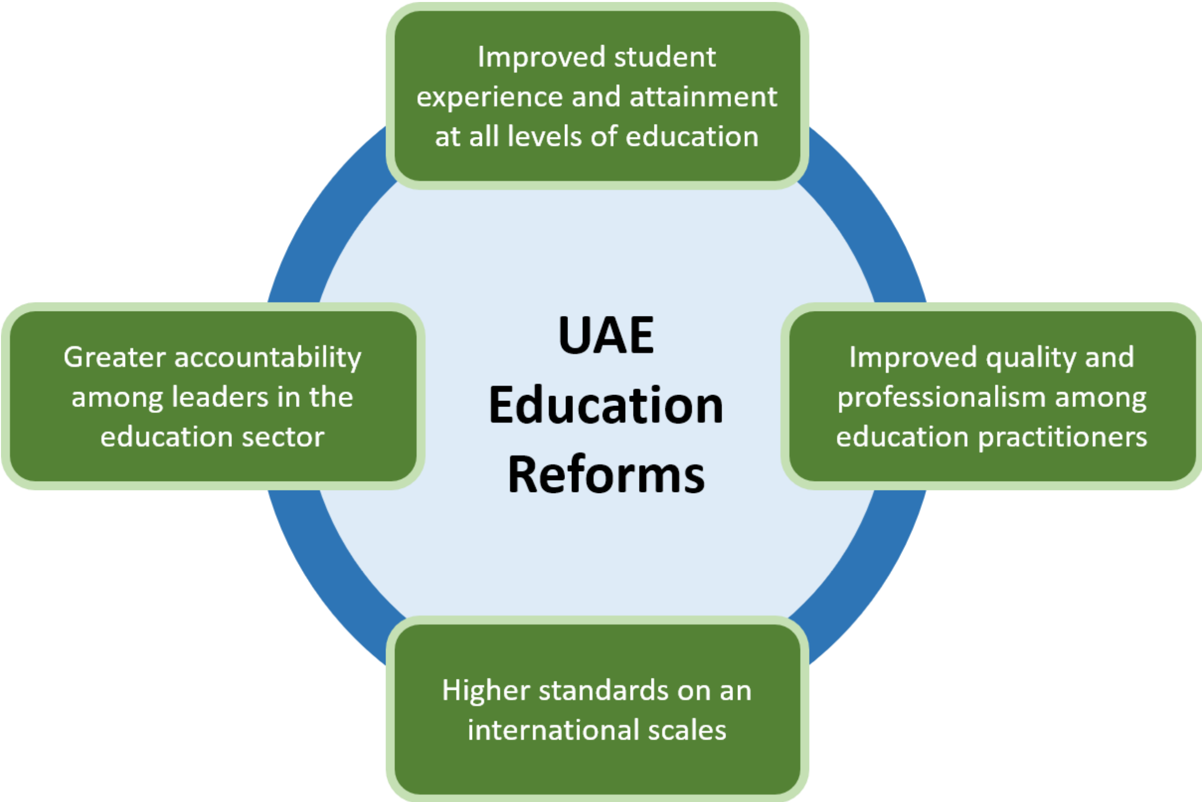

Figure 2: Focal points of UAE Education Reform 2016

Source: (Warner & Burton 2017)

2.2.13 STEM Education in UAE

STEM has been introduced formally and informally in education of UAE over past few years with light focus and coverage (Mahil 2016). However, the demand of STEM in education of UAE has increased recently due to government response to UAE vision 2021 as well as to meet the expectations of diverse economy which is calling for more STEM related professions and sectors in UAE economy especially in burgeoning sectors like science investigation, engineering, and renewable energy in the country. Makhmasi et al. (2012) pointed that the recent STEM initiatives in the country like “Innovation Hub”, which were launched by Al Bayt Mitwahid Association in collaboration in Google has given lots of mediate coverage to STEM education in UAE. The project was launched in Ras Al-Khaima emirate with focus of introducing STEM+ lab curriculum in the schools. Makhmasi et al. (2012) pointed that this is also considered to be first official STEM initiative in the UAE.

With the concentrated efforts from UAE government to strengthen and diversity its oil-based economy, the country has seen the surge in the educational reforms which were highly concentrated on teaching science, technology, engineering and mathematics subjects. The projects like, Smart Learning Programme (SLP) with a similar, albeit more ambitious, vision, has also been introduced in the recent past however, the schools in UAE require more practical knowledge in science and technology subjects, thereby making room for STEM educational reforms (Pennington 2014). Compared to other Middle East countries, UAE is not a leading contributor in technology and science developments given its economical and regional importance. While there have been continuous discussions over the nature, scale, the extent to which there is lack of science and technology developments, majority of experiences have common consensus that the problem is real and growing with the passage of time. Because of lowering trend of STEM in UAE, it is believed that students are mostly enrolling in degrees which are not fruitful for the development of country and will ultimately affect the workforce available for the businesses and industries. Hence, under the UAE Vision 2021, the educational system in UAE needs to evolve and must provide highly talented STEM workers to reach its vision of becoming innovative and self-sustaining economy. Through concerted efforts aimed at diversifying and strengthening the rising oil-based economy, the UAE has begun revamping its education system, particularly in STEM subjects (Makhmasi, Zaki, Barada, & Al-Hammadi, 2012). However, Makhmasi et al. (2012) assert that while STEM subjects are taught by teachers and schools with utmost vigour, interest, and high aspirations, it does not ensure that students will enrol and major in STEM fields and will becoming productive and innovative members of STEM professions. This is due to many challenges and barriers which might influence the choice of students to study for further education and for future career aspirations. Hence, it is important to fulfil this bridge by bringing more awareness of STEM in UAE society through integrated STEM education framework which focuses on all stakeholders in the society (Makhmasi et al. 2012).

Because there is dearth of available in-depth literature and studies regarding STEM in UAE, the current research can be considered as a starting point that intends to determine the policy recommendation for the implementation of integrated STEM Framework in UAE schools and thereby intends address the gaps and the quality issues by understanding STEM advancement, mainly in areas such as stakeholders planning for interconnectedness between sectors and partnership with community and other sectors curriculum and level of integration, STEM job skills and competencies, teachers preparation and professional development, delivery, and workforce demands.

2.2.14 Policy Making in STEM Context

Educators often had to contend with rapidly changing, sometimes conflicting, education policies (Hall & Hord 2006; Hargreaves & Shirley 2009, Mitchell, Crowson & Shipp 2011). Central to process studies was the focus on who was involved in the policy process and how these policy actors interacted with other policy actors, structures, and contexts as they moved through the decision making process (Smith & Larimer 2009). These stages were generally identified as policy definition, agenda setting, policy formation, policy implementation, and policy evaluation (Gerston 1997; Sabatier 2007; Smith & Larimer 2009; Birkland 2010). The policy process began with how policy actors framed particular problems (Fowler 2000; Rushefsky 2002; Jones & Baumgartner 2005; Smith & Larimer 2009). Process scholars focused on how public problems wove their way through varying stages of the policy process, asserting that development of public policies could not be separated from the political sphere (Wirt, Mitchell & Marshall 1988; Lasswell 2003; Colebatch 2009).

Early policy studies focused almost exclusively on the analysis of individual policies using rationalist and empiricist approaches (DeLeon 1998; Birkland 2010; Sapru 2010). The rationalist approach assumed that policies could be understood in the same way as the physical and natural sciences (Yanow 1996; Fischer 1998). This approach failed to recognize that the development of policies (policy making) was embedded in a political/social world (Colebatch 2009; Stone 2012). The policy process was complex, involving a variety of multi-level actors and institutions, embedded in an environment abounding with rules, rituals, conflicting values, power struggles, and governmental structures (Fowler 2000; Sabatier 2007; Smith & Larimer 2009; Birkland 2010), and driven by issues that were framed or socially constructed by policy actors (Fowler 2000, Birkland 2010).

Easton (1953) described policymaking as the "authoritative allocation of values and resources for a society" (p. 130). Iannaccone (1967) asserted that educational policies were the product of political activity. Education was an often-contested area of policy (Wirt & Kirst 1989; Tyack & Cuban 1995; Stone 2012). Policy choices were a reflection of cultural values (Marshall, Mitchell & Wirt 1989). Louis et al. (2008) contended that a state's political culture was a "significant mediating influence" on educational policymaking and that research on how political culture influenced education policy had been lacking (Louis et al. 2008). Critical to understanding the policy process was understanding how dominant cultural ideology was translated into policy (Heck 2004).

Studies in which researchers utilized the cultural lens, were process oriented and constructivist in nature, and shifted the focus away from the study of static systems to the dynamics of change (Heck 2004, p. 82) which is also related to Vygtosky's social development/sociocultural theory. Using the cultural approach, researchers focused on how policy actors created shared meanings, how shifting contextual settings influenced how groups interacted with formal institutions, and how individuals and groups exercise power to influence policy. Heck (2004) maintained that the utilization of the cultural lens in education policy studies worked because of four conceptions related to education. These conceptions included: "education was considered a state function; patterns of activity developed over time reflected state policy making preferences; state governments had their own unique political traditions; and cultural values were often, directly or indirectly, embedded in politics." (p. 82). Marshall, Mitchell, and Wirt (1989) developed a taxonomy of educational policy domains, which they titled State Policy Mechanisms (SPM). These domains provided a framework for examining what types of policies received attention from policymakers. Seven policy domains were identified: "school finance, school personnel training and certification, student testing and assessment, school program definition, school organisation and governance, curriculum materials, and school buildings and facilities" (p. 60-61).

Public policy is the government action toward a public issue, concern, or problem to which people seek answers and resolution (Shafritz, Layne & Borick 2005). With STEM jobs growing three times faster than non-STEM jobs, the lack of STEM talent in the UAE is the growing concern for the quality of education. Employees in STEM-related fields are good for the health and economy of Arkansas as STEM workers earn 26% higher wages than their non-STEM counterparts (Langdon et al. 2011).

Although efforts are continuing to introduce more STEM learning into existing K-12 curricula, the impact of high stakes for standardized testing and educators who are not adequately prepared to teach and integrate STEM into their curriculum and instruction, is hindering this process (Brophy et al. 2008; Dejarnette 2012). Research shows that elementary teachers lack the skills to teach children the most abstract concepts in STEM and thus, "they need support to find ways to incorporate more hands-on, inquiry-based activities into the math and science curricula” (Dejarnette 2012, p.12). Research also suggests that it is very likely that elementary teachers who introduce students to a STEM integrated curriculum that incorporates interactive problem-solving activities, can increase children’s interests in these subjects which may lead to increased interest in students choosing to enter STEM careers (Dejarnette 2012; Katehi, Pearson & Feder 2009).

Education, a crucial link in the *STEM pipeline*, is an important conduit to skilled STEM workers. Economists, entrepreneurs, legislators, and policy makers decry not only the gaps in STEM skills, but also skills gaps between the workforce and educational outcomes (Bosworth et al. 2013). Policy makers as well as business analysts are urging for change: Educators must emphasize science, math, and technology-related programs in K-12 curricula, invest more ineffective teacher education focused on science and math, and ensure that programs regarding career opportunities and requirements for graduation are geared for 21st century employment (Deloitte Consulting LLP 2005, p. 7).

2.2.15 Summary

The literature related to STEM education is diverse and it contains a wide variety of researcher perceptions. It can be argued that STEM education has a long history and has its roots in the past as seen by the three prongs that Kelley (2012) outlines. In literature, there are many conflicting ideas about what STEM education really looks like and how to actually successfully create/implement it (Brown et al. 2011; Householder & Hailey 2012; NAE 2014). Sanders (2012) and others point out many challenges to the implementation of integrated STEM. There are many different ways that the existing curriculum and departments can support integrated STEM education, but it must be intentional (Daugherty 2013; Duff 2012; Fulton & Britton 2011; Museus et al. 2011; Schmidt, Harding & Rokutani 2012; Tchangalova

2009). Numerous STEM projects that serve both the curricular and non-curricular realms are present in the literature. However, these projects report results for their particular project that may have little or no generalisation to other STEM education implementations. Most research identified in the literature related to integrated STEM education has not been conducted in a typical high school setting.

This literature review on the design of STEM professional development centres on how the implementation of the characteristics of effective professional development that is informed by the nature of STEM, particularly its interdisciplinarity approaches to teaching and learning, could impact teacher instructional practices resulting in increased student achievement in STEM disciplines. While the emphasis of the literature review is about teacher experiences and instructional outcomes, the reviewed literature does not specifically address the challenges of implementing interdisciplinary STEM approaches, especially in a middle school setting. An interdisciplinary approach to STEM integration might be an issue, considering that in the middle school setting, while critical thinking is encouraged, teaching and learning methods are often viewed through the lens of a particular instruction. Thus, professional development in this reform effort is needed to minimise adverse negative impacts when and if STEM professional development is implemented.

Very limited information has existed in the literature over the past five years regarding the integration of STEM content, particularly with respect to K-12 in United Arab Emirates (Makhmasi et al. 2012; Pasha-Zaidi & Afari 2016; Alyammahi et al. 2016; Mahil 2016). Due to each area’s important historical significance and the limited amount of research about the integration of STEM curriculum in UAE, the study does not limit the literature review to the past five years. The study uncovered a plethora of information on traditional K-12 programs, but very little information has appeared about K-12 programs or STEM integration in UAE over the past five years (Mahil 2016; Makhmasi et al. 2012; Pasha-Zaidi & Afari 2016; Alyammahi et al. 2016). Rather, combinations of current and older references are provided in order to provide a comprehensive review of all major areas covered in the study.

There is a limited amount of research available that identifies specific learning practices related to policy and an implementation framework for STEM in UAE schools. More research is needed to add to the body of knowledge to determine policy and an implementation framework for STEM in UAE schools that will assist in the integration of STEM curriculum into K-12 programs in UAE. The absence of this kind of research addresses the address the gaps and the quality issues related to its advancement, mainly in areas such as stakeholders planning for interconnectedness between sectors and partnership with community and other sectors curriculum and level of integration, STEM job skills and competencies, teachers preparation and Professional development, delivery, workforce demands. Very little literature exists about the definition and key components of an integrated high school STEM program and what makes it successful.

CHAPTER 3

METHODOLOGY

The purpose of this study was to develop a policy and implementation framework in the UAE by identifying critical elements of an integrated STEM education and key factors related to the implementation of an integrated STEM curriculum in K-12 schools in UAE. The research intends to address the following research questions:

RQ1: What are the international common models of effective instructional practices and policies of STEM education?

RQ2: What are the factors associated with STEM integration and implementation in UAE schools?

RQ3: In the light of the proposed STEM policy, what are stakeholders' knowledge and perception about the future implementation?

This chapter presents the methodology adopted for addressing these research questions. For mixed-methods research, pragmatism allows for multiple methods, varying worldviews and varied methods for data collection and review (Creswell 2013). The second section mainly specifies the site, sampling and participants, data collection tools, data analysis and ethical considerations.

3.1 Research Approach

The researcher employed Exploratory Sequential Mixed Methods (Creswell & Clark 2007) for this study. The purpose of this research method is that both qualitative and quantitative technique provides a better understanding of a study problem or issue than either approach alone (Tashakkori & Teddlie 2003). Exploratory sequential mixed methods according to Clark (2011) entail the collection of quantitative information followed by qualitative data to elucidate the quantitative findings. In context, the researcher settled on this study approach because quantitative information only provides a generalised picture of the core study problem while qualitative aspects delve into more analysis, which is valuable in explaining the posited general picture. This approach involved three phases. The first phase of this study was a document analysis to answer the first research question regarding the international common models of effective instructional practices and policies of the STEM education, using the thematic analysis on various documents such as those published regarding government policies and on articles about STEM education implementation and integration policy in different countries including the US, Japan, UK, and Australia among others. In the second phase, the researcher addressed the second research question of the study regarding what are the factors associated with STEM integration and implementation in UAE schools where teachers and coordinators in UAE schools are surveyed using questionnaire survey. In the third phase, the researcher examined third research question regarding what are stakeholders' knowledge and perception about STEM future implementation using semi-structured interviews with stakeholders (teachers, coordinators, school leaders, and administrators) in UAE schools. The classroom observations are intended to address the third research question. Figure 4 illustrates the research approach of this thesis.

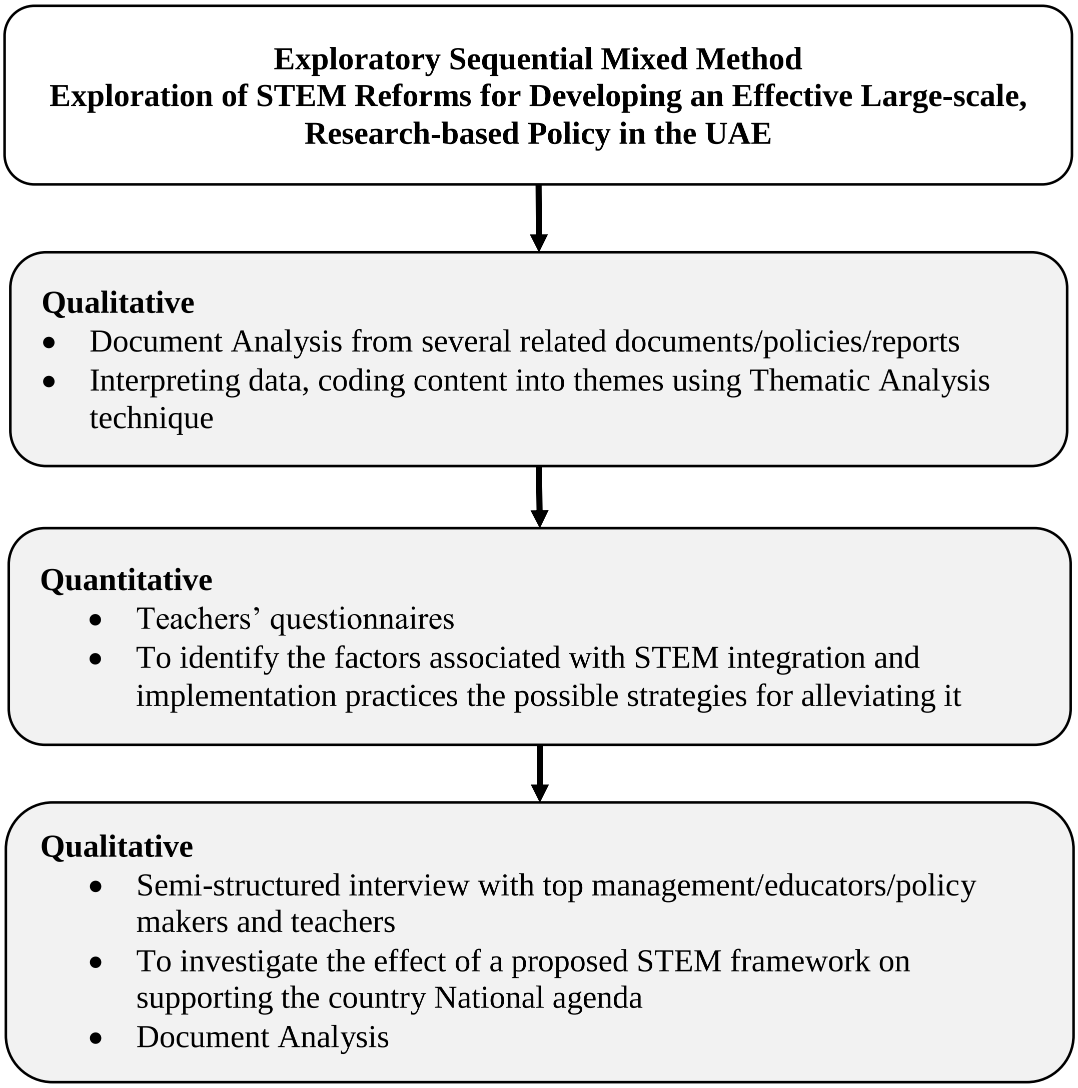

Figure 3: Research Approach for the Current Study

The above figure thereby illustrates the mixed method approach which is adopted by the researcher. Mixed methods design is a research strategy that involves "collecting, analysing, and mixing both quantitative and qualitative data in a single study or series of studies" (Creswell & Clark 2007, p. 5). The main concept behind the mixed methods research design is that "it is the combination of both quantitative and qualitative approaches provides a better understanding of research problems instead of using a single approach" (Creswell & Clark 2007, p.6). Creswell and Clark (2007) suggested mixed methods researchers to discuss philosophical foundations of the methods at the beginning of the study. Moreover, as they stated that mixed methods research comprises of philosophical assumptions which direct the data collection and analysis of qualitative and quantitative approaches, the historical development and the philosophical foundations of mixed methods research are briefly discussed here.

The paradigm that subjugated scientific philosophy until the late nineteenth century was positivism (Onwuegbuzie 2000). Positivism assumes that there is an objective reality. Positivists rely heavily on experimental methods in order to create a distance between the subjective biases of the researchers and the objective reality they study. Quantitative method is typically used (Guba & Lincoln 1994). While positivism is useful in traditional sciences, it was not as useful in social sciences. Thus, at the turn of the twentieth century, interpretivism emerged. The interpretivist assumes reality is socially constructed (Guba & Lincoln 1994). Thus, the aim of the interpretive research is to "understand how members of social group, enact their particular realities and endow them with meaning, and to show how these meanings, beliefs and intentions of the members help to constitute their social action" (Orlikowski & Baroudi 1991, p. 13). Pragmatism emerged since the 1950s. The core ontology of pragmatism is actions and change (Onwuegbuzie & Leech 2005). Pragmatists believe that "the world is changed through reason and action and there is an inseparable link between human knowing and human action" (Goldkuhl 2012, p. 7), and employ the method which "appears best suited to the research problem and not getting caught up in philosophical debates about which is the best approach" (Shirish 2013, p. 68). Realising every method has its limitation, pragmatists utilise any of the "methods and procedures" accompanying with "quantitative or qualitative research" (Shirish 2013, p.6). They recognise that "every method has its limitations and that the different approaches can be complementary" (Rampino 2012, p. 86). In sum, pragmatism allows the researcher to use all available approaches to understand the problem (Creswell 2009). As a philosophical foundation for mixed methods research, scholars (e.g., Morgan 2007; Patton 2002; Tashakkori & Teddlie 1998) have emphasised its significance in social science research for focusing on the research problem and then using mixed approaches to reveal knowledge about the problem (Creswell 2009). One of the philosophical basis for research that pragmatism provides is that it enables individual researchers to select “the methods, techniques, and procedures of research that best meet their needs and purposes” (Creswell 2009, p. 11).

Kuhn (1970) sees paradigm “as an accepted model or pattern, as an organising structure, a deeper philosophical position relating to the nature of social categories and social structures” (p. 23). Research is directly related by the use of the paradigm (Feilzer 2010). Pragmatism attempts to apply the most appropriate research method in order to investigate a particular question, theory, or category (Feilzer 2010). As a pragmatist, the researcher intended to choose the best methods and/or collect and analyse data to answer the research question. Likewise, mixed methods researchers consider pluralistic approaches for collecting and analysing data rather than accepting only one method (e.g., quantitative or qualitative) (Creswell 2009). Employing both qualitative and quantitative methods also allows the research question on teachers’ knowledge and practice regarding pragmatics to be examined in depth (Creswell 2013). In this sense, a paradigm guides research efforts, and serves to confirm itself to utilise the theories it already established (Kuhn 1970; Feilzer 2010). In the next section, the rational for selecting a mixed methodology is discussed.

3.2 Rationale for Conducting Mixed Methods Research

Because modern STEM-based initiatives such as those outlined by the National Research Council (2012) are new to the field of K-12 education, a broad base of empirical research does not yet exist. As such, the base of research that exists with regard to STEM integration in K-12 education is limited. The research that does exist is often qualitative by design (Berlin & White 2012; Brown et al. 2011; Gonzalez & Kuenzi 2012; Koirala & Bowman 2003; Niess 2005). What these studies, collectively, have often lacked are definitive answers to quantify teachers', stakeholders, and they have failed to provide insight as to design integrated STEM curricula. The current study sought to address the lack of quantitative analysis and add to the existing body of qualitative analysis pertaining to STEM integration in UAE schools by utilising a mixed-methods approach that synthesised the two methodologies to look for correlations between the data.

According to Knezek et al. (2012), Nadelson et al. (2013), Schmidt and Fulton (2015), and Stohlman et al. (2011), studies have been conducted on the integration of K-12 through methodologies founded on mixed-techniques. The benefit of a mixed-methodology approach lies in the researcher's ability to examine both qualitative and quantitative data to create a complete understanding of the topic (Creswell & Clark, 2011). Within a mixed-methods study, the researcher must take into consideration the overall design of the study, the level of interaction between qualitative and quantitative components, the priority of each type of data being collected and analysed, and the pacing of the study (Creswell & Clark, 2011).

The mixed method research design used in this study is most clearly related to what Creswell and Clark (2011) described as an Exploratory Sequential Mixed Methods Design. However, West (2009) argues that classifying a mixed methods study in line with a "prearranged neatly outlined and agreed-upon design" (p. 46) is not conceivable at all times. The arena of mixed methods design is still relatively new compared to other research methods design and there remain many issues yet to be resolved (Teddlie & Tashakkori, 2003). While a number of mixed method researchers have bolstered the emerging mixed methods design classifications (e.g., Creswell 2009; Creswell et al. 2003; Greene et al. 1989; Morgan 1998; Morse 1991; Patton 2002; Tashakkori & Teddlie 1998), agreement on design terminology and classification among mixed methods researchers is one of the many issues that remains to be framed and continually accustomed (West 2009). The study employed a mixed methods framework (Creswell & Clark, 2007; Creswell, 2009).

Creswell and Clark (2007) and Creswell (2009) explicate that exploratory design is employed when there is a need to first explore qualitatively. At a basic level, this design focuses on exploring a category (Creswell 2009). This design is typically used when "measures or instruments are not available, the variables are unknown, or there is no guiding framework or theory" (Creswell & Clark 2007, p. 75) and can be used to "generalise qualitative findings to different samples" (Creswell 2009, p. 211). As mentioned earlier in this chapter, it is important to develop a policy and an implementation framework for STEM in UAE schools that address the gaps and the quality issues related to its advancement, mainly in areas such as stakeholders planning for interconnectedness between sectors and partnership with community and other sectors curriculum and level of integration, STEM job skills and competencies, teachers preparation and professional development, delivery, workforce demands, and then administer a survey to a sample of the population. Hence, employing exploratory design is considered most appropriate for the current study. Within the exploratory design models, the researcher used the instrument development model (Creswell & Clark 2007) "which allows researchers to develop and implement a quantitative instrument based on qualitative findings" (p.53).

The use of mixed methods is based upon the paradigm of pragmatism (Onwuegbuzie & Leech 2005; Creswell 2009; Teddlie & Tashakkori 2003) to provide answers to the research question posited in the current study. Onwuegbuzie and Leech (2005) describe pragmatism as a philosophical lens which "rejects binary (either-or) choices suggested in traditional dualisms…facts vs. values, subjectivism vs. objectivism" and "replaces the …epistemic distinction between subject and external object with the naturalistic and process-oriented organism-environment transaction" (Teddlie & Tashakkori 2003, p. 74).

The use of mixed methods is inherently a methodological triangulation (Teddlie & Tashakkori 2003). Triangulation may also occur “at the levels of theory and analysis” (Andres 2012, p. 182). Data may be triangulated to corroborate or explain results from the primary method: in this case, the findings of the quantitative analysis. In this study, mixed methods were used to provide data for analytical triangulation, “…implemented to answer related aspects of the same basic research question” (Teddlie & Tashakkori 2009, p. 26). Qualitative measures were used to reveal emergent themes, concepts, and procedures, in order to build a theoretical framework for future practice.

3.3 Methods

This section presents description of the site, population, sampling and participants, instrumentation, data analysis, and ethical consideration of the study. The researcher then specifies the instruments of data collection and presents a brief overview of data analysis and the ethical issues that should be considered. In the coming sections, the researcher gave insights into a wider descriptions and justifications for each choice.

3.3.1 Site/Context

This section provides the details of site, sampling and participants of the study. The site of this study for primary data collection instruments for both qualitative and quantitative phases both is public and private schools in five emirates of UAE (Dubai, Abu Dhabi, Ras al-Khaimah, Ajman and Sharjah: See Table). The context of the research is to study both public and private schools so as to better understand the gaps and the quality issues related to policy and an implementation framework for STEM in UAE schools. A preliminary communication was initiated by the researcher in all the public and private schools in all these five emirates of UAE for a convenient context and accessibility purposes. This initiative helps the researcher to determine the private and public schools available and accessible for research in each of the five emirates and to determine whether the accessible schools provided information relevant to the context of the current study. The literature suggests that researchers should consult different channels and seek different sources and forms of communication to meet their data needs, based upon the circumstance of the study (Johnson & Christensen, 2014). The researcher interviewed one teacher or coordinator/head/administrator from each school. The study attempted to select participants for interviews that were diverse in many different aspects. Some of these participants had experience in the classroom within one of the STEM disciplines in UAE. Some of them had their primary teaching experiences in high school settings, some had their primary teaching experiences in middle school settings, while some had their primary teaching experiences in the elementary setting.

Table 2: Private and Public Schools from Five Emirates

Dubai		Public	Private
	Dubai GEM Private School		✓
	Uptown School		✓
	Al Eman School Dubai	✓	
	Dubai Sustainable City School	✓	
Abu Dhabi	Al Yasmina School	✓	
	Al Worood Academy		✓
	Al Dhafra Private School		✓
	St Joseph's School	✓	
Ras al-Khaimah	Ras Al Khaimah Academy		✓
	Scholars Indian School		✓
Ajman	Ajman Academy	✓	
	Habitat Private School		✓

	Al Ameer English School, Ajman	✓	
	Indian School Ajman		✓
Sharjah	Delhi Private School, Sharjah		✓
	Leaders Private School		✓
	International School of Choueifat	International	
	American Academy in Al-Mizhar		✓

3.3.2 Sampling and Participants

The target population of this study is K-12 schools in five emirates in UAE. Two delivery modes were used for the questionnaire, online and paper-based. In this regard, the adequacy of response rates obtained in the paper-based mode was anticipated to yield similar results to the electronic mode. Obtaining the appropriate approvals of schools, an email invitation with a covering letter and a link to the online survey was sent to an elected person in each participating school across the five emirates to recruit the participants for data collection. The administrator would send the questionnaire to their mail group by email and teachers responded to the survey. The responses reached directly to me. For hard copies, the questionnaire was distributed by myself to school teachers, in 8 public and 7 private schools, located in Dubai, Abu Dhabi, Ras al-Khaimah, Sharjah and Al Ain, 200 questionnaires were distributed to schools, convenient sampling was used and the response rate of the completed questionnaires was 105 depicting 52.5%.

The sample of participants for this study was determined using convenience sampling technique. In exploratory design, the participants in the qualitative phase of the data collection are the same participants as those in the second (quantitative) phase (Creswell & Clark 2007).

Since the purpose of the quantitative phase is to generalize the results to a population, a larger sample is used in the second phase. (Creswell & Clark 2007), the researcher included the participants from the quantitative phase. The sampling method for the second phase used snowball ball technique with researcher contacted every potential participant from every lead and contact found and the person is considered as the potential participant given their eligibility and availability to take part in the questionnaire surveys, interviews, and classroom observations.

The area of integrated STEM education was explored by talking to dedicated educational practitioners/experts who were selected using the theory of concept sampling techniques outlined by Creswell (2015) where the researcher "samples individuals or sites because they could help the researcher generate or discover a theory or specific concepts within the theory" (p. 207). In this study, the researcher looked for participants who were actively engaged in STEM education either they are teachers, leadership or stakeholders. The researcher included all those STEM education teachers and stakeholders who were identified as "experts" and "practitioners" of STEM in the field by public and private schools in five emirates of UAE. Based on the identification by the institutes, the researcher decided to conduct interview with at least 10-10 minimum eligible participants from teacher and stakeholder groups and conduct questionnaire survey with at least 100 minimum participants from teacher group. For document analysis and classroom observation, the researcher also decided to use at least 10 minimum documents for document analysis and 10 classroom observations in analysing the behaviour of class. As far as the eligible participants are concerned, a saturation strategy was used where the researcher continued to collect the data for interviews and questionnaire surveys until she reached the required sample. In this strategy, the researcher is not worried about the response rate, as the researcher is aiming for 100% response until the target is achieved. This means that researcher has not specified the target response rate for closing the surveys and continued doing the surveys until the target sample is achieved. The researcher hence continued the data collection until all the sample requirements are completed. This technique was used so that the researcher could remain unaware of who was or was not participating in the study.

3.3.3 Participants

As stated by Johnson and Christensen (2014), the research participants are the individuals who take part in the study. The researcher adopted purposive criterion sampling method in the qualitative phase for interviewing teachers and stakeholders and selecting the classes purposively which could provide classroom observations on STEM subjects. This signifies that the sample of the research should be tied to the study objectives. The researcher's focus in this qualitative strategy is less interested in finding about central tendency in a group and much more interested in the processes by which attitudes are constructed and on the articulate participants who advanced the research objectives far better than any other randomly chosen groups (Merriam 2009). The researcher contacted the eligible interview participants to fix the date, time, and venue of appointments and then conducted the interviews face-to-face individually with each participant. For classroom observation, the researcher contacted the principal, administrators and teachers to suggest the suitable date, time, and period where researcher can conveniently sit and observe the classroom environment, teaching practices, and stimulus of students without disturbing the decorum and learning of the students in the classroom.

For quantitative data, the teacher questionnaires were randomly distributed to all teachers in each of the sites. Generally, the researcher preferred to conduct the questionnaire survey on the same day on data collection of classroom observation. The selection criteria of teachers for questionnaire survey included those teachers who have been teaching in a STEM context in K-12 education for one year or more. The eligible participants constituted the main sample for drawing the quantitative and qualitative data.

3.4 Instruments

This section explains the instruments that are used to collect different data of the study. The instrumentation plan is typically defined as a number of composed decisions that are made to determine what, when and how data will be collected and analysed. These decisions guide the progress of the study and assist the researcher to answer the research questions adequately (Creswell 2013). The researcher in this study follows the Exploratory Sequential Mixed Methods Design through which qualitative instruments and the analysis specifically offered synthesis and holistic interpretation.

According to well-known STEM education researchers (Atkinson & Mayo 2010) on fresh approaches to STEM as a means for boosting the U.S. economy, there are a wide variety of instruments available that pertain to STEM education; however, the number of such instruments explicitly targeted at teachers, stakeholders, and students is very small. Even smaller is the pool of STEM-based resources aimed at teachers, stakeholders, and teachers. As such, many studies on STEM education have included modified versions of existing instruments that are designed to study content integration, teacher attitudes, teacher perceptions, stakeholders' perceptions, and student perceptions (Berlin & White 2012; Brown et al. 2011; Frykholm & Glasson 2005; Nadelson et al. 2013; Weld & Funk 2005).

Based on that, the researcher developed the instruments to empirically examine the most important variables, and delineate the conditions and implications for future policy and practice in the study. According to Merriam (2009), one of the most salient characteristics of qualitative research is its focus on describing, analysing and interpreting the pattern of practices and behaviours that allows a researcher to obtain a fuller picture of a category. In this regards, the coming sections primarily consider the qualitative data instruments which focus on data analysis from the key documents that support STEM education, interviews with teachers and stakeholders, and classroom observations. The second section mainly discusses the construction of the questionnaire with teachers and students as a quantitative data instrument in this study.

3.4.1 Qualitative - Document Analysis, Interviews and Classroom Observations

In carrying out the qualitative portion of the study, the researcher explores rich descriptions of three qualitative data collection instruments that are used to gather information for the study, and are described in details in subsequent sections: 1) Document analysis, 2) Interviews with teachers and coordinators, 3) Interviews with leaders, and 4) Classroom Observations.

3.4.1.1 Document Analysis

The researcher was looking for issues present in past literature, and also investigated matters that emerged during the research process. These issues included, but were not limited to: STEM in UAE schools, quality issues related to advancement of STEM, stakeholders planning for interconnectedness between sectors and partnership with community and other sectors curriculum and level of integration, STEM job skills and competencies, teachers preparation and professional development, delivery, workforce demands. Yin (2011) posited that archival documents can provide a support for a case, but do not tell the whole story. Therefore, the researcher used the available archival documents and my observations to shape the questions and discussions with participants. The documents included in this study were public policy documents that aided in implementation and integration framework of STEM in different countries.

When conducting a document analysis, it is important for the researcher to clearly identify the types of documents and their relationship to the research questions (Creswell 2015; Merriam 2009). As such, for the current study, any documents either explicitly or implicitly delving into STEM integration and implementation were studied. The primary tool of document analysis fits well within this study for two primary reasons. One, all research questions aim to understand information that is publicly available via student government association and institution web sites. This makes the document analysis method fitting for the study and efficient for the research process. Two, this study aimed to understand an issue within a large community college system. Thus, the study includes a large sample of institutions, making the process of remotely collecting and analysing data convenient and well organised (Merriam 2009). For the purpose of collecting data from documents, the researcher created a document analysis protocol. The document analysis protocol (Appendix 1) was adapted from an instrument created by Ortiz, Locks, and Olson (2016). Collecting documents requires locating them and also determining their authenticity (Merriam 2009). Thus, key elements of this protocol include the document type, document title, document source, document author, document objective or stated purpose, and which research questions it helps answer. The document analysis protocol also reflects the collection date and whether follow up is needed to clarify the document.

The document analysis was analysed using the thematic analysis. Thematic analysis is "the process of recovering the theme or themes that are embodied and dramatised in the evolving meanings and imagery of the work" (Van Manen 1990, p. 78). Braun and Clarke (2006) believe that thematic analysis can identify, analyse and report themes (patterns) within data. They outline the following steps to perform a thematic data analysis as shown in Table 2.

Table 3: Phases of thematic analysis

Phase	Description of the process
“1. Familiarising yourself with your data:”	“Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas.”
“2. Generating initial codes:”	“Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.”
“3. Searching for themes:”	“Collating codes into potential themes, gathering all data relevant to each potential theme.”
“4. Reviewing themes:”	“Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic ‘map’ of the analysis.”
“5. Defining and naming themes:”	“Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.”
“6. Producing the report:”	“The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.”

Note. Braun and Clarke’s thematic analysis procedure.

3.4.1.2 Interviews with Stakeholders (Teachers and Leaders)

As depicted in appendix 2 and 3, the researcher conducted interviews with teachers, leaders, district decision-makers, and coordinators. The interviews were semi-structured as recommended when there is a high possibility of getting only one chance to interview the participant (Bernard 1988, Seidman 2006). Interview questions were developed by the researcher after reviewing the available literature and themes of document analysis on STEM professional learning and development among teachers. In the next stage of model articulation process, the researcher shared the results from the exploration phase, and to gauge validity about the importance of the core components in the framework and policy of implementation. Stakeholders and school leaders were invited for interviews to verify the accuracy of the representations and how core these elements are to their school contexts. The interviews were conducted with the school leaders who are the most knowledgeable about their unique school model as identified by their schools.

The process of validation included a review of the interview questions by three experts in the field. This process was used to ensure the instrument was measuring what it is intended, that it represented content related to the study, that it was appropriate for the sample population in the research study, and that it was comprehensive. Interviews were conducted by the researcher through audio recording. The researcher listened to the recordings to transcribe, analyse and thematically code the interviews. The researcher reviewed all transcripts two times to ensure that all statements were part of the record. Descriptive categories were established for each interview question. An analysis grid was created using an Excel spreadsheet for each question. Main questions were placed at the top of the spreadsheet and denoted with lower case letters and interviewees (respondents) were indicated on the left side of the spreadsheet by capital letters. Substantive statements were extrapolated and entered into the designated categories on the spreadsheet. Frequency of response statements were indicated on the spreadsheet as well. As statements were entered into the spreadsheet, a reference mark was placed with the corresponding statement on the original transcript in an effort to document and locate statements. Patterns, emerging themes, and frequency of statements were denoted by the researcher (Bottge et al., 2009; Braun & Clarke, 2006). A pilot for the study was conducted using with four participants. It was determined that the interviews would last about one half hour. It was also determined that the pilot interviews would solicit responses which could be logically expanded in the study

The interviews conducted by the researcher attempted to follow a “script” while remaining flexible enough to follow the conversation of the interview (Creswell 2015). The script included the same introduction and open-ended questions together with follow-up questions being asked. This allowed the interview to flow freely to its natural conclusion. Creswell (2013) states that “the qualitative research process is emergent which means that the initial research plan put forth by the researcher “cannot be tightly prescribed, and that all phases of the process may change or shift after the researchers enter the field and begin to collect data” (p. 47). The questions can change, data collection methods can change, and the people interviewed can be modified during the study (Creswell 2013). Using this methodology, if additional insights are gained about a particular area related to integrated STEM education during the interview, additional questions off script were asked of the participants to gain further understanding of what they are trying to convey. These further probing questions became data to consider during the data analysis process. The researcher spent approximately 30-40 minutes on each classroom for recording check list items from the observation list.

Ideally, the researcher, after designing and ensuring the validity of the research questionnaire, the leaders and teachers were invited to the interview. After this, the investigator manually fielded the questionnaires to be filled by the leaders and teachers and recorded the interviews using an audio tape. Before undertaking these vital steps, the researcher took about 10 minutes to unravel the concept under investigation. After the interview, the researcher collected gave the participants adequate time to ask questions or make any comments (Alshenqeeti, 2014). Further, the investigator expressed gratitude towards having the interviewees and discussed ways to be contacted.

3.4.1.3 Classroom Observation Checklist

A classroom observation checklist is a technique utilised in monitoring the specific behaviours, skills, and dispositions of students in a classroom setting (Burke, K. (1999). The checklist provides formative evaluations that focus on certain behaviours, social skills, thinking, speaking, and writing skills. When crafting a classroom observation checklist, the examiner should establish the skills or behaviours to be observed. To ensure that the observation checklist addressed the relevant items in the study, the researcher drafted a table with two main columns where one indicated the key indicators and another depicted the level of implementation. In this case, the key indicator column included the expected concepts such as events that are evident in project-based learning in the STEM subjects, inquiry-based aspects, curricula and corresponding syllabi, classroom culture, and delivery of the suggested curricula. In light of utilising this research instrument, the researcher was aware of the issues with validity, reliability, and piloting. For instance, the observation process often requires the researchers to be present during the collection of information; the investigator plays vital roles during data collection. In this regard, researcher bias, which might emerge due to selective observation and recording or subjective interpretation of circumstances threaten validity and reliability of the information gleaned. In addition, piloting, in the case of observation, entails difficult tasks where the researcher must access a similar setting and populace like the one for an actual study so that problems with the instrument can be realised.

Teachers conducted observations of STEM instruction with the researcher and de-brief and dialogue occurred between the researcher and participants. The researcher took notes, analysed, and thematically coded them. Observation notes served as a qualitative data point for implementation of STEM instruction and provided an opportunity for reflective practice (a component of a professional learning team). An analysis grid was created using an Excel spreadsheet for each performance standard. Emerging themes were placed at the top of the spreadsheet and denoted with lower case letters and key phrases were indicated on the left side of the spreadsheet by capital letters. Substantive statements were extrapolated and entered into the designated categories on the spreadsheet. Frequency of response statements were indicated on the spreadsheet as well. As statements were entered into the spreadsheet, a reference mark was placed with the corresponding statement on the original transcript in an effort to document and locate statements. Patterns, emerging themes and frequency of statements were noted by the researcher.

Data collection included many classroom observations in random classes at three schools in Al Ain, Dubai, and Abu Dhabi. These observations involved field notes, reflections, and tentative interpretations of classroom lessons to gather data. For observations of the classroom, the researcher used an unstructured-observational tool with the focus of the study written on the tool to ensure targeted observations. The researcher kept and recorded track of the times between classroom activities, interactions between teachers and students, and check for actions that reveal self-regulating behaviours and cues that signal confidence levels. The researcher also looked for signs of growing or diminishing self-efficacy of teachers when engaged in the STEM subjects. The protocol of classroom observation is designed by the researcher and provided in Appendix 4.

3.4.2 Quantitative - Questionnaire with Teachers

A questionnaire survey with teachers (See Appendix 5) was conducted in order to address the second research question of the study regarding stakeholders' knowledge and perception about STEM future implementation. For the purpose of this study, a convince sample of teachers are surveyed using a questionnaire survey. The questionnaires are structured in representable, readable and clear look and carefully consider the placement of the questions (Johnson and Christensen 2014). The questionnaire of teachers is developed by the researcher based on the findings of qualitative data collection instruments including document analysis, interviews, and classroom observations. Participants responses are sought on a 5-point likert scale anchored between 5 (Strongly Agree) and 1 (Strongly Disagree). In addition, demographics information was collected from the participants on questionnaire surveys to distinguish the responses of the participants based on socio-demographic groups.

For designing questionnaire, once all the categories were identified, the researcher started writing the items. The emerged categories from qualitative phase served as the headings in the instrument. The questionnaires detailed an introduction in the beginning, which described what the interview was about, how it was going to be used, and approximately how long it takes to complete.

The initial questionnaire was designed as open for the teachers in order to avoid the direction bias which occurs due to labelling the questionnaire. However, these questionnaire items were labelled and stored by the researcher before deleting them for the final questionnaire. The redesign of the questionnaire items as per the categories is provided in Appendix 7. The questionnaire contains 44 questionnaire items which were categorised into six categories (Assessment, Connection; Curriculum and Delivery, Leadership, Pedagogical Content Knowledge, and Technology and Resources) as the components of STEM integration and implementation. Based on these identified categories, the researcher intends to examine the following hypotheses.

Modality of the questionnaire revolves around the concerns regarding the measures the questions are intended to achieve. The modality of this questionnaire is embedded in the validity types that have been explicated in the subsequent section. Firstly, the researcher considered content, face, and construct validity. Ideally, content validity, in this case, was completed to affirm that the details of the questionnaire are relevant and appropriate to the purpose of the study. It depicts that the content reflects the attributes investigated in the study and is ascertained by at least seven experts (DeVon, Block, Moyle-Wright, Ernst, Hayden, Lazzara (2007). In this regard, the research defined the theoretical framework of STEM policy and delved into vast literature review as well as seeking opinions from experts. Another ideology addressed was that of face validity where the researcher sought to establish whether the questionnaire is appropriate to the area and purpose of study. In context, this type of validity looks into the readability, feasibility, formatting, and consistency as well as clarity of the lingo used (DeVon et al. 2007). Typically, the researcher checked on the wording clarity, style and layout, and whether the audience will answers the questions drafted. Finally, DeVont et al. (2007) ascertains that construct validity focuses on the items that relate to the appropriate theoretical constructs. Here, this is a quantitative value to distinguish between invalid and valid ideologies. **Hypothesis 1**: "Assessment" factors Predicts the Overall Perceived STEM Implementation and Integration of Teachers

Hypothesis 2: "Connection" factors Predicts the Overall Perceived STEM Implementation and Integration of Teachers

Hypothesis 3: "Curriculum and Delivery" factors Predicts the Overall Perceived STEM Implementation and Integration of Teachers

Hypothesis 4: "Leadership" factors Predicts the Overall Perceived STEM Implementation and Integration of Teachers

Hypothesis 5: "Pedagogical Content Knowledge" factors Predicts the Overall Perceived STEM Implementation and Integration of Teachers

Hypothesis 6: "Technology and Resources" factors Predicts the Overall Perceived STEM Implementation and Integration of Teachers

3.4.3 Validity and Reliability of Teacher Questionnaire

The initial questionnaire was administered followed by the interviews. After the initial instrument was developed, it was administered to 25 teachers who participated in the interview. The initial stage of checking validity was conducted at one public and one private school in Dubai and Al Ain. The researcher met some teachers in Dubai and Al Ain individually at a site, and gave the initial instrument. During the interview, the researcher wrote down the notes.. Each item was assessed for clarity, aesthetics, relevancy, tone, length of time and needed for a response. The focus at this phase was on content-related validity (i.e., item validity) and generalisability of the initial instrument. After the survey was developed, it was tested for its reliability.

Creswell (2013) stated that "Cronbach's alpha has the advantage of being applicable when questions are small scales in their own right like the Likert scale questions found on many questionnaires" (p.5). Cronbach's alpha is often the reliability estimate of choice for survey research (Brown 2011; Cohen & Swerdlik 2010; Streiner 2003). As a general rule of thumb, a good alpha value is greater than .70; the researcher reviewed the questions again and examined if any items needed to be removed because they have an alpha value less than .70.

From the survey, numeric data was analysed. Data was entered into an Excel file, screened for any missing data, and was saved. After finishing the data cleaning, response rate and instrument reliability were calculated. Response rates were calculated before and after cleaning the data. For instrument reliability, Cronbach's alpha was employed and factor analysis was conducted using SPSS. While Cronbach's alpha shows internal consistency of participants, factor analysis result shows whether the questions are tied together asking the same construct. Then, descriptive and inferential statistics were calculated and analysed to answer research questions.

3.5 Data Analysis

In order to facilitate the triangulation process for the study, all forms of data collected by the same researcher which included document analysis of related documents of STEM, semi-structured interviews with teachers and stakeholders, questionnaire surveys with teachers and students, and observations of classroom instructions were analysed for addressing the research questions. The overall purpose of the analysis of this exploratory mixed method study is to empirically examine the best practices of STEM education in an attempt to design and conceptualise a policy for effective implementation and to develop a forward- looking decision making to spur the formation of a systematic STEM integrated framework in K-12 education in the UAE. Data was analysed quantitatively and qualitatively to address the guiding research questions and objectives of this study as follows in Table 3.

Table 4: Data Analysis Plan for Addressing Research Questions

Research Questions	**Qualitative/ Quantitative**	**Instruments**	**Data analysis techniques**
RQ1: What are the international common models of effective instructional practices and policies of the STEM education?	**Qualitative -** *Document Analysis*	• Document analysis from several related documents/policies/reports	Thematic Analysis using Content Analysis on MS Word
RQ2: What are the factors associated with STEM integration and implementation in UAE schools?	**Quantitative -** *Questionnaire Survey with Teachers and Coordinators*	• Questionnaire Survey with teachers •	Statistical empirical analyses including descriptive statistics, Pearson correlation, EFA, CFA, SEM, ANOVA, and Multiple regression analysis using IBM SPSS Statistics and IBM SPSS AMOS
RQ3: In the light of the proposed policy, what are	**Qualitative -**	**Interviews with Stakeholders** • Semi-structured interview with top management/educators/policy makers and teachers •	Thematic Analysis using Content Analysis on MS Word

stakeholders' knowledge and perception about STEM future implementation?	*1. Interview survey with key stakeholders (Teachers, Coordinators, School Leaders, and Administrators)* *2. Classroom Observations*	**Classroom Observation** • Field notes, reflections, and tentative interpretations of classroom lessons • Classroom observations of selected teacher STEM classes to determine classroom activities, interactions between teachers and students, and check for actions that reveal self-regulating behaviours and cues that signal confidence levels in STEM integration and implementation in UAE schools	Taking notes from the classroom observations.

In order to address the first research question, the researcher first examined and interpreted data and draw frequent themes related to international common models of effective instructional practices and policies of the STEM education. The researched used thematic analysis and applied six steps of Braun and Clarke's (2006) strategy to analyse and report themes (patterns) within data. The researcher used Content Analysis on MS Word qualitative software for thematic analysis. As denoted by Elo and Kyngas (20017), content analysis is utilised in both quantitative and qualitative aspects with either deductive or inductive tactics. In this case, the researcher used deductive content analysis since there was operationalisation of the structure founded on the past knowledge together with study purpose in testing theory. The process of content analysis incorporates preparation, organising, and reporting phases. Firstly, there is selection of units of analysis, which, in the current study is founded on themes. With regard to deductive content analysis, the researcher intends to retest the extant information in novel contexts, which encompasses testing models, concepts, and categories (Elo & Kyngas, 20017). The next step is establishment of a categorisation matrix and coding of the information pertinent to these categories. After the categorisation matrix, the information gleaned is then reviewed for coded and content for correspondence with the categories identified.

In order to address the second research question, the researcher analysed the responses of teachers from the questionnaire survey to explore the factors associated with STEM integration and implementation in UAE schools. The researcher applied both descriptive and inferential statistics to determine those factors, which are significant with STEM integration and implementation in UAE schools. In this regard, the researcher used IBM SPSS Statistics and IBM SPSS AMOS software to compute descriptive statistics, Pearson correlation, Explanatory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), Structural Equation Modelling (SEM), Analysis of variance (ANOVA), and Multiple Regression Analysis (MLR) to reach the concluding points.

In order to address the third research question, the researcher analysed the interview responses of various stakeholders (teachers, coordinators, school leaders, and administrators) to explore possible practices of STEM integration and implementation and then analysis on classroom observations. The researcher used thematic analysis and applied six steps of Braun and Clarke's (2006) strategy to analyse and report themes (patterns) within data. Further, the researcher used Content Analysis on MS Word qualitative software for thematic analysis. Following interview analysis, the researcher examined the data collected from the classroom observation list. Afterward, the researcher examined all the personal notes, field notes, reflections, and tentative interpretations during classroom lessons. These classroom observations were examined in light of document analysis, questionnaires, and interview data.

The researcher monitored classroom activities, interactions between teachers and students, and checked for actions that reveal self-regulating behaviours and cues that signal confidence levels in STEM integration and implementation in UAE schools.

As alluded to in the previous paragraphs, the information was gleaned from an Arab speaking sample populace that was also eloquent in the English language. Contextually, the respondents preferred to provide feedback using the English language because they are knowledgeable and their STEM skills were imparted through this communication channel. In this regard, the responses in English made it easier for the interpretation of the feedback from the participants. Since the current research was conducted and written in English, it was easier to directly commence the data analysis and presentation because the feedback was done in English as well; were it to be in Arabic, the researcher could start by interpreting the information before starting off with the analysis process. As such, providing feedback in English made it easier for the researcher to detail the findings, analyse, and interpret.

3.6 Ethical Considerations in Data Collection

Strategies were used to prevent coercion and avoid any conflicts of interest from arising. The target population was selected because the researcher had no connections or previous history with the schools, thereby reducing the changes of any conflicts of interest (Yin 2014). During the recruitment process, the researcher sent an email to her own email account with all potential participants blind copied to ensure anonymity and reduce possible coercion that may result from participant knowledge of other staff members being recruited (Yin 2009). Further, the researcher requested that participants not use any identifying names during the interviews to avoid conflicts of interest. The researcher adhered to the approved recruitment plan in which participants were not offered any monetary incentives or any other incentives that would coerce them into participation.

As the primary researcher, it was important to address my own individual biases. Assistance was requested from the committee to address any personal bias and any unforeseen situations within the data. At the completion of the investigation of documents, the researcher was careful to avoid assumptions from the data. The data were examined with accuracy using methods of internal and external validity, which are the "coin of the realm, experimentally and morally" (Christians 2011, p. 66).

The survey instrument was sent to school teachers, coordinators, leaders, and administrators in five selected, 8 public and 7 private schools, located at Abu Dhabi, Ajman, Al Ain, Dubai, Ras Al Khaimah, and Sharjah obtaining the appropriate approvals of schools, an email invitation with a covering letter and a link to the online survey was sent to an elected person (an informer) in each participating school to recruit the participants for data collection.

CHAPTER 4

DATA ANALYSIS AND RESULTS

This chapter of the study presents the data analysis of each research question using both qualitative and quantitative methods. The researcher first conducted document analysis from several related documents/policies/reports. The researcher first examined and interpreted data and draw frequent themes related to international common models of effective instructional practices and policies of the STEM education. The researched used thematic analysis and applied six steps of Braun and Clarke's (2006) strategy to analyse and report themes (patterns) within data. The researcher used Content Analysis on MS Word qualitative software for thematic analysis.

Subsequently, the researcher analysed the responses of teachers from the questionnaire survey to explore the factors associated with STEM integration and implementation in UAE schools. The researcher used applied both descriptive and inferential statistics to determine those factors which are significant with STEM integration and implementation in UAE schools. In this regards, the researcher used IBM SPSS Statistics and IBM SPSS AMOS software to compute descriptive statistics, Pearson correlation, Explanatory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), Structural Equation Modelling (SEM), Analysis of variance (ANOVA), and Multiple regression analysis (MLR) to reach the concluding points.

Following the document analysis and analysis of questionnaire survey responses, the researcher analysed the interview responses of various stakeholders (teachers, coordinators, school leaders, and administrators) to explore possible practices of STEM integration and implementation. The researched used thematic analysis and applied six steps of Braun and Clarke's (2006) strategy to analyse and report themes (patterns) within data. The researcher used Content Analysis on MS Word qualitative software for thematic analysis. Lastly, the researcher examined the data collected from the classroom observation list. The researcher examined all the personal notes, field notes, reflections, and tentative interpretations during classroom lessons. These classroom observations were examined in light of document analysis, questionnaires, and interviews data. The researcher monitored classroom activities, interactions between teachers and students, and check for actions that reveal self-regulating behaviours and cues that signal confidence levels in STEM integration and implementation in UAE schools.

4.1 Results of Research Question 1 - Document analysis

This section presents the results of first research question: *"What are the international common models of effective instructional practices and policies of the STEM education?"* In this regard, the researcher conducted document analysis using the content analysis method. This allowed the researcher to begin drawing themes based on which the researcher designed questionnaire, interviews, and classroom observations of the study (Bogden & Biklen 2007;

Creswell & Clark 2011). The documents within each phase of the study provided insight as to participants' perceptions, abilities, attitudes, and confidence in integrating STEM into their instruction.

To determine an appropriate starting point for preparing K-12 teachers, administrators, leaders, and policy-makers to integrate STEM, researchers should examine past studies that have prepared teachers for other types of curriculum integration. Because little research on STEM-specific integration exists in UAE, document analysis serves as an excellent starting point for policy makers in UAE who wish to drive the future of K-12 teacher STEM preparation. The findings of document analysis add to current literature pertaining to preparing K-12 teachers, administrators, leaders, and policy makers for STEM instruction and integration in UAE, which is valuable in the sense that STEM content is increasingly laced throughout the K-12 curriculum as states begin to adopt and implement the Next Generation Science Standards (Achieve Inc. 2013). Embedded within the Next Generation Science Standards is an emphasis on building STEM knowledge and skills; thus, it becomes imperative to accommodate for this shift in content by taking steps to ensure that the teachers, administrators, leaders, and policy makers who are being prepared today are equipped to handle the rigors of STEM-based curricula of tomorrow in the UAE schools. Yet, because STEM-based initiatives are so new in UAE context, a lack of significant research on K-12 teachers, administrators, leaders, and policy-makers STEM preparation exists. Thus, this study adds to the foundational platform for current and future research studies on K-12 teachers, administrators, leaders, and policy makers' preparation for STEM integration.

A need exists for teacher preparation programs to ensure that K-12 teachers enter the field with the ability to prepare students for STEM-based futures (Atkinson & Mayo 2010; PCAST 2010). Even so, federal initiatives that are pushing for STEM to be integrated throughout the K-12 curriculum (PCAST; National Research Council 2012) have come to the forefront of the field at a time when there is a lack of research on K-12 teacher preparation for STEM integration. Because of this, K-12 teacher education programs must now determine the best methods for preparing teachers for various levels of STEM integration while STEM integration is concurrently being defined within the field. Researchers have suggested that the most effective way to prepare K-12 teachers and leaders for STEM integration is to immerse them in relevant practice before their teacher education program has culminated (Atkinson & Mayo 2010; Bybee 2013).

There are several specific approaches for document analysis research (Hsieh & Shannon 2005). The specific document analysis strategy used in this study is known as directed content analysis (Cooper et al. 2016; Hsieh & Shannon 2005) which is also similar to Braun and Clarke (2006). Directed content analysis requires the defining of codes based on existing research and theory prior to conducting new research (Hsieh & Shannon 2005). The existing information on STEM integration and implementation components are the basis for a priori codes in this study. This strategy provides structure in analysing the various components of STEM that exist among the documents analysed (Miles & Huberman 1994). Through analysis of findings, existing and new coding categories helped create an applicable set of new data that can benefit practitioners and policy makers understanding of how STEM can be integrated and implementation using these successful models. Relying solely on those documents is important in order to meet the parameters of identifying and categorising consistent and relevant findings within the directed content analysis approach (Hsieh & Shannon 2005; Miles & Huberman 1994).

K-12 teachers, administrators, leaders, can practice the level at which STEM integration and policy makers may vary depending on factors such as the vision of the teacher education program and the perceived need within the field (Sanders 2009). Several researchers have explicitly called for a full integration of the four content areas of STEM within the K-12 curricula to mirror the current direction of the field (Brophy et al. 2008; Drake 2012; Rockland et al. 2010). To prepare for such a complex level of integration, K-12 teachers must first be provided with a foundational knowledge of content integration (National Research Council 2012). Next, K-12 teachers must be provided with the ability to apply their knowledge of STEM integration within learning experiences designed refine and extend their understanding of integration (National Research Council 2012).

4.1.1 Braun and Clarke's (2006) Six Steps of Thematic Analysis

This researcher performed thematic analysis according to Braun's and Clarke's (2006) model of analysis "which aims to identify, interpret, and report themes found within the data" (p.41). Braun and Clarke (2006) further defined thematic analysis as a "method for identifying, analysing and reporting patterns (themes) within data," and it "minimally organises and describes your data set in (rich) detail" (p. 6). Thematic analysis provided clarity about meanings of the raw data. This type of analysis "involves searching across a data set" in order "to find repeated patterns of meaning" (p. 15). This thematic analysis, as Braun and Clarke (2006) developed, allowed the researcher to commence inquiry toward the understanding of main components of STEM integration and implementation in K-12 education. Data obtained from qualitative generic thematic analysis allow a comprehensive foundation of understanding a global theme, supporting a researcher's themes (Aronson 1994). Braun and Clarke (2006) offer the following regarding qualitative thematic analysis procedures: "1. Familiarising yourself with the data, 2. Generate initial codes, 3. Searching for themes, 4. Reviewing themes, 5. Defining and naming themes, and 6. Producing the report" (p. 87).

The justification for utilising thematic analysis emerged from its alignment with the research questions. In answering “how” questions, thematic analysis was able to provide an effective process of identifying, interpreting, and reporting themes discovered within the data (Braun & Clarke 2006). The “how” questions pertained to perceptions; therefore, any data analysis procedures selected needed to uncover the deeper meaning within the participant experiences and responses.

The steps outlined in the thematic analysis provided a distinct prescription of moving from surface level to the underlying meaning within the data. When adopting this six-step process, the researcher begins with becoming familiar with the data, moves through the steps, digs deeper in each step of analysis, uncovers the themes, determines the connections, defines the themes, finalises the work, and produces the report (Braun & Clarke 2006). The thematic analysis process required substantial reflection on the purpose of the study and the research questions, refinement of the codes and themes, and data analysis (Patton 2002). Therefore, the reflection process allowed maintaining consistent focus on answering the research questions while data analysis focused researcher’s attention on participant responses. This combination proved effective at answering this study’s research questions.

Further, thematic analysis was also selected because it has the ability to delve into the data presented and provide in-depth elucidations (Patton 2002), especially when multiple sources of data were collected, such as in this study. Multiple sources of data were utilised to search documents for analysis. Thematic analysis was the most appropriate tool for gaining an understanding of the raw data, which were analysed and organised in order to produce a rich, thick description of the global theme (Yin 2009). Moreover, thematic analysis fulfilled the purpose of the study, answered the research questions, and provided narrative accounts of the global theme.

4.1.2 Selection of Documents for Document Analysis

The method used by the researcher is document analysis, wherein the researcher collected documents from STEM education websites. Searching for documents within STEM education websites assists in answering the first research question on the international common models of effective instructional practices and policies of the STEM education. Searching for documents within STEM education websites and other sources assists in answering the first and partially the second research questions on understanding of main components of STEM integration and implementation in K-12 education. According to Clark and Creswell (2014), document analysis is helpful in qualitative research and is often used through case study methodology to help the researcher understands the central topic of interest. In order to uncover the central topics of STEM integration and implementation, several relevant document types were collected and analysed in order to identify components of STEM integration and implementation in K-12 education. Only those documents were purposely selected which pointed out towards STEM policy education, integration and implementation. The documents were selected based on the criteria that they were up-to-date, published, and developed in the last five years, are based on committee work, reform reports, executive level etc., and provides the governmental or national interest towards the implementation and integration of STEM. The selected documents are highly important and relevant to contribute to the best factors that determine successful implantation of STEM. All these documents were purposely selected and hence they were in common in contributing to answer the first question of the research. These documents provide the insights of STEM integration from different countries. Also, these documents are relevant and of high importance to the context of the UAE since they offer the internationally recognised models of effective instructional practices and policies of the STEM education which policy makers in UAE can utilise to integrate and implement STEM in K-12 education. By understanding these models, the researcher can highlight that how these international reforms can be localised to UAE context of integration and implementation of STEM in K-12 education.

The researcher began with the first step to be familiarised with the data by immersing in each document's content. Repeated reading was incorporated to understand the content of each document related to components of STEM integration and implementation. The researcher then commenced to generate initial codes by extracting interesting segments of the components of STEM and placing them on a table that was arranged by level 1, level 2, and level 3 headings. The researcher "searched the coded data for commonalities of meaning and developed themes from collated codes". The researcher "created a table containing established themes, and all codes were implemented within the related theme". Eighteen STEM policy and research documents were selected from different countries like the US, UK, and Japan among others including STEM in UAE to examine the international common models of effective instructional practices and policies of the STEM education and gaps and quality issues related to STEM provision in the UAE. The names, purpose, and brief description of each of these ten documents are described in Appendix 6.

4.1.3 Thematic Analysis

The document analysis was analysed using the thematic analysis. Thematic analysis is "the process of recovering the theme or themes that are embodied and dramatized in the evolving meanings and imagery of the work" (Van Manen 1990, p. 78). Braun and Clarke (2006) believe that thematic analysis can identify, analyse and report themes (patterns) within data. The purpose of document analysis is to answer the first research question on the international common models of effective instructional practices and policies of the STEM education, using the thematic analysis on various documents on STEM education implementation and integration policy in different countries.

The model of thematic analysis developed by Braun and Clarke (2006) was used during data collection and analysis to address the research question. Data were gathered through selected documents described in previous sections, which were analysed and reported by the researcher. After reviewing the data and their commonalities and dissimilarities, the highlights emerged, which were considered initial codes or main items or recording patterns. Common initial codes were then clustered and implemented into overarching themed categories that were reviewed multiple times toward global theme development. Each theme was reviewed for accuracy of collation, and subsequently identified as thematic analysis of the STEM implementation and integration. The method was both positive and seamless. The six steps of thematic analysis were followed to properly analyse the data and accurately reflect the results. The steps include: "(a) familiarising oneself with the data; (b) generating initial codes; (c) searching for themes; (d) revising themes; (e) defining and naming themes; and (f) producing the report (Patton 2002)". Open coding, also known as initial coding, was used to identify, name, categorise, and describe the global theme. Axial coding was also performed to relate codes to each other. Further, open coding was used to separate, distinguish, condense, and remove codes to select the most appropriate codes to describe the global theme and answer the research questions (Yin 2009). During thematic analysis, the researcher also searched for codes across and within the population, as well as triangulated the three sources of data to increase data validity (Radhakrishna, 2007; Yin, 2009).

Step 1. Familiarisation with the data began during the data collection process. During the reading and review process of documents, the researcher created a Microsoft Word document for taking notes from each document relevant to the research questions being investigated for document analysis. While this particular process was not part of the six-step data analysis procedures described previously, the act of taking notes while read by the researcher enabled the researcher to produce the common codes/themes that might occur in the analysis in MS Word. This research is more acute in comprehension when information is presented visually; therefore, the quality of questions was enhanced as a result of visually displayed data. Moreover, typing ensured the researcher remained attentive to the specific content and data presented at the time, maintaining continuity and chronology during the review of document analysis.

Within an hour from completing review of each document, the researcher typed a reflection into the researcher’s journal. Information included a reflection regarding the review of documents as well as additional thoughts, biases, connections to other documents, and relationships to past literature (Yin 2009). While this was not directly part of the thematic analysis procedures, it contributed to the familiarisation with the data because the researcher re-read previous entries following every additional entry. Further, re-reading entries from documents kept within the dynamic and process of data familiarisation per data analysis agenda.

In addition to creating and reviewing the documents, the researcher became familiar with the past literature review (Braun & Clarke 2006). The researcher accessed the literature review in relation to initial codes being observed by her. The accomplished tasks for Step 1 of the six-step analysis process include completed review and reading of all the documents, collation of the ten documents of data analysis, and the identification of keywords or codes and possible information that may answer the research questions (Braun & Clarke 2006). A final reading through all of the data from all ten documents marked the conclusion of the first step of thematic analysis.

Step 2. The second step of thematic analysis pertained to generalising initial codes and conducting open coding in MS Word (Braun & Clarke 2006) that would highlight the components of STEM integration and implementation. This began with using the initial review codes typed in Word documents that contained the researcher's review from all sources of data. These documents were then printed in black and white to exclude the highlighted content and ensure a fresh look at the data. A green highlighter was used throughout the documents to highlight keywords related to STEM integration and implementation. Additionally, a red pen was selected to bracket lines or paragraphs that depict data relevant to the global theme, research questions, or study's purpose. Meanwhile, thoughts on potential patterns, codes, or units were written in the margins using a pencil, as exemplified in Table 4.

Table 5: Sample of Coding Process

Open Code	**Sub-Code**	**Pattern**
STEM outcomes	STEM learning	Integration
Project tasks	Project learning	Project-based learning
STEM initiatives	STEM programs	Connection to in and out programs

Table 4 depicts the sample of coding process used to arrive at the dominant and supplemental codes. During the initial open coding process, some axial coding was used (Yin 2009). For example, if the document stated "Incorporation," the researcher wrote "Incorporation" in the margins. However, the researcher decided to rename future instances of "incorporation" to "Integration," considering that "Integration" was also found within the data with the two terms being used almost synonymously in the passages. After generating a list of codes and keywords, the researcher began further refining axial coding with the purpose of consolidating, merging, separating, and removing codes, as well as distinguishing anomalies (Yin 2009).

The researcher initially identified 53 codes related to STEM integration and implementation. The codes were placed in two Microsoft Excel spreadsheets to establish frequency, allowing the seven most frequently encountered codes for each group to be identified. Additionally, with the seven codes identified by each population, the researcher compared the two spreadsheets to assess frequency across the documents. As a result, six codes were determined to be dominant based on frequency.

The six words, presented in descending order in terms of usage frequency included: (1) integration; (2) curriculum; (3) community; (4) connections; (5) implementation; and (6) collaboration. Axial coding was completed with the purpose of merging and condensing similar codes, such as “integration”, “project-based learning”, and “connection to and in program” into the code “curriculum.” Nonetheless, all remaining codes were retained and were categorised as supplemental codes (Braun & Clarke 2006). Supplemental codes provided the researcher with the means to organise the findings and categorise results through identification of keywords or phrases that contributed to the formation of the dominant codes.

Step 3. The third step of the thematic analysis, the theme search, was initiated using the codes as a guide that also established some parameters. The parameters were used to assist in searching for themes that related to the research questions, global theme, and purpose of the study (Braun & Clarke 2006). The theme search was also conducted using paper and a highlighter. A pink highlighter was used to bracket phrases, lines, passages, and paragraphs that related to the codes and offered data that contributed to the study’s purpose. Notes were made in the margins to document thoughts and make connections between topics. Moreover, additional journal entries were made each day the researcher engaged with the data and actively conducted the theme search. After manual theme searching, the researcher replicated the process on the Word documents using the pink highlighter option in Word.

Within the documents, particular remarks were able to contribute to the formation of 73 theme titles. The analysis of documents ultimately triggered the development of the themes, although all ten data sources justified the 73 themes and revealed the relationships amongst the themes related to STEM integration and implementation.

Step 4. Once the themes were established, the fourth step of thematic analysis, revising themes, was initiated. In this step, the goal was to evaluate the quality of the themes and establish whether the themes were supported by the data. Further, the researcher evaluated the relationship of the themes to the overarching conceptual framework of the study and verified the connection with the study's purpose (Yin 2009).

The assessment of the themes was accomplished by analysing the data in relationship to the dominant and supplemental codes (Yin 2009). Further, the researcher reread the list of supplemental codes to re-assess the validity of the codes (Yin 2009), as well as established firm parameters for data placement based on dominant and supplemental codes.

Once dominant and supplemental coding was established, the researcher revisited the pertinent literature sources and evaluated codes found in previous studies relevant to this study's global theme. This additional step was included to align terminology amongst the studies. The researcher evaluated the keywords, codes, and patterns used within the studies that revealed the gaps that contributed to the formation of this study's research questions and objectives (Braun & Clarke 2006).

After the themes were proven to support the data, the connection between the themes and codes was realised. A review of the themes, codes, patterns, and excerpts was conducted with the focus on the ability to develop a narrative account of the results (Braun & Clarke 2006). Moreover, the researcher assessed the relationship searching for anomalies, irrelevant content, and improper relationships. The connections between the themes and codes were apparent, as the codes contributed directly to the themes, as the data matched with the codes and aligned with the themes. No instances where data was forced into categories or themes were found, although some data were found applicable to two or more themes. This is a common aspect of thematic analysis (Braun & Clarke 2006). Further, the researcher noted the data related to the conceptual framework within the margins of the Word document to allow for immediate access to data that supported and advanced the theories. During the fourth step of thematic analysis, the themes were revisited in order to establish patterns that were dependent upon the dominant codes (Braun & Clarke 2006). After completing Step 4, the researcher commenced the fifth step of thematic analysis, *defining and naming themes*.

Step 5. In the fifth step of thematic analysis, the researcher defined the themes after organising and clustering them, communicated the captured data, identified what was interesting about the themes, and established why the themes were interesting. The process of defining themes began with identifying the connection between the codes and the themes (Braun & Clarke, 2006). A journal entry was made to reflect the connections between the codes and themes as well as a definition of the themes based on the codes-themes relationships and the data. The entry also included a section on what each theme's data identified and how the data supported the theme. The researcher also noted interesting concepts about the data and the themes, explaining why the themes were important. Any thoughts pertaining to how the data or themes contributed to the literature, theories, methodology, research design, or other features of the study were also recorded for each theme (Yin 2009).

At this point, the researcher conducted a final review of all previous steps of thematic analysis, checking for completion, quality, and accuracy. An additional review of data was conducted and any additional supporting excerpts were added for final review.

Changes were made based on the data and some patterns were renamed as well. Missing or incorrectly placed data items were promptly added and rearranged, respectively.

Step 6. After an additional visual review, the researcher initiated the sixth and the final step of thematic analysis, *producing the report*. The researcher began with the document and wrote the "Results" section. The researcher searched for similarities and differences, accuracies in the reporting, aiming to determine if modifications were needed in presenting the narrative accounts of the participants (Braun & Clarke 2006). The selected documents were thoroughly scrutinised for STEM related key components in the content. The themes were mainly observed by those which researcher examined in her initial readings and later used in other data collection tools. Table 5 provides the complete list of the themes and their levels identified by the researcher through the reading and examination of eighteen selected STEM documents for document analysis. The table 5 provides the complete picture of codes, themes, clusters, and global themes.

Table 6: Codes, Themes, Clusters, and Global Themes from Document Analysis

Codes	**Themes Identified**	**Organising/Clustering Themes**	**Global Themes**
• Curriculum • Learning • Projects • Programs • Connections • Culture • Technology • Virtual Environment • Professional Development • Innovation and Design • STEM Resources • Funds	• Integrated curriculum • Project based learning • Inquiry-based learning • Connection to in and out programs • Classroom Culture • Integration of technology and virtual learning • Authentic assessment • Professional development • Innovative Curriculum Design • Setting up STEM Resources/Labs/Virtual Learning Environments • Extra Funds for Equipment and Supplies for STEM Curriculum	Curriculum	STEM Content/"subject integration/project-based learning/design-based education"
• Business • Community • Industry • Mentorship • Job Opportunities	• A communicated plan across education and business • STEM work-based learning experiences • Mentorship and internship opportunities	Community	Outside support from organisations

• Collaborations • Investments • Acceptance • Encouragement • Research • Politics	• Public and Private Investments and Collaborations • Acceptance and Encouragement from Community, Business, Industries, and Universities • Role of politicians and researchers in identifying challenges and their help in resolving them	Community focus on strategic partnerships	Outside support from organisations
• Vision • Mission • Values • Interdisciplinary • Collaboration • Creativity • Teamwork • Critical Thinking • Problem Solving • Flexible Schedule • Awareness • Interest • Motivation	• Vision, Mission, Values • Student Achievement • Interdisciplinary learning and teaching • Collaboration • Innovation and Creativity • Promoting Team Work • Promoting Critical Thinking and Problem Solving • Involving industry and experts from the community • Creating Flexible Timetables and Curriculum Delivery • Enhancing Awareness and Interest of Teachers, Students, Parents, Stakeholders, and Community towards STEM field and careers	Leadership domain	Leadership
• Motivations • Learning • Success • Persistence • Parents' Support • Teaching Style • Self-Efficacy • Experiences and Interest • Family Values • Clubs • Organisations • Financial Assistance • Friends in STEM related majors	• Perceptions Towards Teachers • Project-Based Learning • Success vs. Failure • Parental Education • Parental Support • Parents' Sacrifices and Students' Gratitude • Course Teaching Style • Self-Efficacy • Motivation as a Form of Gratitude • Childhood experiences and interest • Positive educational experiences • Self-motivations • Positive experiences with professors • Family encouragement and values • Lack of educational preparation • The need for financial assistance • Clubs and organisations • Friends within the major	Continuity and Motivation	Authentic/relevant/meaningful experiences
• Collaboration • Team teaching • Willingness • Resources • Certification • Professional Development • Staffing	• Collaboration/team teaching/cohorts to create integrated STEM • Willingness of teachers to create integrated STEM • Resources needed to create integrated STEM • Certification and the creation of integrated STEM • Professional development and the creation of integrated STEM	Integrated STEM education in School Settings	Willingness and Collaboration

	• Staffing changes and the creation of integrated STEM • Creation of integrated STEM		
• Teachers' Integration • STEM school curriculum • School changes and structures	• Teachers of integrated STEM • Integrated STEM and the school curriculum • Integrated STEM and changes to school structures • Implementation of integrated STEM	Implementation of Integrating STEM education in a school setting	Professional development (the need for and the type of)
• Assessment • State Standards • Testing • National Standards	• Non-traditional assessment • Integrated STEM and state standards • Integrated STEM and standardised testing • Integrated STEM and national standards • Integrated STEM assessment	Assessment of integrated STEM	Teacher Assessment
• Knowledge of interdisciplinary lesson • Samples • Collaboration and Planning • Shared Collaboration • Lesson Plans • Connecting with other disciplines • Instructional strategies • Resources • Reflections	• Knowledge of the characteristic features of an interdisciplinary lesson • Opportunities to analyse sample interdisciplinary lessons • Collaboration in STEM lesson planning • Integration and shared collaboration • Creating lesson plans that incorporate other related STEM disciplines • Connecting with other disciplines • Interdisciplinary lesson instructional strategies • Resources for STEM integration • Reflection on the practice • Professional Development that supports STEM interdisciplinary integration • Pedagogical content knowledge in integrated STEM education	Interdisciplinary STEM Professional Development	Professional development (the need for and the type of)
• STEM definitions • STEM preparation • STEM challenges	• Definitions and Discourse Abilities • Connectivity within STEM Preparation Experiences • Circumstances That Might Make STEM Difficult to Manage • Confidence from Preparation • Confidence from Experiences	STEM Integration Abilities	Time

4.1.4 Discussion

Themes were generated as the data was analysed in each of the documents. However, when the identified themes began to surface in more than one of the analyses, the themes became something more important. Some of the identified themes rise to the level of global theme that seem necessary for integrated STEM to exist. With this realisation, the global themes that were identified in the synthesis can be considered both critical components for the definition and implementation factors. There are two broad classes of implementation global theme: structural and interpersonal. The structural implementation global theme include: "subject integration/project-based learning/design-based education, non-traditional assessment, STEM content, time, professional development, and outside support (from businesses and industry). The interpersonal implementation global theme include: leadership, collaboration, willingness, authentic/meaningful/relevant experiences for participants, and outside support (from people in business and industry)".

The structural implementation global theme that were identified all relate to physical things, strategies, or quantities, which according to the documents analysed must be in place for successful integrated STEM to occur. These are things that schools strongly need to consider if they are going to create and implement an integrated STEM program.

4.1.4.1 Global Theme 1: "Subject integration/project-based learning/design-based education"

The global theme of "subject integration/project-based learning/design-based education" surfaced in all the documents. Twelve out of 18 documents specifically stated that integrated STEM education must have a project-based learning approach. The concept of subject of integration of the STEM disciplines surfaced throughout all the documents. All 18 documents also mentioned or implied the real-world nature of design-based education. The global theme of "subject integration/project-based learning/design-based education" was found documents mentioned about integrated STEM education, the creation of integrated STEM, the implementation of integrated STEM, and the assessment of integrated STEM.

This global theme was related to other global theme including assessment, professional development, willingness, and STEM content. The relationship between the "subject integration/project-based learning/design-based education" global theme and assessment can be found in the words in the documents. One document suggested that general assessments would be projects which should include interviews, talking to people about their [student's] project, talking about what they think the value point-wise or grade-wise of what they did is and was. Another document stated that there is some sort of product [project] and that there is some assessment going on through the project in the form of journaling or discussion with teachers. Another document stated that assessments that are maybe more project-based when referring to integrated STEM. The document indicated this would facilitate the learning of teachers in a way that is different than a traditional high school test would look like and that project assessments are equally as important, if not more important, than standardised testing. Another document indicated that that integrated STEM assessments should be project-based, problem solving based and higher level inquiry. The document referred that this is the best way to assess integrated STEM because a project gives a student [the chance] to really demonstrate their connections and their understanding. Similarly, another document indicated that assessment should be project-based activities and competition based activities.

One more document showed the agreement with the project nature of integrated STEM assessment and what the project should entail. The types of assessments that policy makers need to be more invested in are product based, project-based, outcome-based. It should all be project-based, problem-based where the students are exploring and asking questions, or trying to solve a problem, or come up with a new technology, or come up with something innovative to help solve a problem in the world, and there are different levels or different degrees so they are building up all those skills and knowledge to hit the major project of STEM.

The relationship between the “subject integration/project-based learning/design-based education” global theme and professional development is also found. This type of training relates closely to the design-based educational experiences in integrated environments when referring to other teachers that are interested in teaching in an integrated STEM environment.

The relationship between the “subject integration/project-based learning/design-based education” global theme and the willingness of teachers was also evident when documents talked about integrated, project-based environments. The relationship between the “subject integration/project-based learning/design-based education” global theme and STEM content which must be integrated is also. STEM content is seen as a key component of integrated STEM.

The prevalence of the “subject integration/project-based learning/design-based education” global theme, and due to the sheer number of documents that stated about it in multiple places in the content, made it a strong implementation factor related to integrated STEM education. This global theme also tied directly to the conceptual framework for the study, which again emphasised its importance. According to the current data, it would seem that integrated STEM cannot take place without subject integration, project-based learning, and design-based education.

4.1.4.2 Global theme 2: “STEM content”

The global theme of the importance of STEM content was evident throughout the entire document analysis where content of documents stated integrated STEM education, the creation of integrated STEM, the implementation of integrated STEM, and the assessment of integrated STEM. This global theme was related to the other identified global theme by the documents including "subject integration/project-based learning/design-based education", professional development, and willingness.

STEM content is logically connected to "subject integration/project-based learning/design-based education", professional development, and willingness in the following ways. STEM content is what is being delivered by the pedagogical method of "subject integration/project-based learning/design-based education". Teachers must be knowledgeable in STEM content and need continued training to gain skills related to additional STEM content to provide the best integrated STEM environment possible for students. Finally, teachers must have the willingness to teach STEM content.

STEM content is an important implementation factor for integrated STEM. While it was not mentioned specifically by all the documents, its importance seemed to be assumed by the documents when it is mentioned science, technology, engineering, and math in their contents. STEM content is also one of the legs of the conceptual framework of the study, which again demonstrates its importance.

4.1.4.3 Global theme 3: "Professional development (the need for and the type of)"

The global theme of professional development was found in all the documents, which was related to the creation of integrated STEM. The need for training (professional development) was also mentioned in various parts of each document. This global theme was related to other global theme including "subject integration/project-based learning/design-based education", authentic/relevant/real-world experiences, STEM content, collaboration, leadership, authentic/relevant/real-world experiences, outside support, and willingness. The following comments demonstrate these connections. While these comments are not grouped specifically by their relationships to other global theme, it is obvious that the professional development of them is highly connected to numerous other identified global theme related to integrated STEM. Giving the teachers the freedom or the suggestion to figure out what they really want to do themselves within integrated STEM, what they enjoy doing, what they feel comfortable doing, what do they want to do, what do they want to learn more about, and have them figure that out before they enter the classroom and have them understand that, that is important to know.

Collaboration was also mentioned as an area needing professional development. Constantly collaborating with a community is a must. Professional development needs to include situations for educators when they get a chance to come together and discuss things and share their ideas.

The manner of professional development was also a point of discussion. Professional development was needed to be ongoing, focused, and driven. This speaks not only to the constant, on-going nature of needed professional development, it also stresses the importance of the experiential nature of professional development that can help teachers understand and instruct in an integrated STEM environment.

The nature of the discussions around professional development and integrated STEM education has implications related to this study. All the documents identified professional development as critical tool for STEM because it was identified as an integrated STEM support structure. However, these discussions related to the nature, content, and delivery of professional development should help provide a frame of reference for those school leaders who want to implement integrated STEM education.

With the sheer volume of comments related to the need for and type of professional development related to integrated STEM, it should be obvious that professional development is a critical implementation factor for integrated STEM. Teachers must have diverse experiences related to the type of instruction that they are providing students. This involves teachers having authentic/relevant/real-world experiences provided by school leadership with the willingness to learn STEM content using "subject integration/project-based learning/design-based education" through a collaborative process. Professional development was also one of the support structures identified in the conceptual framework. The identification of professional development as an implementation factor for integrated STEM was not surprising, nor was the type of professional development that is needed.

4.1.4.4 Global theme 4: "Time"

The global theme of time surfaced in all the documents. Twelve out of 18 documents specifically mentioned the need for time related to integrated STEM education. Time is needed for collaboration, for planning, for exploring (for students and teachers), and thinking. The global theme of time was found when documents discussed about integrated STEM education, the creation of integrated STEM, the implementation of integrated STEM, and the assessment of integrated STEM.

This global theme was related to other global themes including collaboration, professional development, assessment, and authentic/relevant/real world experiences. The relationship between the time global theme and collaboration is evident. The administration actually gives the team, of the different subject area matters, planning time to talk about things, to talk about the students that are in the classes. The integrated STEM takes a commitment to the district to provide time for planning and there has to be time dedicated to allowing the teachers to find the meaningful connections among the content prior to instructing that content or providing activities and lessons that connect the content together. There has to be more instructional planning time than a traditional classroom setting.

The relationship between the time global theme and professional development is also evident. The training comes in constantly collaborating and adapting to the change that is happening around. Professional development needs to include situations for educators when they get a chance to come together and discuss things and share their ideas. All these discussions either specifically state or imply that time is needed for teachers in professional development related to integrated STEM.

The global theme of time is prevalent throughout the documents, not just time for teaching and learning, but time for planning and collaboration. Time is also mentioned as necessary for professional development. In addition, it is considered a general resource for both teachers and students in integrated STEM environments. When considering integrated STEM education, the collected data shows that time for the process of integrated STEM education in all of its aspects, is important for STEM integration and implementation.

4.1.4.5 Global theme 5: "Assessment"

The global theme of assessment was found in all the documents. There were discussions related to assessment of integrated STEM because assessment is an important part of today's educational culture. Several documents stated that assessment (or the lack of good assessments) of integrated STEM is going to be the reason that integrated STEM would not become mainstreamed in public or private schools. From the analysis of documents, it is apparent that schools would have to think differently about assessment for integrated STEM environments. The non-traditional nature of integrated STEM assessment is what makes it an important implementation factor.

4.1.4.6 Global theme 6: "Outside support from organisations"

The global theme of outside support from organisations for integrated STEM surfaced in most of the documents. Outside resources is an important global theme related to integrated STEM education. The concept of outside support for integrated STEM ran throughout all the documents, from their different perspectives. Outside support for training and providing resources shows that outside support is an important implementation factor for integrated STEM. It should be noted that outside resources are also highly related to the interpersonal implementation global theme identified in the documents.

The interpersonal implementation global theme that were identified all relate to people skills and abilities that must be in place for successful integrated STEM to occur. These are things that schools strongly need to consider if they are going to create and implement and integrated STEM program.

The prevalence of outside support for integrated STEM can be seen in the documents. Outside support takes on two facets by helping with the structural as well as the interpersonal implementation of integrated STEM. This global theme, as with the other global theme identified from the documents is intertwined with all the other global theme. On this basis, the data indicates that these global theme appear to be critical for integrated STEM. If one global theme is missing it is like removing a critical part from a complex machine. It may function, but definitely not as it was designed or as efficiently.

4.1.4.7 Global theme 7: "Collaboration"

The global theme of the importance of collaboration was evident throughout the document analysis. Nearly all the documents mentioned collaboration in numerous situations. The global theme of collaboration was closely intertwined with several other identified integrated STEM global theme and it can be argued that "subject integration/project-based learning/design-based education" and authentic/relevant/real-world experiences for students can only be achieved in collaborative environments, since these global theme are connected via other identified global theme. Collaboration is prevalent in the document analysis and its interconnected nature with the other identified integrated STEM global theme makes a strong case that it is indeed a key implementation factor for integrated STEM.

4.1.4.8 Global theme 8: "Willingness"

The global theme willingness of teachers to participate in integrated STEM was evident throughout the document analysis. The global theme of willingness of teachers is also connected to the global theme of "subject integration/project-based learning/design-based education" and professional development. If a teacher is going to work in an integrated STEM environment, logically they are going to have to understand and have training in those types of environments. "subject integration/project-based learning/design-based education" are the backbone pedagogical methods for integrated STEM, and professional development would provide the necessary training. Specific evidence related to these links can be found in the "subject integration/project-based learning/design-based education" and professional development global theme that are developed in the structural implementation global theme section. The global theme of willing teachers with the desire to participate in integrated STEM was evident throughout the documents. Willingness of teachers is closely relate to several other identified global theme by the connecting threads of the identified global theme related to integrated STEM. By the number and type of connections, it can be clearly argued that willingness of teachers to participate in integrated STEM is a key implementation factor for integrated STEM education.

4.1.4.9 Global theme 9: "Authentic/relevant/meaningful experiences"

The global theme of authentic/relevant/meaningful experiences was evident in 14 documents in several different places. It can be argued that both project-based assessments and portfolio-based assessments fit as authentic and competency based models for assessment. In fact, several of the documents mentioned the application of project-based or portfolio-based models in their description of authentic, competency-based assessments for teachers in integrated STEM. Ultimately, the assessments of integrated STEM are going to be non-traditional, where students create a product that demonstrates their skills in a real life authentic setting.

The global theme of authentic/relevant/meaningful experiences is also closely connected to the global theme of professional development and outside support by people and businesses. Logically, for teachers to understand and create integrated STEM environments for students, they must be trained in these types of environments. The training must come from somewhere, so outside support by people and businesses would be important. There is also concrete evidence supporting these logical arguments, which are detailed in the professional development and outside support global theme that are included in the implications for research questions section.

Authentic/relevant/meaningful experiences for both teachers and students, surfaced throughout the documents. Authentic/relevant/meaningful experiences are closely related to many other global theme through the connecting web of the identified global theme related to integrated STEM. With the nature and number of these connections, it logically can be concluded that authentic/relevant/meaningful experiences is a key implementation factor for integrated STEM education.

4.1.4.10 Global theme 10: “Leadership”

The global theme of leadership related to integrated STEM surfaced in most of the documents. School leadership can be defined in many ways. For the purpose of the results, the researcher has combined comments about school leadership from anyone directly attached to the school, except teachers and students. This includes building and district level administrators, curriculum specialists, and school board members. Leadership by teachers, students, and outside the school, was also mentioned as important to integrated STEM. Possibly the best way to sum up the leadership needs for integrated STEM is through shared leadership. The global theme of leadership being essential to integrated STEM resounded across all the documents. Each document put a unique spin on exactly who and how the leadership must be applied, nevertheless it appears leadership is an important aspect of integrated STEM.

From the preponderance of discussions related to leadership, it is apparent that leadership is essential to integrated STEM education. The integrated STEM takes leadership in many forms and aspects. It takes leadership from teachers, school officials, people outside the school, and students. That leadership must be present in professional development and the classroom. As with any change, leadership is crucial to its success. Leadership was found in the literature as being important to integrated STEM, and leadership was one of the support structures for integrated STEM in the conceptual framework of the study. It was not a surprise that leadership was identified as a key implementation factor for integrated STEM.

The ten identified global theme: “subject integration/project-based learning/design-based education, non-traditional assessment, STEM content, time, professional development, outside support (from and by businesses and industry), leadership, collaboration, willingness, and authentic/meaningful/relevant experiences are critical for integrated STEM as identified in the documents”.

One idea on which the documents indicated, but did not rise to the level of a global theme, is that staffing changes were not necessary to implement integrated STEM education. The documents indicated that it is not necessary to fire and rehire different staff. Rather, the documents suggested that through the use of leadership, outside support, professional development, collaboration, authentic/relevant/real-world experiences, and willingness, any teacher could become a competent integrated STEM teacher; particularly current STEM discipline teachers. The documents further suggested that it might be necessary to hire a specialty teacher in some cases.

4.1.4.11 Global theme 11: "Dissent/concerns for schools"

The final global theme developed in the data analysis of the documents was related to dissent among the schools. There were four major areas of dissent that must be addressed. Schools should be aware of these areas of dissent when creating and implementing an integrated STEM curriculum. They could pose potential stumbling blocks, which would need to be addressed. The primary areas of dissent present in the documents were: 1) elective vs. core class, 2) certification, 3) standardised testing, and 4) cost.

The first area that was not retaliated in all the documents was whether integrated STEM is an elective or a core class. The documents; however, indicated that an integrated STEM could be a core class, or an elective, or somewhere in between. Another area of disagreement was related to certification of teachers of integrated STEM. Some documents mentioned that certification is not needed for integrated STEM teachers. The educator with a STEM certificate or a STEM degree would have a deep enough knowledge in any one of the areas to excel. Another area of dissent among the schools is whether integrated STEM would help or hinder the standardised testing culture found in education. Seven documents indicated that integrated STEM cannot be assessed through standardised testing. Eleven documents discussed the difficulty with standardised tests. Another area of contention is the cost of an integrated STEM program. The areas of dissent between the schools related to cost, certification, standardised testing, and core class vs. elective class are worth noting. These are exactly the types of discussions that must be conducted, and where compromise must be identified if integrated STEM is going to gain traction in public or private schools. Knowing the areas of agreement provides common ground for possible integrated STEM implementations, and knowing the areas of disagreement can drive discussions that make integrated STEM better if handled correctly.

4.1.5 Summary of Results of Research Question 1 - Document Analysis

Through the findings of this study, the analysis and synthesis identified 10 global themes that can be considered both a critical component and key implementation factor for integrated STEM. All these are emerged as *the international common models of effective instructional practices and policies of the STEM education.* The themes generated from document analysis can be divided into two broad classes of implementation: structural and interpersonal. The structural implementation category included the following themes: "subject integration/project-based learning/design-based education, non-traditional assessment, STEM content, time, professional development, and outside support (from businesses and industry). The interpersonal implementation global theme include: leadership, collaboration, willingness, authentic/meaningful/relevant experiences for participants, and outside support (from people in business and industry)". On the other hand, the interpersonal implementation category included the following themes: "leadership, collaboration, willingness, authentic/meaningful/relevant experiences for participants, and outside support (from people in business and industry)".

The structural implementation global theme were deemed structural, not because they are structures (even though some of them are), but because these global theme represent things that must be in place either from the schools or outside influences. The interpersonal implementation global theme were considered interpersonal, because they all are something that people (teachers, students, outside experts) all do, or in which they participate. These global theme are more connected to the people involved in the integrated STEM process, where the structural global theme are more about needs for integrated STEM.

While STEM-based initiatives are not altogether new to the field of education, the recent focus by policymakers and educators has echoed the UAE's call for more explicit STEM curricula within our nation's K-12 schools to boost student achievement in STEM. Within the context of document analysis, it has become apparent that science is now becoming more highly prioritised within K-12 curricula and is intended to serve as a vehicle for delivering STEM-based instruction to students in UAE.

STEM education represents a fundamentally different approach to organising the curriculum than approaches that have been used in the past. Among the greatest strengths of STEM identified by Vasquez et al. is the promise of breaking down the barriers between the content areas and bringing together formerly isolated subject areas such as engineering or technology. STEM learning and teaching strives to boost student engagement and achievement, deepen understanding, and provide relevance to learning. Even as young as kindergarten, students engaged in an integrated curriculum involving STEM content can begin to see how the concepts and skills learned work together to help them solve problems and answer questions. An integrated STEM curriculum shifts K-12 teachers' focus from a discipline-based mind-set to that of one in which "they are helping students learn to apply STEM concepts and skills and relate what they are learning to the real world".

It is during the preparatory phases of teaching when teachers are thought to be the most malleable in terms of embracing changes and challenging new ways of thinking, learning, and teaching. Therefore, K-12 teachers and policy makers in UAE “who have yet to venture into the field are at the forefront of the STEM movement”. Additionally, “as the future leaders of the field in UAE, K-12 teachers are in a position to lead the charge for new initiatives encouraging the use of best practices”. For these reasons, it is imperative that as STEM in UAE continues to filter into K-12 classrooms, teachers must be prepared to meet the demands of new initiatives.

Adding to the appeal of an integrative approach is a rooting in constructivism, which is a learning theory in which students build their own knowledge based on previous experience, inquiry, and provided learning experiences. Constructivist-based approaches to integration are highly effective within STEM curricula because the STEM concepts outlined within for K-12 students include a myriad of constructivist practices to help build 21st -century skills within students in UAE. Additionally, students can approach the content within an integrative unit from different angles based on their prior knowledge or personal interests, which in turn makes the learning experience more rigorous and complex, promoting the acquisition of 21st -century skills.

The findings of document analysis add to current literature pertaining to preparing K-12 teachers for STEM instruction and integration in UAE, which is valuable in the sense that STEM content will be increasingly laced throughout the K-12 curriculum as UAE begin to adopt and implement the UAE vision 2021 for high quality education. Embedded within the Next UAE vision 2021 is an emphasis on building STEM knowledge and skills; thus, it becomes imperative to accommodate for this shift in content by taking steps to ensure that the teachers who are being prepared today are equipped to handle the rigors of STEM-based curricula of tomorrow. Yet, because STEM-based initiatives are so new, a lack of significant research on pre-service teacher STEM preparation exists in UAE. Thus, document analysis adds to the foundational platform for current and future research studies on pre-service teacher preparation for STEM integration.

4.2 Results of Research Question 2 - Teacher Questionnaire

This section presents the results of second research question: *"What are the factors associated with STEM integration and implementation in UAE schools?"* In this regards, an online and face-to-face questionnaire survey with teachers were conducted using the representative sample of 203 final teacher participants to examine the teacher perceptions related to factors associated with STEM integration and implementation in UAE schools. This section presents analyses and results that examine the components of STEM implementation and integration perceived by the teachers in UAE schools.

This section is divided into four sub-sections. It begins with a description of the demographics of the study participants. The second section deals with the assumptions for Confirmatory Factor Analysis (CFA) and Structural Equation Modelling (SEM) which are tested and adjustments made for violations of assumptions.

Third, inter-item reliability and Pearson bivariate correlations were conducted to determine if any study variable demonstrated poor internal consistency and/or showed no significant relationships with other variables, both of which would preclude the need to conduct CFA and SEM analyses for the specific variable or sets of variables (Hu & Bentler 1998; Thompson 2004).

Fourth, this section provides a comprehensive analysis of CFA and SEM findings pertaining to the study hypotheses formulated for each the purpose of CFA and SEM analysis.

Lastly, this section provides a multiple regression analysis to determine the strength of each predictor on perceptions of teachers regarding STEM integration and implementation in UAE schools.

4.2.1 Descriptive Statistics: Study Participants

This study was conducted with 201 teachers who worked in both public and private organisations in six cities in five Emirates of UAE: Abu Dhabi, Ajman, Al Ain, Dubai, Ras Al Khaimah, and Sharjah. Nearly 60% of the teachers are teaching at high school. Table 6 presents the frequencies and percentages of categorical demographic and work data of study participants. The subsequent charts present the individual results of the demographics of the teachers participated in this study.

Figure 4 presents the sector of teachers participated in the survey. The ratio of both public and private teachers was almost same with private teachers were slightly higher (53%, n=108) compared to public teachers (46%, n=93). Two teachers did not answer this question.

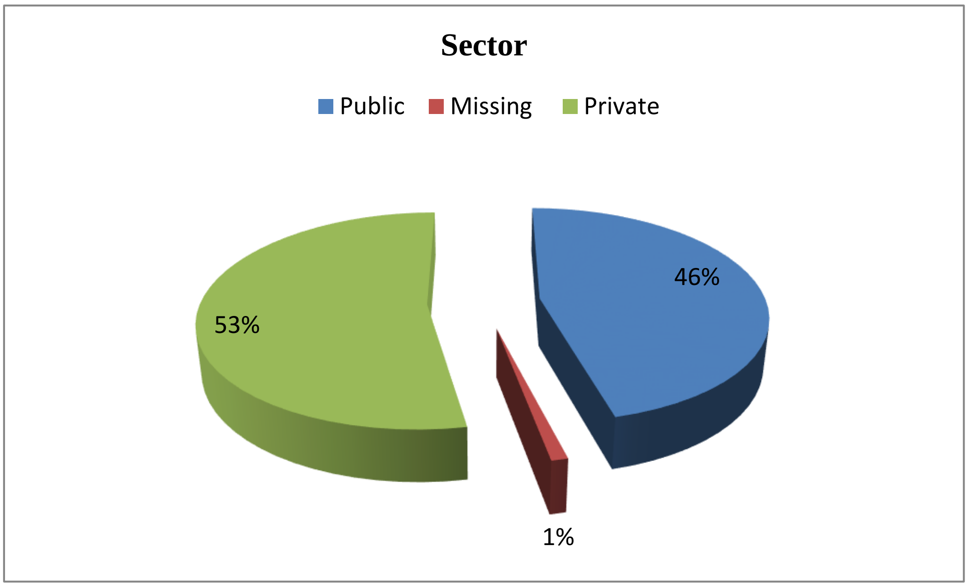

Figure 4: Participant Educational System

Figure 5 presents the campus of teachers where they are currently teaching. Majority of the teachers are teaching at Dubai campus (49%, n=100) followed by teachers who are teaching at Al-Ain and Sharjah campuses of their schools. The rest of the teachers are teaching at Ras Al Khaimah and Ajman.

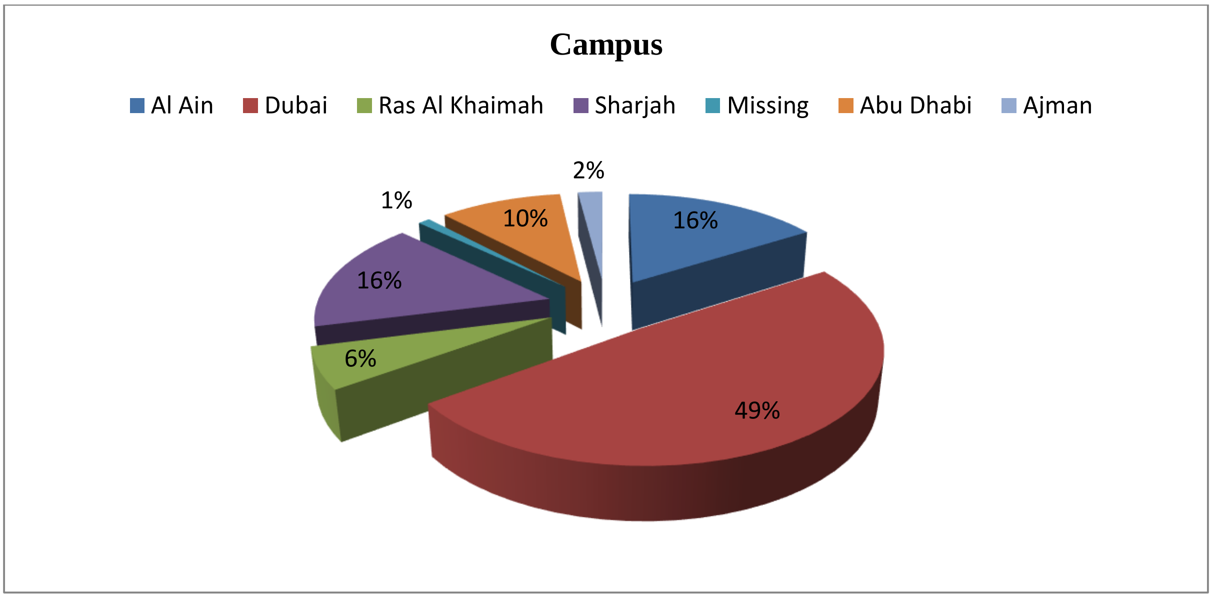

Figure 5: Participant City

Figure 7 presents the degree major which they have done for their education. Majority of the teachers have completed their education in the Education major (24%, n=48) followed by teachers who have completed their education in Science, Maths, Computer Science, and Engineering. Around 8% participants have completed their education in other majors.

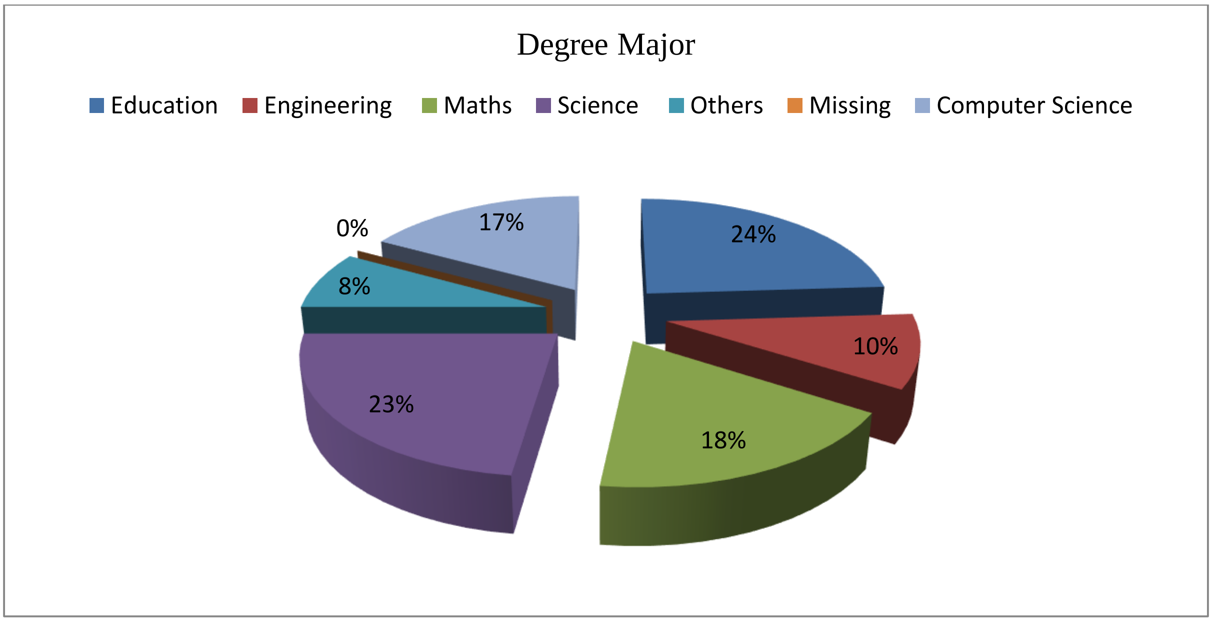

Figure 6: Degree Major of Teachers

Figure 8 presents the level of instruction in which they are currently teaching. Majority of the teachers are currently teaching at high school level (60%, n=121) followed by teachers who are currently teaching at Middle school, primary school, and Kindergarten.

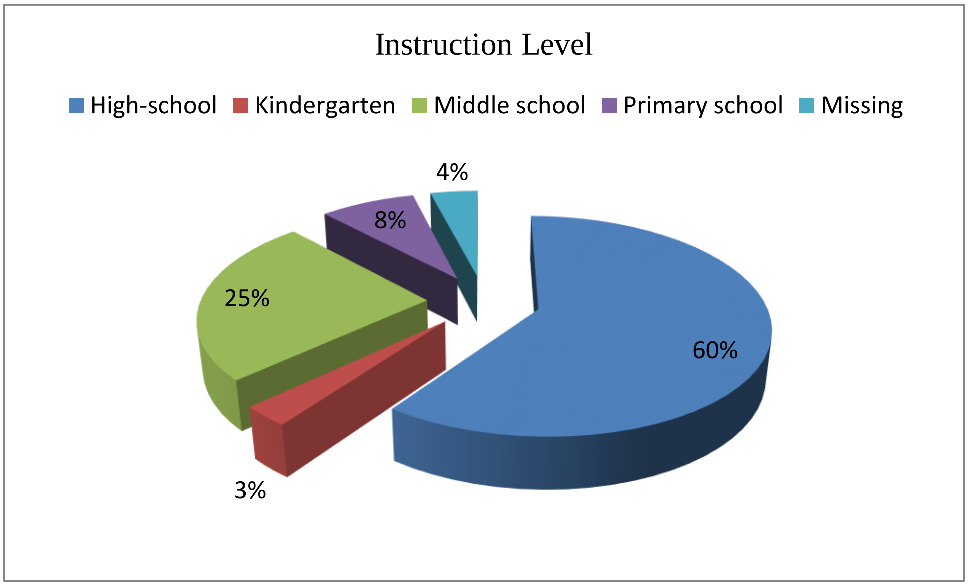

Figure 7: Instructional Level of Teachers

Figure 9 presents gender distribution of teachers participated in the questionnaire survey. More males than females (51% as compared to 45%) participated in the study.

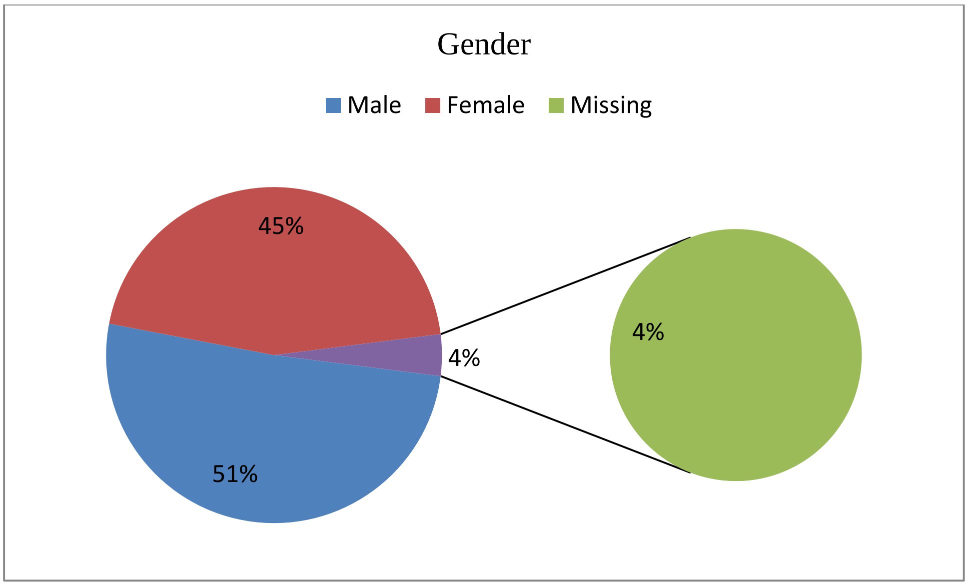

Figure 8: Gender of Teachers

Figure 10 presents experience by number of years of teachers participated in the questionnaire survey. The findings showed that a great majority of teachers have more than 2 years of teaching experience (63%, n=128) followed by teachers who have 2 years and 1 year teaching experience.

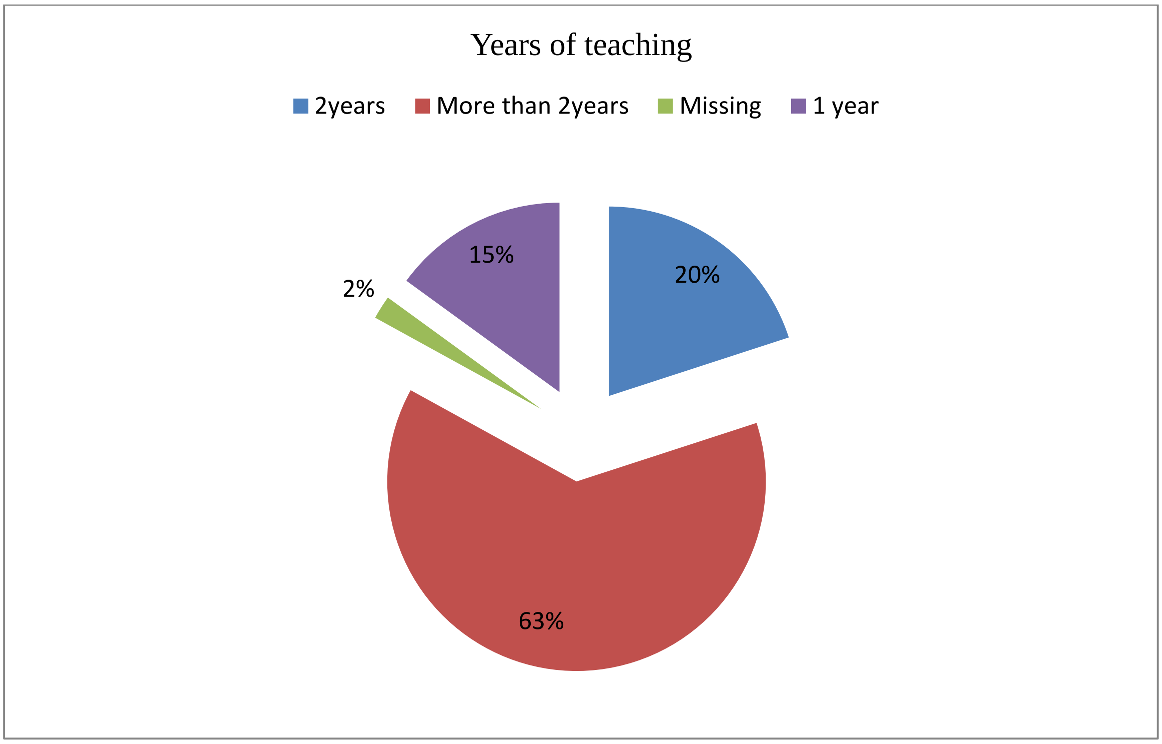

Figure 9: Participants' Years of Teaching

The above descriptive statistics of the participants indicated that the sample representation of teachers from diverse backgrounds, degree majors, campuses, sectors, gender, and teaching experience, thereby indicating that there will be good amount of diversity related to STEM related integration and implementation responses. Apparently, there are no major differences between gender, sector, and campus regarding STEM perceptions. In UAE mostly high school teachers are the ones experience in STEM. Mostly teachers with more than 2 years of experience have positive perceptions about STEM education. However, it is important to determine whether there are significant differences in the perceptions among different teachers based on these groups so as to determine which teacher groups have more positive perceptions towards each of the factor identified from the questionnaire.

4.2.2 Results from Significant Testing Among Demographic Groups

Before conducting the empirical tests, it is important to discuss the design of the questionnaire items. The initial questionnaire was designed as open for the teachers in order to avoid the direction bias which occurs due to labelling the questionnaire. However, these questionnaire items were labelled and stored by the researcher before deleting them for the final questionnaire. The redesign of the questionnaire items as per the categories is provided in Appendix 7. The questionnaire contains 44 questionnaire items which were categorised into six categories (Assessment, Connection; Curriculum and Delivery, Leadership, Pedagogical Content Knowledge, and Technology and Resources) as the components of STEM integration and implementation. The abbreviated form of each factor is used in the table and full-form is provided in notes.

The following results presented the T-test results (when comparing 2 groups) and one-way ANOVA results (when comparing more than 2 groups) for these 6 categories/components of STEM integration and implementation. The researcher analysed if there were differences in teachers' overall perceptions about STEM implementation and integration between their demographic characteristics. The mean closer to 4 or 5 indicates that teachers have agreed with integrating the particular factor in STEM while the mean closer to 1 or 2 indicates that teachers have disagreed with integrating the particular factor in STEM.

Table 7 shows the t-test results of Teachers' Sector (Public and Private) and Seven STEM Factors. The findings indicated that there are no statistically significant differences in teachers working in public and private sector towards their perception regarding assessment, connection, curriculum and delivery, leadership, pedagogical content knowledge and overall perceived integration and implementation. However, there is statistically significant differences in teachers working in public and private sector towards their perception regarding Technology and Resources (Sig = 0.018, $p < 0.05$). This means that public teachers (Mean = 3.4645) have slightly more positive attitudes towards Technology and Resources compared to private teachers (Mean = 3.1907) in UAE schools.

Table 7: T-test Results of Sector and STEM Factors

	Sector	N	Mean	Sig
OAS	Public	93	3.59	0.863
	Private	108	3.48	
OC	Public	93	3.56	0.391
	Private	108	3.56	
OCD	Public	93	3.79	0.111
	Private	108	3.74	
OL	Public	93	3.27	0.156
	Private	108	3.11	
OPCK	Public	93	3.83	0.075
	Private	108	3.82	
OTR	Public	93	3.46	0.018**
	Private	108	3.19	
OPII	Public	93	13.48	0.237
	Private	108	12.93	

OAS = Overall Assessment**; OC =** Overall Connection**; OCD =** Overall Curriculum and Delivery**; OL =** Overall Leadership**; OPCK =** Overall Pedagogical Content Knowledge**; OTR =** Overall Technology and Resources**; OPII =** Overall Perceived Integration and Implementation
**. Significant at the 0.05 level

Table 8 shows the one-way ANOVA results of Teachers' Campus and Seven STEM Factors. The findings indicated that there are no statistically significant differences among teachers working in different campuses towards their perception regarding connection and curriculum and delivery. However, there are statistically significant differences in teachers working in different campuses towards their perception regarding Assessment (Sig = 0.013, $p < 0.05$), Leadership (Sig = 0.014, $p < 0.05$), Pedagogical Content Knowledge (Sig = 0.013, $p < 0.05$), Technology and Resources (Sig = 0.043, $p < 0.05$), and Overall Perceived Integration and Implementation (Sig = 0.006, $p < 0.05$). It is indicated that teachers from Ajman, Ras Al

Khaimah, and Al Ain have more positive attitudes than teachers from Abu Dhabi, Dubai, and Sharjah.

Table 8: One-way ANOVA Results of Campus and STEM Factors

		Abu Dhabi	**Ajman**	**Al Ain**	**Dubai**	**Ras Al Khaimah**	**Sharjah**	**Total**
	N	**21**	**5**	**32**	**100**	**12**	**32**	**202**
OAS	Mean	3.35	3.95	3.76	3.51	3.90	3.35	3.54
	Sig	0.013**						
OC	Mean	3.32	4.00	3.80	3.59	3.73	3.30	3.56
	Sig	0.029						
OCD	Mean	3.67	4.06	3.78	3.75	4.08	3.69	3.76
	Sig	0.233						
OL	Mean	2.82	3.88	3.41	3.17	3.66	3.01	3.19
	Sig	0.014**						
OPCK	Mean	3.72	4.00	3.95	3.82	4.30	3.61	3.83
	Sig	0.013**						
OTR	Mean	3.15	3.64	3.58	3.23	3.85	3.25	3.32
	Sig	0.043**						
OPII	Mean	11.71	16.05	14.26	13.18	16.05	11.86	13.23
	Sig	0.006**						

OAS = Overall Assessment**; OC =** Overall Connection**; OCD =** Overall Curriculum and Delivery**; OL =** Overall Leadership**; OPCK =** Overall Pedagogical Content Knowledge**; OTR =** Overall Technology and Resources**; OPII =** Overall Perceived Integration and Implementation
**. Significant at the 0.05 level

The findings indicated that teachers teaching at Ajman (3.95) followed by teachers teaching at Ras Al Khaimah (3.90) and Al Ain (3.76) have more positive attitudes towards integrating Assessment in STEM compared to teachers teaching in other emirates. Similarly, the findings indicated that teachers teaching at Ajman (3.88) followed by teachers teaching at Ras Al Khaimah (3.66) and Al Ain (3.41) have more positive attitudes towards integrating Leadership in STEM compared to teachers teaching in other emirates.

The findings indicated that teachers teaching at Ras Al Khaimah (4.30) followed by teachers teaching at Ajman (4.00) and Al Ain (3.95) have more positive attitudes towards integrating Pedagogical Content Knowledge in STEM compared to teachers teaching in other emirates. The findings indicated that teachers teaching at Ras Al Khaimah (3.85) followed by teachers teaching at Ajman (3.64) and Al Ain (3.58) have more positive attitudes towards integrating Technology and Resources in STEM compared to teachers teaching in other emirates.

Table 9 shows the one-way ANOVA results of Teachers' Degree Major and Seven STEM Factors. The findings indicated that there are no statistically significant differences among teachers with different degree majors towards their perception regarding Assessment, Connection, Curriculum and Delivery, Leadership, and Pedagogical Content Knowledge. However, there are statistically significant differences in teachers with different degree majors towards their perception regarding Technology and resources (Sig =0.016, $p < 0.05$). It is indicated that teachers with Mathematics degree majors (3.55) followed by teachers with Science degree majors (3.47) and teachers with Education degree majors (3.39) have more positive attitudes than teachers with degree majors of computer science, engineering, and others.

Table 9: One-way ANOVA Results of Teachers' Degree Major and STEM Factors

		Computer Science	**Education**	**Engineering**	**Maths**	**Science**	**Others**	**Total**
	N	**34**	**48**	**21**	**36**	**47**	**16**	**202**
OAS	Mean	3.38	3.60	3.42	3.64	3.58	3.54	3.54

	Sig	0.503						
OC	Mean	3.51	3.65	3.34	3.62	3.634	3.45	3.57
	Sig	0.554						
OCD	Mean	3.66	3.81	3.76	3.88	3.74	3.70	3.76
	Sig	0.592						
OL	Mean	2.84	3.29	2.96	3.25	3.36	3.33	3.19
	Sig	0.068						
OPCK	Mean	3.69	3.86	3.78	3.95	3.84	3.82	3.83
	Sig	0.579						
OTR	Mean	3.02	3.39	2.96	3.55	3.47	3.27	3.32
	Sig	0.016**						
OPII	Mean	11.85	13.58	12.29	13.97	13.75	13.21	13.23
	Sig	0.222						

OAS = Overall Assessment**; OC =** Overall Connection**; OCD =** Overall Curriculum and Delivery**; OL =** Overall Leadership**; OPCK =** Overall Pedagogical Content Knowledge**; OTR =** Overall Technology and Resources**; OPII =** Overall Perceived Integration and Implementation
**. Significant at the 0.05 level

Table 10 shows the one-way ANOVA results of Teachers' Instructional Level and Seven STEM Factors. The findings indicated that there are no statistically significant differences among teachers teaching at different instruction level towards their perception regarding Assessment, Connection, Curriculum and Delivery, Leadership, and Technology and resources. However, there are statistically significant differences in teachers teaching at different instruction level towards their perception regarding Pedagogical Content Knowledge (Sig =0.013, $p < 0.05$), It is indicated that teachers teaching at primary school (3.94) followed by teachers teaching at high school (3.85) and teachers teaching at middle school (3.84) have more positive attitudes than teachers teaching at kindergarten.

Table 10: One-way ANOVA Results of Teachers' Instructional Level and STEM Factors

		High School	Kindergarten	Middle School	Primary School	Total
	N	**121**	**7**	**50**	**16**	**194**
OAS	Mean	3.61	3.10	3.47	3.30	3.53
	Sig	0.065				
OC	Mean	3.59	3.28	3.52	3.63	3.57
	Sig	0.674				
OCD	Mean	3.79	3.41	3.74	3.79	3.76
	Sig	0.334				
OL	Mean	3.29	3.22	3.10	2.76	3.19
	Sig	0.104				
OPCK	Mean	3.85	3.11	3.84	3.94	3.83
	Sig	0.013**				
OTR	Mean	3.40	3.08	3.25	2.96	3.31
	Sig	0.146				
OPII	Mean	13.62	11.07	12.80	12.24	13.20
	Sig	0.218				

OAS = Overall Assessment**; OC =** Overall Connection**; OCD =** Overall Curriculum and Delivery**; OL =** Overall Leadership**; OPCK =** Overall Pedagogical Content Knowledge**; OTR =** Overall Technology and Resources**; OPII =** Overall Perceived Integration and Implementation
**. Significant at the 0.05 level

Table 11 shows the t-test results of Teachers' Gender (Male and Female) and Seven STEM Factors. The findings indicated that there are no statistically significant differences in male and female teachers towards their perception regarding assessment, curriculum and delivery, leadership, pedagogical content knowledge, technology and resources and overall perceived integration and implementation. However, there is statistically significant differences in male and female teachers towards their perception regarding Connection (Sig =

0.019, $p < 0.05$). This means that male teachers (Mean = 3.6981) have slightly more positive attitudes towards Connection compared to female teachers (Mean = 3.4418) in UAE schools.

Table 11: T-test Results of Teachers' Gender and STEM Factors

	Gender	N	Mean	Sig
OAS	Male	104	3.63	0.343
	Female	91	3.43	
OC	Male	104	3.69	0.019**
	Female	91	3.44	
OCD	Male	104	3.85	0.303
	Female	91	3.68	
OL	Male	104	3.35	0.292
	Female	91	3.03	
OPCK	Male	104	3.90	0.117
	Female	91	3.75	
OTR	Male	104	3.48	0.383
	Female	91	3.14	
OPII	Male	104	13.96	0.419
	Female	91	12.47	

OAS = Overall Assessment**; OC =** Overall Connection**; OCD =** Overall Curriculum and Delivery**; OL =** Overall Leadership**; OPCK =** Overall Pedagogical Content Knowledge**; OTR =** Overall Technology and Resources**; OPII =** Overall Perceived Integration and Implementation
**. Significant at the 0.05 level

Table 12 shows the one-way ANOVA results of Teachers' Years of Teaching Experience and Seven STEM Factors. The findings indicated that there are no statistically significant differences among teachers with different teaching experience towards their perception regarding Connection, Curriculum and Delivery, Pedagogical Content Knowledge and Technology and resources. However, there are statistically significant differences among teachers with different teaching experience towards their perception regarding Assessment (Sig =0.016, $p < 0.05$) and Leadership (Sig =0.018, $p < 0.05$). It is indicated that teachers with more than 2 years of teaching experience (3.64) followed by teachers with 2 years of experience (3.35) have more positive attitudes regarding integration of assessment in STEM than teachers with 1 year of teaching experience. Similarly, the results showed that teachers with more than 2 years of teaching experience (3.33) followed by teachers with 1 year of experience (3.03) have more positive attitudes regarding integration of leadership in STEM than teachers with 2 years of teaching experience.

Table 12: One-way ANOVA Results of Teachers' Years of Teaching Experience and STEM Factors

		1 Year	**2 Years**	**More than 2 Years**	**Total**
	N	**31**	**40**	**128**	**199**
OAS	Mean	3.39	3.35	3.64	3.54
	Sig	0.016**			
OC	Mean	3.50	3.44	3.63	3.57
	Sig	0.276			
OCD	Mean	3.65	3.67	3.83	3.77
	Sig	0.101			
OL	Mean	3.03	2.94	3.33	3.20
	Sig	0.018**			
OPCK	Mean	3.66	3.89	3.86	3.84
	Sig	0.21			
OTR	Mean	3.19	3.15	3.42	3.33
	Sig	0.117			
OPII	Mean	12.27	12.20	13.86	13.28

	Sig	0.03**

OAS = Overall Assessment**; OC =** Overall Connection**; OCD =** Overall Curriculum and Delivery**; OL =** Overall Leadership**; OPCK =** Overall Pedagogical Content Knowledge**; OTR =** Overall Technology and Resources**; OPII =** Overall Perceived Integration and Implementation
**. Significant at the 0.05 level

4.2.3 Descriptive Statistics: Study Variables

Descriptive statistics of study variables are reported in Table 13. Normality tests were also computed for the study variables. According to Byrne (2013), normality in the data is evident if the Shapiro-Wilk test or Kolmogorov-Smirnova is higher than 0.7. Shapiro-Wilk test and Kolmogorov-Smirnova are performed to determine normality in the data for conducting CFA and Structural Equation Modelling tests. As shown in Table 3, all variables were higher than 0.8. Because CFA and SEM is rigorous against non-normality (Byrne 2013), the normality is examined for SEM models. A Latent variable is computed for category from their respective items. Different researchers use different methods for computing latent variables. Some add the individual items to extract a latent variable while some others use average of individual items. Given the unbalanced items in each category, an average method is applied for calculating the latent variable. These all average variables were again averaged for computing the dependent variable for the study i.e. Overall Perceived Integration and Implementation. The results indicated that mean of all the variables is greater than 3 indicating that majority of the teachers have mostly agreed and strongly agreed on items. The highest mean is reported for the item of Pedagogical Content Knowledge (OPCK = 3.83), followed by Curriculum and Delivery (OCD = 3.76) indicating that participants have mostly checked on agreed on their statements. The standard deviation of all items is mostly less than 1 indicating that their data is closer to their mean.

Table 13: Descriptive Statistics and Tests of Normality: Study Variables (N = 203)

Descriptive Statistics							
	N	**Mean**	**Std. Deviation**	**Min**	**Max**	**Kolmogorov-Smirnova**	**Shapiro-Wilk**
AS1	201	3.89	0.789	1	5	0.333	0.81
AS2	199	4.15	0.794	2	5	0.296	0.795
AS3	198	4.09	0.801	1	5	0.261	0.826
AS4	200	4.06	0.831	1	5	0.308	0.786
AS5	199	3.13	1.101	1	5	0.216	0.905
AS6	200	2.94	1.092	1	5	0.223	0.89
AS7	200	3.04	1.107	1	5	0.174	0.914
AS8	199	3.55	1.118	1	5	0.286	0.869
OAS*	**203**	**3.54**	**0.64428**	**1.25**	**5**	**0.087**	**0.966**
C1	200	3.87	0.866	1	5	0.316	0.825
C2	200	3.03	1.129	1	5	0.2	0.903
C3	200	3.56	0.917	1	5	0.279	0.869
C4	197	3.84	0.915	1	5	0.255	0.861
C5	198	3.9	0.888	1	5	0.275	0.846
OC*	**203**	**3.56**	**0.72489**	**0**	**5**	**0.11**	**0.96**
CD1	201	4.28	0.75	1	5	0.297	0.732
CD2	201	4.11	0.733	1	5	0.345	0.754
CD3	203	4.2	0.711	2	5	0.279	0.8
CD4	202	4.16	0.745	1	5	0.286	0.799
CD5	201	4.02	0.751	1	5	0.294	0.824
CD6	201	3.43	0.988	1	5	0.246	0.887
CD7	201	3.47	0.985	1	5	0.258	0.882
CD8	200	3.56	0.944	1	5	0.282	0.867
CD9	198	3.03	1.094	1	5	0.176	0.911
OCD*	**203**	**3.76**	**0.54315**	**1.56**	**5**	**0.128**	**0.915**
L1	197	4.18	0.785	1	5	0.262	0.808
L2	201	2.93	1.191	1	5	0.192	0.909

L3	201	2.91	1.147	1	5	0.186	0.913
L4	195	3.05	1.17	1	5	0.205	0.908
L5	200	3.27	1.077	1	5	0.213	0.905
OL*	**203**	**3.19**	**0.86435**	**0.8**	**5**	**0.102**	**0.978**
PCK1	201	4.18	0.691	2	5	0.301	0.771
PCK2	201	3.92	0.857	1	5	0.245	0.864
PCK3	199	4	0.847	1	5	0.277	0.824
PCK4	199	4	0.759	1	5	0.308	0.824
PCK5	202	3.65	0.925	1	5	0.281	0.869
PCK6	200	4.01	0.793	1	5	0.309	0.799
PCK7	202	3.07	1.065	1	5	0.186	0.908
PCK8	198	4.06	0.862	1	5	0.272	0.805
PCK9	199	4.06	0.842	1	5	0.282	0.812
PCK10	198	4.02	0.824	2	5	0.29	0.819
PCK11	199	3.96	0.867	1	5	0.288	0.836
PCK12	197	3.89	0.823	1	5	0.309	0.83
OPCK*	**203**	**3.83**	**0.59587**	**1.5**	**5**	**0.164**	**0.896**
TR1	200	3.46	1.079	1	5	0.262	0.885
TR2	201	3.02	1.218	1	5	0.197	0.907
TR3	198	3.44	1.015	1	5	0.275	0.866
TR4	199	3.66	1.006	1	5	0.285	0.859
TR5	198	3.36	1.117	1	5	0.254	0.888
OTR*	**203**	**3.32**	**0.8156**	**0**	**5**	**0.093**	**0.983**
OPII*	**203**	**3.53**	**0.59025**	**1.14**	**5**	**0.081**	**0.958**

* **Average of all the Items - OAS =** Overall Assessment**; OC =** Overall Connection**; OCD =** Overall Curriculum and Delivery**; OL =** Overall Leadership**; OPCK =** Overall Pedagogical Content Knowledge**; OTR =** Overall Technology and Resources**; OPII =** Overall Perceived Integration and Implementation

4.2.4 Tests of Multicollinearity / Pearson Correlation

The data were also examined to determine if multicollinearity existed among the study latent constructs of Assessment, Connection, Curriculum and Delivery, Leadership, Pedagogical Content Knowledge, and Technology and Resources. In order to confirm that, Pearson correlation and tolerance and variance inflation factor tests were performed. The findings indicated that almost all latent variables are strongly correlated with each other and on statistical significant level. While these correlations were very strong, they did not demonstrate multicollinearity, which is evident at $r >= .90$, $p < .001$ (Howell 2002). Additionally, each predictor variable was low to moderately correlate with the dependent variable as well, at the .000 level, as indicated in Table 14.

Table 14: Test of Multicollinearity: Pearson Bivariate Correlations

Correlations								
		OAS	**OC**	**OCD**	**OL**	**OPCK**	**OTR**	**OPII**
OAS	Pearson Correlation	1	.656**	.750**	.738**	.681**	.766**	.903**
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.000
	N	203	203	203	203	203	203	203
OC	Pearson Correlation	.656**	1	.672**	.618**	.653**	.673**	.843**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.000
	N	203	203	203	203	203	203	203
OCD	Pearson Correlation	.750**	.672**	1	.619**	.654**	.622**	.832**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000
	N	203	203	203	203	203	203	203
OL	Pearson Correlation	.738**	.618**	.619**	1	.353**	.773**	.837**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.000

	N	203	203	203	203	203	203	203
OPCK	Pearson Correlation	.681**	.653**	.654**	.353**	1	.592**	.749**
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000
	N	203	203	203	203	203	203	203
OTR	Pearson Correlation	.766**	.673**	.622**	.773**	.592**	1	.891**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000
	N	203	203	203	203	203	203	203
OPII	Pearson Correlation	.903**	.843**	.832**	.837**	.749**	.891**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	
	N	203	203	203	203	203	203	203
**. Correlation is significant at the 0.01 level (2-tailed).								

Note: **OAS =** Overall Assessment**; OC =** Overall Connection**; OCD =** Overall Curriculum and Delivery**; OL =** Overall Leadership**; OPCK =** Overall Pedagogical Content Knowledge**; OTR =** Overall Technology and Resources**; OPII =** Overall Perceived Integration and Implementation
**. Significant at the 0.05 level

The findings indicated that all the factors are positively and statistically correlated with each other. The factors are most strongly correlated with Technology and Resources factors indicating that combination of these factors with Technology and Resources are significant for STEM implementation and integration as perceived by the teachers. Assessment factor is significantly and positively correlated with Connection, Curriculum and Delivery, Leadership, Pedagogical Content Knowledge, and Technology and Resources. It is strongly correlated with Perceived Integration and Implementation followed by Technology and Resources, Curriculum and Delivery and Leadership factors. In addition, Connection is most strongly correlated with Technology and Resources followed by Curriculum and Delivery. Similarly, Curriculum and Delivery is most strongly correlated with Pedagogical Content Knowledge. Leadership is most strongly correlated with Technology and Resources and Assessment. Pedagogical Content

Knowledge is also most strongly connected with Assessment. Technology and Resources is most strongly connected with Leadership and Assessment. These results indicated that combination of one or two of these factors are significant for STEM implementation and integration as perceived by the teachers.

The data were further tested for potential violations of the lack of multicollinearity assumption by examining tolerance and variance inflation factor (VIF) values. Collinearity tolerance values of less than .10 and variance inflation factors (VIFs) of greater than 10.00 indicate a violation of multicollinearity (Howell 2002). Tolerance values ranged from .28 to 1.00, and VIFs ranged from 1.00 to 3.54, as indicated in Table 15. These results confirmed that the lack of multicollinearity assumption was not violated.

Table 15: Test of Multicollinearity: Tolerance and Variance Inflation Factors (N = 203)

Predictor	**Tolerance**	**VIF**
Overall Assessment	.227	4.411
Overall Connection	.379	2.638
Overall Curriculum and Delivery	.353	2.830
Overall Leadership	.248	4.026
Overall Pedagogical Content Knowledge	.321	3.117
Overall Technology and Resources	.272	3.679

4.2.4 Results from Explanatory Factor Analysis (EFA) and Reliability Analysis of Individual Items

In order to confirm the categories or factors assigned to individual items of the questionnaire as per their objective to measure, explanatory factor analysis (EFA) was performed before confirmatory factor analysis (CFA). Also, the reliability statistics using the

Cronbach's Alpha was tested for entire questionnaire items and for each factor examined. The recommendation for good inter-item reliability is that instruments should have a Cronbach's alpha of .70 or higher (Tavakol & Dennick 2011). The Cronbach alphas for the entire questionnaire is α = .941 for the entire items. Overall, the questionnaire itself displayed excellent inter-item reliability.

For EFA analysis, each item of the category or factor was individually examined for factor loadings on single factor. Hence, only factor was assigned for the assessment items. Each of these items was then loaded into one factor and examine whether their factor loading scores are minimum 0.4. After that, all of the factors were checked for the reliability score again using their items together. For that, the Cronboch score should be more than 0.7. This confirms that teacher questionnaire used in this study is an effective tool as indicated by a very high Cronbach's Alpha reliability (0.940). After these assumptions are met, it is confirmed that the selected items constitute one factor. This process is later confirmed through explanatory factor analysis (EFA) and confirmatory factor analysis (CFA) techniques. Table 16 shows the almost all the items are meeting the assumption of loading on the factor and also giving the acceptable reliability scores except L1from leadership factor and PCK7 from Pedagogical Content Knowledge. These items were omitted from leadership and Pedagogical Content Knowledge in CFA and SEM analysis.

Table 16: EFA Factor Loadings of Factors and Cronbach's Alpha Reliability Scores

Factor	Sub-Items	Factor Loadings	Cronbach's Alpha	N of Items
Assessment	AS1	0.589	0.79	8
	AS2	0.665		
	AS3	0.677		
	AS4	0.691		
	AS5	0.452		

	AS6	0.652		
	AS7	0.685		
	AS8	0.705		
Connection	C1	0.649	0.708	5
	C2	0.455		
	C3	0.706		
	C4	0.801		
	C5	0.81		
Curriculum and Delivery	CD1	0.647	0.785	9
	CD2	0.591		
	CD3	0.672		
	CD4	0.691		
	CD5	0.654		
	CD6	0.556		
	CD7	0.538		
	CD8	0.607		
	CD9	0.553		
Leadership	L1	0.246	0.805	5
	L2	0.833		
	L3	0.9		
	L4	0.878		
	L5	0.741		
Pedagogical Content Knowledge	PCK1	0.608	0.867	12
	PCK2	0.572		
	PCK3	0.649		
	PCK4	0.679		
	PCK5	0.523		

	PCK6	0.658		
	PCK7	0.291		
	PCK8	0.773		
	PCK9	0.731		
	PCK10	0.765		
	PCK11	0.75		
	PCK12	0.73		
Technology and Resources	TR1	0.693	0.741	5
	TR2	0.74		
	TR3	0.566		
	TR4	0.665		
	TR5	0.824		

4.2.5 Results from CFA for Exogenous and Endogenous Latent Constructs

Statisticians recommend that investigators utilise a two-phase process for SEM models, with the first phase testing measurement models using CFA followed by the second phase testing the structural models using SEM (Anderson & Gerbing 1988; Kenny, Kaniskan & McCoach 2015; Mueller & Hancock 2008). SEM results would not display good model fit if the latent constructs show poor fit in CFA results (Anderson & Gerbing 1988; Kenny, Kaniskan & McCoach 2015; Mueller & Hancock 2008). The first step in the analysis of models involved conducting CFAs for exogenous construct of Assessment, Connection, Curriculum and Delivery, Leadership, Pedagogical Content Knowledge, and Technology and Resources factors and the endogenous construct of Perceived Integration and Implementation. In the following sections, the researcher refers several times to “constraining” variables and error terms. In this section of the results, a comprehensive discussion is presented with regard to the proposed latent constructs in the study, ending with a presentation of the best latent constructs that emerged from CFA.

The CFA assessed the 6-factor model comprised of six latent constructs of STEM questionnaire: (a) Assessment, (b) Connection, (c) Curriculum and Delivery, (d) Leadership, (e) Pedagogical Content Knowledge, and (f) Technology and Resources as shown in figure 11. Results showed that the 6-factor model had good fit to the data, with a significant model chi-square, an IFI of .572, a TLI of .537, a CFI of .568, and a RMSEA of .120. According to Byrne (2013), chi-square value should be non-significant, for IFI, TLI, and CFI an acceptable output is .50 but the preferred index value should be .6. An acceptable χ 2 /DF is between 2.00 or 3.00, and is indicative of an acceptable fit between the hypothesised model and the actual model (Carmines & McIver 1981). Thus, the χ 2 /DF was within the acceptable range of values, which documented good model fit. An acceptable RMSEA is equal to or less than .08, but a preferred RMSEA value is equal to less than .05 (Byrne 2013). The latent constructs were first constrained to 0.0, which prevented the population matrix from being positive definite. Error terms were then correlated. The model was also considered a good fit to the data because the latent constructs displayed no multicollinearity, suggesting that a single work factors latent construct would likely have better model fit. The figure 11 below shows the model fit for 6-factor model comprised of six latent constructs of STEM questionnaire: (a) Assessment, (b) Connection, (c) Curriculum and Delivery, (d) Leadership, (e) Pedagogical Content Knowledge, and (f) Technology and Resources.

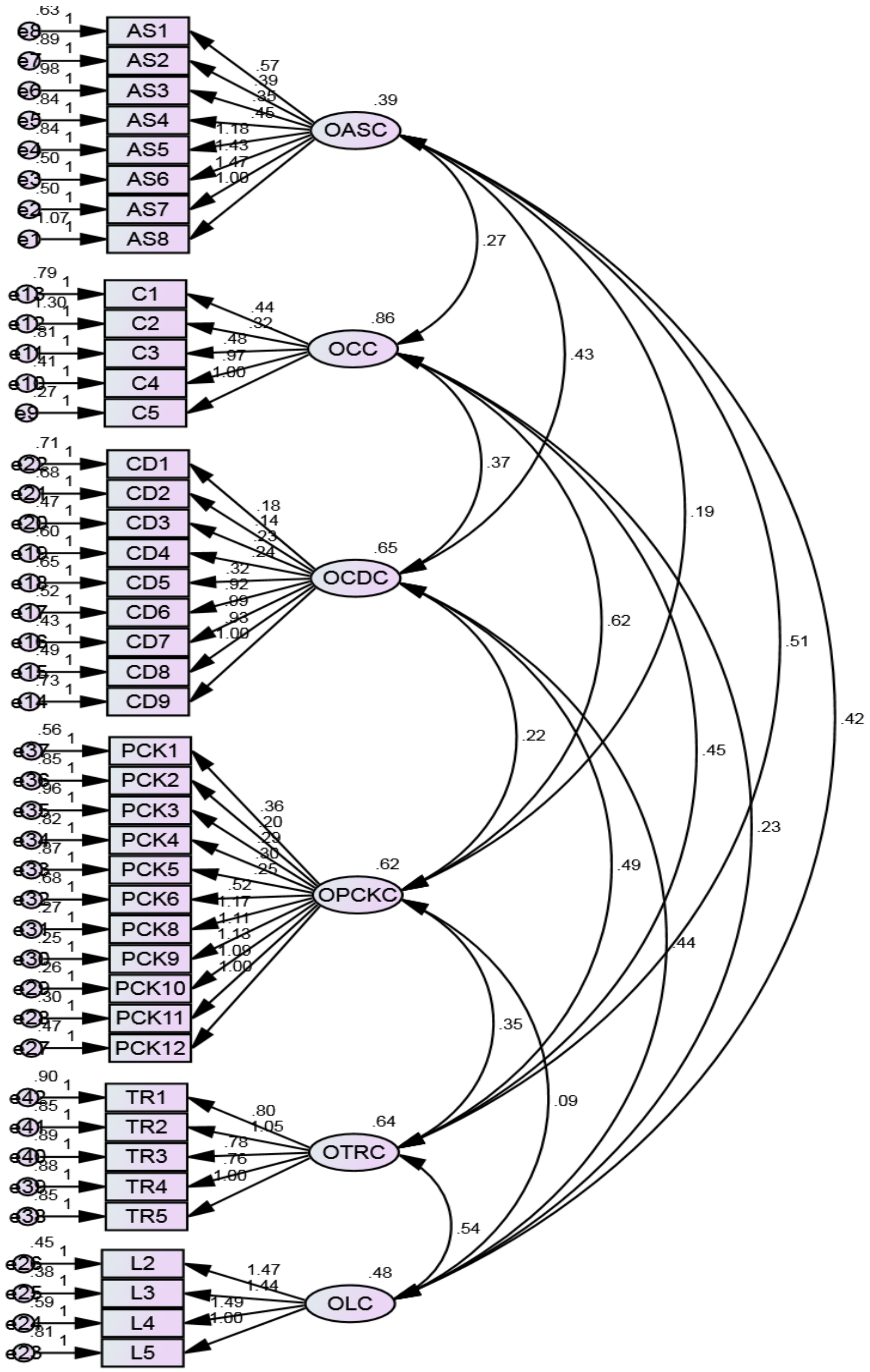

Figure 10: CFA Model Fit

4.2.6 Results from SEM for Hypothesis Testing

This section presents the results of the SEM models that were conducted to test the study hypotheses. As stated previously, while SEM models can have excellent fit, pathways in the model can be non-significant (Hu & Bentler 1998). Therefore, in the following sections, a table of model results precedes the SEM model. The tables provide information on model variables' respective pathways, estimates, SE, CR, and P values.

4.2.6.1 Results for Hypothesis 1: Assessment

The first hypothesis was that the latent construct of Assessment factors would predict perceived STEM implementation and integration of teachers, an observed variable. To test this hypothesis, Structure Equation Modelling (SEM) was conducted, to impute relationships between unobserved constructs (latent variables) from observable variables and results from the SEM are shown in Table 17. The assessment factor latent construct significantly predict perceived STEM implementation and integration of teachers across all the individual statements. This means that participants perceived that integrating Assessment in STEM is effective for STEM implementation and integration in UAE schools.

Table 17: Structural Equation Modelling: Assessment Factors Predicting Overall Perceived STEM Implementation and Integration of Teachers (N =203)

Observed variables		Latent Variable	Estimate	S.E.	C.R.	P
AS8	←	ASC	1.000 [a]	--	--	<0.001
AS7	←	ASC	1.144	.141	8.119	<0.001
AS6	←	ASC	1.082	.136	7.940	<0.001
AS5	←	ASC	.950	.133	7.165	<0.001
AS4	←	ASC	.603	.104	5.805	<0.001
AS3	←	ASC	.542	.107	5.064	<0.001

AS2	←	ASC	.594	.104	5.687	<0.001
AS1	←	ASC	.648	.097	6.659	<0.001

Note. [a]1.00 indicates that the observed variables were set to 1.00 per CFA/SEM requisites so that variable scaling aligned (Hu & Bentler 1998).

All the sub-factors of Assessment factor are statistically significant. However, the most significant sub-factors among them are: AS8, AS7, AS6, and AS5. These sub-factors mostly explain the perceptions of teachers related to having clear STEM assessment policy for the assessment of students. This means that participants perceived that integrating STEM assessment policy within Assessment factor is effective for STEM implementation and integration in UAE schools.

AS8 = As a teacher, I believe that I can develop different kinds of assessments to measure students' integrated knowledge of STEM at the end of an instructional unit
AS7 = STEM assessment policy in my organisation has a clear structure for both summative and formative assessments.
AS6 = STEM assessment policy in my organisation has a clear structure for formative assessments only.
AS5 = STEM assessment policy in my organisation has a clear structure for summative assessment only

Figure 12 presents the findings in chart and confirms that Assessment is a significant predictor of teachers' perceived STEM implementation and integration. Assessment predicts around 89% of teachers' perceived STEM implementation and integration. Further results indicated that AS8, AS7, AS6, and AS5 (measuring perceptions towards some form of assessment policy) are most powerful predictors within Assessment model. Based on the significance of the results, Hypothesis 1 was supported.

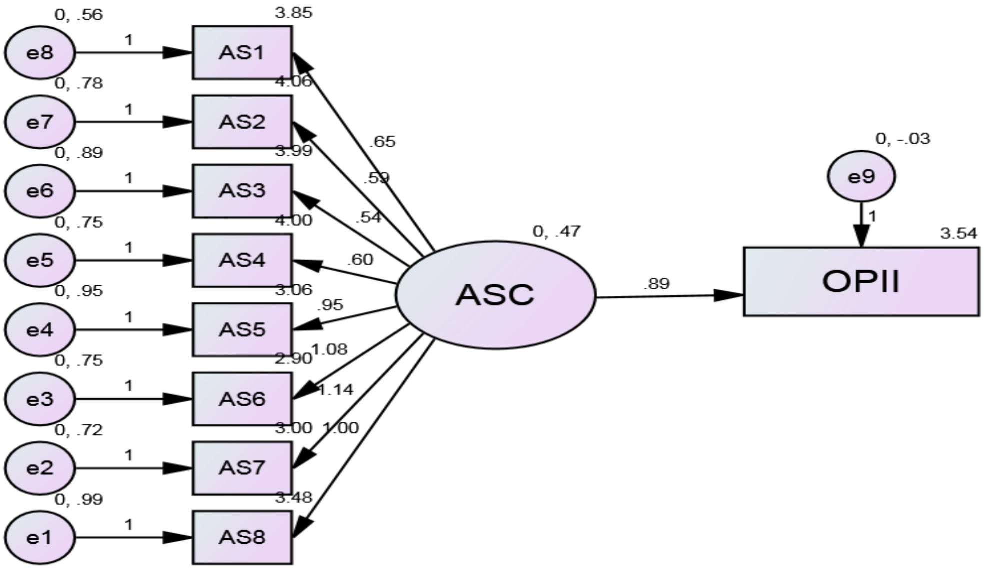

Figure 11: SEM model for Hypothesis 1: Assessment factors predicting Overall Perceived STEM Implementation and Integration of Teachers

4.2.6.2 Results for Hypothesis 2: Connection

The second hypothesis was that the latent construct of Connection factors would predict perceived STEM implementation and integration of teachers, an observed variable. To test this hypothesis, Structure Equation Modelling (SEM) was conducted, to impute relationships between unobserved constructs (latent variables) from observable variables and results from the SEM are shown in Table 18. The connection factor latent construct significantly predicts perceived STEM implementation and integration of teachers across all the individual statements. This means that participants perceived that integrating connection in STEM is effective for STEM implementation and integration in UAE schools.

Table 18: Structural Equation Modelling: Connection Factors Predicting Overall Perceived STEM Implementation and Integration of Teachers (N =203)

Observed variables		Latent Variable	Estimate	S.E.	C.R.	P
C5	←	OCS	1.000 [a]	--	--	<0.001
C4	←	OCS	1.209	.199	6.086	<0.001
C3	←	OCS	1.089	.179	6.072	<0.001
C2	←	OCS	1.580	.233	6.776	<0.001

C1	←	OCS	.973	.168	5.778	<0.001

Note. [a]1.00 indicates that the observed variables were set to 1.00 per CFA/SEM requisites so that variable scaling aligned (Hu & Bentler 1998).

All the sub-factors of connection factor are statistically significant. However, the most significant sub-factors among them are: C2, C4, and C3. These sub-factors mostly explain the perceptions of teachers related to connecting STEM subjects with practical world by integrating the industries/businesses, latest technologies, and innovation and entrepreneurship so that both teachers and students can take meaning full advantage of STEM integration and implementation. This suggests that STEM should not be bound to be only theory based but it should connect with some form of practice.

C2 = Business and industry partners are involved with STEM education in my organisation
C4 = As a teacher, I believe that I can connect concepts to those of engineering, science, and technology
C3 = My organisation promotes a culture of innovation and entrepreneurship in STEM field amongst students.

Figure 13 presents the findings in chart and confirms that Connection is a significant predictor of teachers' perceived STEM implementation and integration. Connection predicts around 100% of teachers' perceived STEM implementation and integration. Further results indicated that C2, C4, and C3 (measuring perceptions towards connecting STEM subjects with practical) are most powerful predictors within Connection model. Based on the significance of the results, Hypothesis 2 was supported.

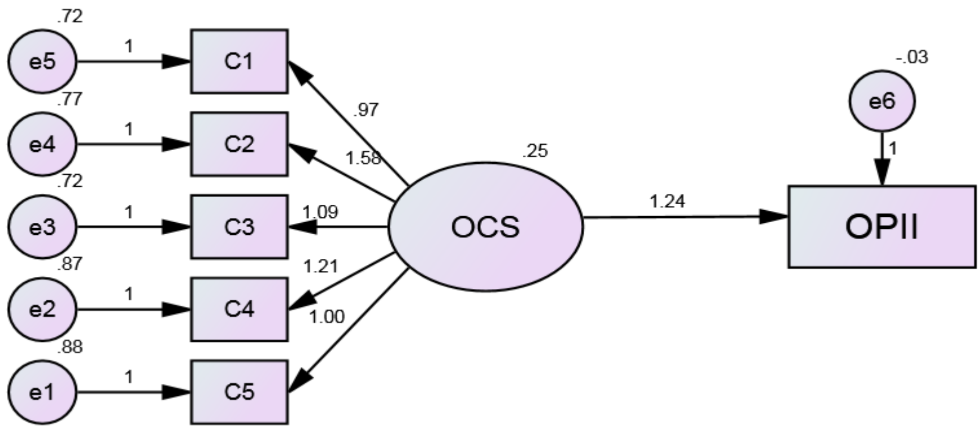

Figure 12: SEM model for Hypothesis 2: Connection factors predicting Overall Perceived STEM Implementation and Integration of Teachers

4.2.6.3 Results for Hypothesis 3: Curriculum and Delivery

The third hypothesis was that the latent construct of Curriculum and Delivery factors would predict perceived STEM implementation and integration of teachers, an observed variable. To test this hypothesis, Structure Equation Modelling (SEM) was conducted, to impute relationships between unobserved constructs (latent variables) from observable variables and results from the SEM are shown in Table 19. The curriculum and delivery factor latent construct significantly predict perceived STEM implementation and integration of teachers across all the individual statements. This means that participants perceived that integrating curriculum and delivery in STEM is effective for STEM implementation and integration in UAE schools.

Table 19: Structural Equation Modelling: Curriculum and Delivery Factors Predicting Overall Perceived STEM Implementation and Integration of Teachers (N =203)

Observed variables		Latent Variable	Estimate	S.E.	C.R.	P
CD9	←	OCDC	1.000 [a]			<0.001
CD8	←	OCDC	.821	.096	8.556	<0.001
CD7	←	OCDC	.789	.096	8.188	<0.001
CD6	←	OCDC	.783	.096	8.115	<0.001
CD5	←	OCDC	.497	.078	6.396	<0.001
CD4	←	OCDC	.413	.073	5.656	<0.001
CD3	←	OCDC	.371	.065	5.713	<0.001
CD2	←	OCDC	.276	.076	3.648	<0.001
CD1	←	OCDC	.302	.078	3.879	<0.001

Note. [a]1.00 indicates that the observed variables were set to 1.00 per CFA/SEM requisites so that variable scaling aligned (Hu & Bentler 1998).

All the sub-factors of curriculum and delivery factor are statistically significant. However, the most significant sub-factors among them are: CD9, CD8, CD7, and CD6. These sub-factors mostly explain the perceptions of teachers related to giving equal emphasis regarding content of each four subjects of STEM and having transdisciplinary, interdisciplinary, and multi-disciplinary instruction models. This suggests that STEM curriculum and delivery should be holistic where each subject should be given equal emphasis around transdisciplinary, interdisciplinary and multi-disciplinary instruction models.

CD9 = A STEM class or course in my organisation has equal emphasis regarding content (instruction) in the four disciplines/areas
CD8 = STEM curriculum in my organisation is transdisciplinary (Knowledge and skills learned from two or more disciplines are applied to real-world problems and projects, thus helping to shape the learning experience
CD7 = STEM curriculum in my organisation is interdisciplinary (Closely linked concepts and skills are learned from two or more disciplines with the aim of deepening knowledge and skills)
CD6 = STEM curriculum in my organisation is a multi-disciplinary (Concepts and skills are learned separately in each discipline but within a common theme).

The figure 14 below further presents the findings in chart and confirms that Curriculum and Delivery is a significant predictor of teachers' perceived STEM implementation and integration. Curriculum and Delivery predicts around 70% of teachers' perceived STEM implementation and integration. Further results indicated that CD9, CD8, CD7, and CD6 (measuring perceptions towards curriculum of STEM as holistic approach) are most powerful predictors within Curriculum and Delivery model. Based on the significance of the results, Hypothesis 3 was supported.

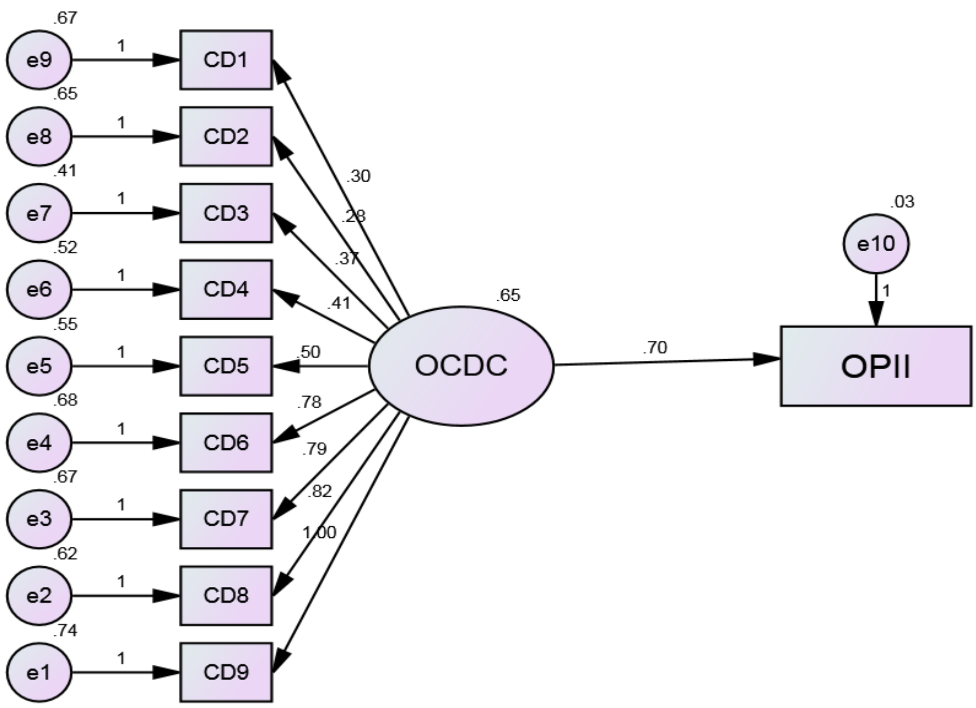

Figure 13: SEM model for Hypothesis 3: Curriculum and Delivery factors predicting Overall Perceived STEM Implementation and Integration of Teachers

4.2.6.4 Results for Hypothesis 4: Leadership

The fourth hypothesis was that the latent construct of Leadership factors would predict perceived STEM implementation and integration of teachers, an observed variable. To test this hypothesis, Structure Equation Modelling (SEM) was conducted, to impute relationships between unobserved constructs (latent variables) from observable variables and results from the SEM are shown in Table 20. The leadership factor latent construct significantly predict perceived STEM implementation and integration of teachers across all the individual statements. This means that participants perceived that integrating leadership in STEM is effective for STEM implementation and integration in UAE schools.

Table 20: Structural Equation Modelling: Leadership Factors Predicting Overall Perceived STEM Implementation and Integration of Teachers (N =203)

Observed variables		Latent Variable	Estimate	S.E.	C.R.	P
L5	←	OLC	1.000 [a]			<0.001

L4	←	OLC	1.450	.150	9.693	<0.001
L3	←	OLC	1.350	.137	9.841	<0.001
L2	←	OLC	1.343	.141	9.551	<0.001

Note. [a]1.00 indicates that the observed variables were set to 1.00 per CFA/SEM requisites so that variable scaling aligned (Hu & Bentler 1998).

All the sub-factors of leadership factor are statistically significant. However, the most significant sub-factors among them are: L4, L3, and L2. These sub-factors mostly explain the perceptions of teachers related to collaboration and professional development opportunities of collaborating with other teachers to learn about the best assessment strategies in STEM. This suggests that STEM leadership, through collaboration and professional development, is very important for teachers' self-efficacy and confidence in teaching the STEM content and achieving the desired achievement levels of their students.

L4 = STEM teachers collaborate often to reflect on student work
L3 = We received appropriate PD on best assessment strategies in the STEM field.
L2 = Professional development opportunities around STEM are regularly provided to teachers in my organisation.

The figure 15 below further presents the findings in chart and confirms that Leadership is a significant predictor of teachers' perceived STEM implementation and integration. Leadership predicts around 69% of teachers' perceived STEM implementation and integration. Further results indicated that L4, L3, and L2 (measuring perceptions towards collaboration and professional development of teachers) are most powerful predictors within Leadership model. Based on the significance of the results, Hypothesis 4 was supported.

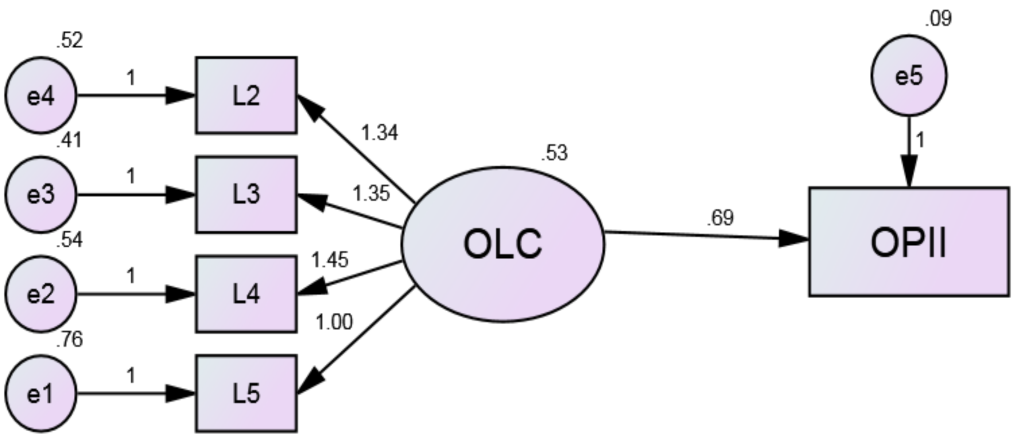

Figure 14: SEM model for Hypothesis 4: Leadership factors predicting Overall Perceived STEM Implementation and Integration of Teachers

4.2.6.5 Results for Hypothesis 5: Pedagogical Content Knowledge

The fifth hypothesis was that the latent construct of Pedagogical Content Knowledge factors would predict perceived STEM implementation and integration of teachers, an observed variable. To test this hypothesis, Structure Equation Modelling (SEM) was conducted, to impute relationships between unobserved constructs (latent variables) from observable variables and results from the SEM are shown in Table 21. The pedagogical content knowledge factor latent construct significantly predicts perceived STEM implementation and integration of teachers across all the individual statements. This means that participants perceived that integrating pedagogy and content knowledge in STEM is effective for STEM implementation and integration in UAE schools.

Table 21: Structural Equation Modelling: Pedagogical Content Knowledge Factors Predicting Overall Perceived STEM Implementation and Integration of Teachers (N =203)

Observed variables		Latent Variable	Estimate	S.E.	C.R.	P
PCK12	←	OPCKC	1.000			<0.001
PCK11	←	OPCKC	1.083	.082	13.156	<0.001

PCK10	←	OPCKC	1.113	.082	13.511	<0.001
PCK9	←	OPCKC	1.084	.081	13.391	<0.001
PCK8	←	OPCKC	1.110	.086	12.961	<0.001
PCK6	←	OPCKC	.527	.081	6.502	<0.001
PCK5	←	OPCKC	.262	.086	3.043	<0.001
PCK4	←	OPCKC	.295	.084	3.519	<0.001
PCK3	←	OPCKC	.283	.090	3.124	<0.001
PCK2	←	OPCKC	.203	.084	2.406	<0.001
PCK1	←	OPCKC	.344	.071	4.820	<0.001

Note. [a]1.00 indicates that the observed variables were set to 1.00 per CFA/SEM requisites so that variable scaling aligned (Hu & Bentler 1998).

All the sub-factors of pedagogical content knowledge factor are statistically significant. However, the most significant sub-factors among them are: PCK 10, PCK 8, PCK 9, and PCK 11. These sub-factors mostly explain the perceptions of teachers related to learning about new teaching styles, gaining teaching skills, learning new technologies, adapting new teaching situations, and inspiring students which teachers believe are important in their pedagogical content knowledge and are significant in STEM implementation and integration in UAE schools.

PCK 10 = As a teacher, I believe that I can learn new technologies that will enable me to teach from within an integrated STEM framework
PCK 8 = As a teacher, I believe that I can develop new knowledge and skills necessary to teach subjects from within an integrated STEM framework
PCK 9 = As a teacher, I believe that I can adapt to new teaching situations such as those necessary to teach subjects from within an integrated STEM framework
PCK 11 = As a teacher, I believe that I can get students to experience excitement, interest, and motivation to learn about science, technology, engineering and mathematics connection to the real world

The figure 16 below further presents the findings in chart and confirms that pedagogical content knowledge is a significant predictor of teachers' perceived STEM implementation and integration. Pedagogical Content Knowledge predicts around 44% of teachers' perceived STEM implementation and integration. Further results indicated that PCK 10, PCK 8, PCK 9, and PCK 11 (measuring perceptions towards new teaching styles, gaining teaching skills, learning new technologies, adapting new teaching situations, and inspiring students) are most powerful predictors within pedagogical content knowledge model. Based on the significance of the results, Hypothesis 5 was supported.

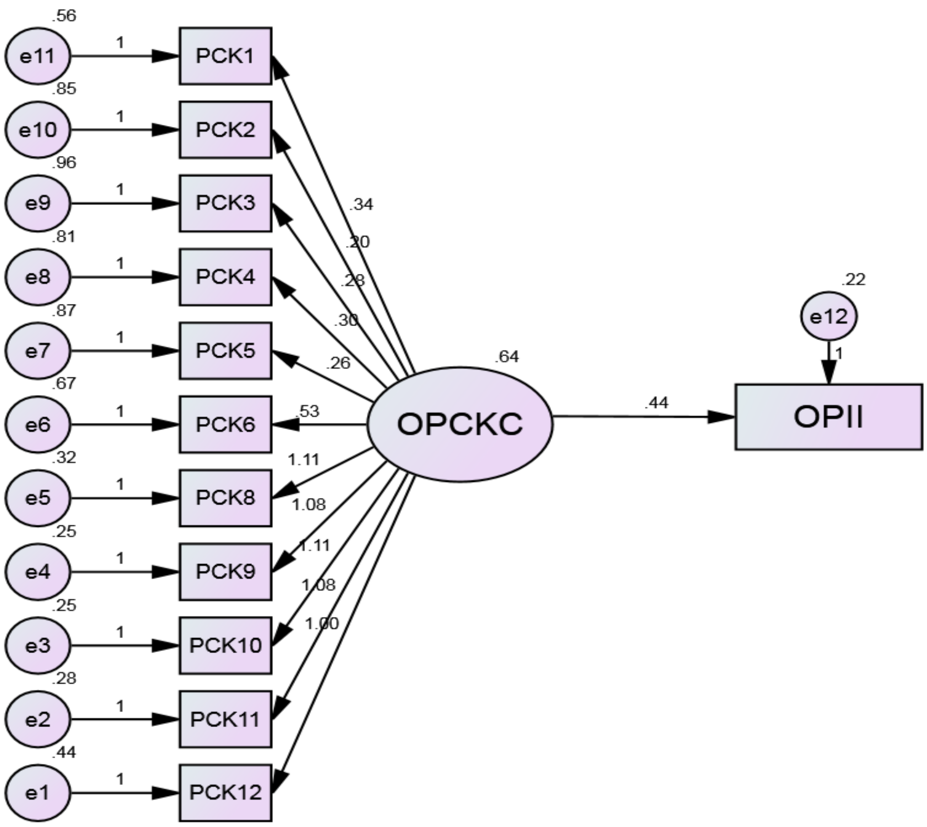

Figure 15 : SEM model for Hypothesis 5: Pedagogical Content Knowledge factors predicting Overall Perceived STEM Implementation and Integration of Teachers

4.2.6.6 Results for Hypothesis 6: Technology and Resources

The sixth hypothesis was that the latent construct of Technology and Resources factors would predict perceived STEM implementation and integration of teachers, an observed variable. To test this hypothesis, Structure Equation Modelling (SEM) was conducted, to impute relationships between unobserved constructs (latent variables) from observable variables and results from the SEM are shown in Table 22. The technology and resources factor latent construct significantly predict perceived STEM implementation and integration of teachers across all the individual statements. This means that participants perceived that integrating technology and resources in STEM is effective for STEM implementation and integration in UAE schools.

Table 22: Structural Equation Modelling: Technology and Resources Factors Predicting Overall Perceived STEM Implementation and Integration of Teachers (N =203)

Observed variables		Latent Variable	Estimate	S.E.	C.R.	P
TR5	←	1.000 [a]	--	--	--	<0.001
TR4	←	.868	.121	7.170	13.156	<0.001
TR3	←	1.017	.128	7.960	13.511	<0.001
TR2	←	1.111	.140	7.922	13.391	<0.001
TR1	←	.936	.126	7.431	12.961	<0.001

Note. [a]1.00 indicates that the observed variables were set to 1.00 per CFA/SEM requisites so that variable scaling aligned (Hu & Bentler 1998).

All the sub-factors of technology and resources factor are statistically significant. However, the most significant sub-factors among them are: TR2, TR3, and TR5. These sub-factors mostly explain the perceptions of teachers related to equipment, facilities, resources, technology, and supporting materials which teachers believe are important for delivering the STEM content and curriculum and are significant in STEM implementation and integration in UAE schools. The importance of technology and resources factor also imply that teachers would be effectively teach in virtual or distance learning environments of STEM in UAE schools.

TR2 = Equipment, facilities, and resources are available in the classroom or at the college site to meet STEM education goals, objectives, or standards.
TR3 = Technology is used throughout my STEM program as a tool to facilitate research
TR5 = As a teacher, I believe that I can obtain the materials necessary to teach mathematics through STEM in an integrated way

The figure 17 below further presents the findings in chart and confirms that technology and resources factor is a significant predictor of teachers' perceived STEM implementation and integration. Technology And Resources predicts around 89% of teachers' perceived STEM implementation and integration. Further results indicated that TR2, TR3, and TR5 (measuring perceptions towards equipment, facilities, resources, technology, and supporting materials) are most powerful predictors within technology and resources model. Based on the significance of the results, Hypothesis 6 was supported.

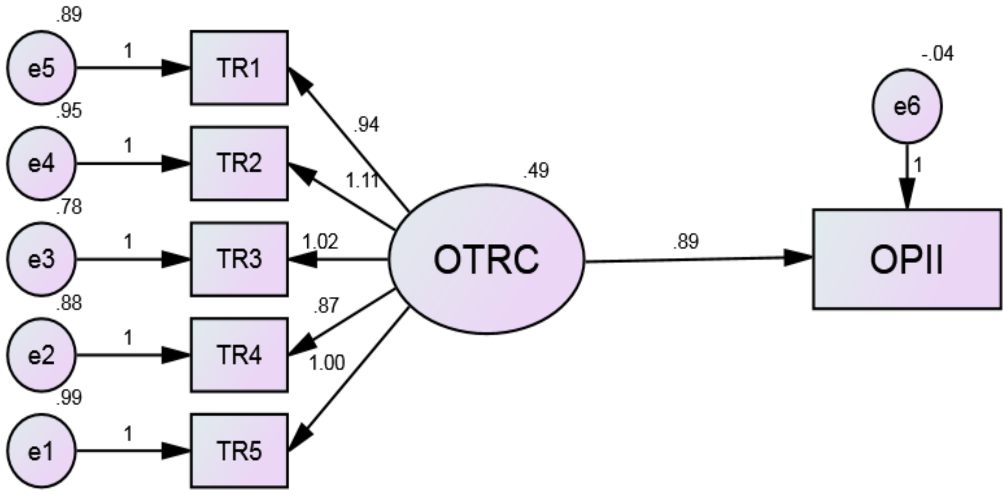

Figure 16: SEM model for Hypothesis 6: Technology and Resources factors predicting Overall Perceived STEM Implementation and Integration of Teachers

4.2.7 Results from Multiple Regression Analysis

While the above SEM results indicated that all the factors are significantly associated with STEM integration and implementation, they did not indicate which among these factors are most significant or highly significant compared to others so that educators and policy makers should give more importance and emphasis to these factors for implementation and integration of STEM in K-12 education in UAE schools. In this regards, the researcher used the Multiple Regression Analysis. Multiple Regression is a statistical technique is used to examine the which among these latent factors are most significant in influencing perceived STEM implementation and integration of teachers. The regression analysis is used to determine if there is significant association between independent and dependent variables.

For measuring the impact of each factor on the overall STEM integration and implementation based on teacher questionnaire responses, a composite variable of perceived STEM implementation and integration of teachers is computed. The model summary in table 23 indicated that model is fit for using perceived STEM implementation and integration of teachers as dependent variable and six factors of STEM implementation as independent variables. The prediction in dependent variable by these independent variables is around .976 or 97.6% which is also acceptable for measuring the dependent variable perceived STEM implementation and integration of teachers. The model fit is further tested in following ANOVA table from regression output.

Table 23: Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.988[a]	.976	.975	.65435
a. Predictors: (Constant), OTR, OPCK, OCD, OC, OL, OAS				

Table 24 showed the ANOVA model results of Multiple Regression Model. The above output related to ANOVA indicates the model fit summary of multiple regression and variables used for computing dependent and independent variables. The results show model fit at statistically significant level ($F(6, 196) = 1329.144$, $p < .05$) and indicates that regression coefficients can be examined for most significant independent variables measuring dependent variable. This is examined in the following table.

Table 24: ANOVA from Multiple Regression

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3414.655	6	569.109	1329.144	.000[a]
	Residual	83.923	196	.428		
	Total	3498.578	202			
a. Predictors: (Constant), OTR, OPCK, OCD, OC, OL, OAS b. Dependent Variable: OPII						

Table 25 shows the findings of multiple regression analysis where Composite Variable of perceived STEM implementation and integration of teachers is dependent variable and construct of Assessment, Connection, Curriculum and Delivery, Leadership, Pedagogical Content Knowledge, and Technology and Resources factors are independent variables. The findings indicated that all the predictors are significant with perceived STEM implementation and integration of teachers. The results indicated that there is positive and significant relationship between perceived effectiveness of Assessment, Connection, Curriculum and Delivery, Leadership, Pedagogical Content Knowledge, and Technology and Resources with perceived STEM implementation and integration of teachers. This suggests as well as confirms the CFA and SEM results. Among all these predictors, leadership has the higher predicted power with 25.3% prediction power. Followed by that, Technology and Resources have the second highest predicted power with 19.2% prediction power. Assessment has the third highest predicted power with 15.8% prediction power. Connection and Pedagogical Content Knowledge have the third highest predicted power with 14.1% prediction power each. Lastly, Curriculum and Delivery has the fourth highest predicted power with 11.5% prediction power. These findings indicated that teachers give highest importance to leadership, technology and resources, and assessment as the most significant factors associated with STEM integration and implementation in UAE schools.

Table 25: Regression Coefficients of Factors Associated with STEM Integration and Implementation

Coefficients[a]							
Model		Unstandardized Coefficients		Standardised Coefficients		t	Sig.
		B	Std. Error	Beta	Contribution to Model*		
1	(Constant)	-11.000	.348			-31.648	.000
	OAS	1.189	.150	.184	15.8%	7.923	.000
	OC	.947	.103	.165	14.1%	9.177	.000
	OCD	1.028	.143	.134	11.5%	7.210	.000
	OL	1.419	.107	.295	25.3%	13.280	.000
	OPCK	1.151	.136	.165	14.1%	8.437	.000
	OTR	1.145	.108	.224	19.2%	10.579	.000

a. Dependent Variable: OPII

*Computed by Researcher

4.2.8 Summary of Results of Research Question 2 - Teacher Questionnaire

This section examined the results related to second research question: *"What are the factors associated with STEM integration and implementation in UAE schools?"* The findings indicated that apparently there are no major differences between gender, sector, and campus regarding STEM perceptions. In UAE mostly high school teachers are the ones experience in STEM. Mostly teachers with more than 2 years of experience have positive perceptions about STEM education. However, when determining their differences through t-test and ANOVA, the findings indicated some differences in the perceptions among different teachers towards different factors of STEM that should be integrated and implementation in UAE schools. The findings indicated that public teachers have slightly more positive attitudes towards Technology and Resources compared to private teachers in UAE schools. Further, the findings indicated that teachers from Ajman, Ras Al Khaimah, and Al Ain have more positive attitudes than teachers from Abu Dhabi, Dubai, and Sharjah. The findings also indicated that teachers with Mathematics, Science, and Education degree majors have more positive attitudes than teachers with degree majors of computer science, engineering, and others. Moreover, the teachers teaching at primary schools, high schools, and middle schools have more positive attitudes than teachers teaching at kindergarten. The findings also indicated that male teachers have slightly more positive attitudes compared to female teachers in UAE schools. In addition, the findings revealed that teachers with more than 2 years of teaching experience have more positive attitudes regarding integration of assessment in STEM than teachers with 2 years and 1 year of teaching experience. Overall, the participants have reported most positive attitudes towards integration of Pedagogical Content Knowledge and Curriculum and Delivery factors.

The findings also indicated that all the factors are positively and statistically correlated with each other. The factors are most strongly correlated with Technology and Resources factors indicating that combination of these factors with Technology and Resources are significant for STEM implementation and integration as perceived by the teachers. The Cronbach alphas for the entire questionnaire is $\alpha = .941$ for the entire items. Overall, the questionnaire itself displayed excellent inter-item reliability. In addition, almost all the items have 0.5 loading scores except L1from leadership factor and PCK7 from Pedagogical Content Knowledge and also giving the acceptable reliability scores with 0.7 and above alpha for all items.

The CFA assessed the 6-factor model comprised of six latent constructs of STEM questionnaire: (a) Assessment, (b) Connection, (c) Curriculum and Delivery, (d) Leadership, (e) Pedagogical Content Knowledge, and (f) Technology and Resources. Results showed that the 6-factor model had good fit to the data, with a significant model chi-square, an IFI of .572, a TLI of .537, a CFI of .568, and a RMSEA of .120.

All six hypotheses of the study, one for each factor, are accepted from SEM analysis. The findings indicated that Assessment is a significant predictor of teachers' perceived STEM implementation and integration. Assessment predicts around 89% of teachers' perceived STEM implementation and integration. Further results indicated that AS8, AS7, AS6, and AS5 (measuring perceptions towards some form of assessment policy) are most powerful predictors within Assessment model. The findings also indicated that Connection is a significant predictor of teachers' perceived STEM implementation and integration. Connection predicts around 100% of teachers' perceived STEM implementation and integration. Further results indicated that C2, C4, and C3 (measuring perceptions towards connecting STEM subjects with practical) are most powerful predictors within Connection model. Curriculum and Delivery is also a significant predictor of teachers' perceived STEM implementation and integration. Curriculum and Delivery predicts around 70% of teachers' perceived STEM implementation and integration. Further results indicated that CD9, CD8, CD7, and CD6 (measuring perceptions towards curriculum of STEM as holistic approach) are most powerful predictors within Curriculum and Delivery model. Leadership is a significant predictor of teachers' perceived STEM implementation and integration. Leadership predicts around 69% of teachers' perceived STEM implementation and integration. Further results indicated that L4, L3, and L2 (measuring perceptions towards collaboration and professional development of teachers) are most powerful predictors within Leadership model. Pedagogical content knowledge is also a significant predictor of teachers' perceived STEM implementation and integration.

Pedagogical Content Knowledge predicts around 44% of teachers' perceived STEM implementation and integration. Further results indicated that PCK 10, PCK 8, PCK 9, and PCK 11 (measuring perceptions towards new teaching styles, gaining teaching skills, learning new technologies, adapting new teaching situations, and inspiring students) are most powerful predictors within pedagogical content knowledge model. Lastly, technology and resources factor is also found as a significant predictor of teachers' perceived STEM implementation and integration. Technology And Resources predicts around 89% of teachers' perceived STEM implementation and integration. Further results indicated that TR2, TR3, and TR5 (measuring perceptions towards equipment, facilities, resources, technology, and supporting materials) are most powerful predictors within technology and resources model. Lastly, the findings of regression analysis indicated that teachers give highest importance to leadership, technology and resources, and assessment as the most significant factors associated with STEM integration and implementation in UAE schools.

4.3 Results of Research Question 3 - Teacher Interviews

This section presents the results of third research question: *"In the light of the proposed policy, what are stakeholders' (teachers, coordinators, school leaders, and administrators) knowledge and perception about STEM future implementation?"* In this regards, interviews with different stakeholders, first with teachers and coordinators and then with school leaders and administrators, were conducted and then field notes and check list from classroom observation were also analysed. This section specifically analyses the responses from teachers and coordinators' interviews in light of third research question.

During the course of the research study, 20 teachers and coordinators were interviewed either in person or over the phone at three UAE schools in Al Ain, Dubai, and Abu Dhabi. The interviews were transcribed in their entirety and analysed following document analysis. Initial data analysis of the interviews began in three different stages. First, the big ideas from the raw interview data were compiled and sent to the Interviewee for feedback along with the entire interview transcription. Next, Interviewees were allowed to add, detract, and clarify information from the interview. Second, each question was analysed using the raw data to generate initial codes related to integrated STEM education in UAE. These codes were grouped together to identify themes that emerged from each question. Third, the data was analysed to remove all names and questions from within the raw interviews and to generate coding of the raw text.

4.3.1 Demographics of Interviewees

The interviews were conducted with teachers and coordinators. The study attempted to select participants for interviews that were diverse in many different aspects. The educational level attained by the participants was well above average with eight of the subjects having a Master's Degree and five of the participants having a Doctoral Degree, while seven had bachelor degrees. Sixteen of the Interviewees were male, while four were female. Most participants (18 out of 20) had experience in the classroom within one of the STEM disciplines in UAE and while 2 or 3 of them have had experience of teaching STEM in international schools outside UAE. Eight of the Interviewees had their primary teaching experiences in high school settings, three had their primary teaching experiences in middle school settings, while one had their primary teaching experiences in the K-12 setting. Not all the participants of the study are currently in the classroom. This was intentional to garner responses from different teachers that influence and shape STEM education in UAE. The current positions of the interview participants in no particular order are as shown in table 26.

Table 26: Current Job Descriptions of Interview Participants

1. Computer Science Teacher – Large High school at Al Ain
2. Teacher and Computer Science Education Support Staff – Large High school at Dubai

3.	Teacher and Director Education Centre – Small High School at Abu Dubai
4.	Science and Mathematics teacher – Large high school at Dubai
5.	Teacher and Senior Administrator - Large high school at Al Ain
6.	Engineering Teacher – Large high school at Abu Dubai
7.	Physics and Computer Science Teacher – Large high school at Abu Dubai
8.	Physics and Computer Science Teacher – Large high school at Dubai
9.	Teacher and Senior Administrator - Large high school at Dubai
10.	Engineering Education Professor – Large high school at Al Ain
11.	Educational Leadership Professor - Large high school at Al Ain
12.	Teacher Math Education – Large high school at Al Ain
13.	Teacher and Administrator – Large high school at Al Ain
14.	Science and Mathematics teacher – Large high school at Dubai
15.	Computer Science Teacher – Large High school at Dubai
16.	Science and Mathematics teacher – Large high school at Abu Dubai
17.	Computer Science Teacher – Large High school at Al Ain
18.	Science and Mathematics teacher – Large high school at Dubai
19.	Computer Science Teacher – Abu Dhabi
20.	Science and Mathematics teacher – Large high school at Al Ain

4.3.2 Identified Themes across Interviews

To identify themes across interviews, all the names and questions were removed from the text and the raw data for each interview was coded based on Braun and Clarke's (2006) thematic analysis. Similar codes were grouped together to identify themes in the data. If other Interviewees did not use the exact words, but the researcher could imply that the context of what the participant meant was the same, this information was grouped together as being semantically identical. Further detail related to this process and how it was applied will appear in the expanded themes below.

4.3.2.1 Theme 1: "Subject integration/project-based learning/design-based education"

As the interviews were analysed codes related to project-based learning, subject integration, and design-based education began to surface. Most Interviewees (18 out of 20) specifically stated that integrated STEM education in UAE must have a project-based learning approach. Project-based learning is defined by Dym et al. (2005) as a multidisciplinary approach combining design-oriented project-organised education and problem-oriented organised project-education. Design-oriented project-organised education is related to 'know how'. Specifically, "the problems students encounter are related to constructing and designing using the synthesis of knowledge from many disciplines. Problem-oriented project-organised education is related to 'know why'. This is specifically related to the solution of theoretical problems through the use relevant knowledge from any discipline. Together, the 'know how' and 'know why' that students learn and use to solve problems in a project setting make up project-based learning" (Interviewee 5).

The importance of project-based learning to integrate STEM in UAE is highlighted by the responses of the interview participants. Most of the participants specifically referenced project-based learning as part of their definition and consequently project-based learning arose as a primary vehicle for integrated STEM in UAE. For example, Interviewee 3 said, "it [integrated STEM] is either project or activity based and that it is active and not passive in UAE." Interviewee 5 believes, "it's [integrated STEM] all project-based in UAE." Interviewee 16 stated, "I would say certainly project-based learning. Because a project gives a student [the chance] to really demonstrate their connections and their understanding." Interviewee 19 believes, "integrated STEM in UAE I think would need to occur in a project-based activity" and that students need "project-based experiences."

Interviewee 8 says, "It [integrated STEM] is project-based, outcome-based, real world in UAE." Interviewee 9 thinks integrated STEM in this classroom is an "experiential learning experience either project-based or problem-based." Interviewee 10 says students in this classroom should need "to do a project of something based on the engineering design process." He goes on to say that when standards for different disciplines align, **"**that is when you approach a STEM type of project for the school or the class or the grade. Interviewee 11 thinks that integrated STEM in UAE consists of “a broad project in career-based or project-based learning or even some product that you want to come up with and affix certain academic content to that project.”

Several respondents related assessment of integrated STEM in UAE to long term or extended projects. Interviewee 1 stated, “you can show their math learning through these projects, through their demonstrated knowledge on final results and what they have done. Understanding that is acceptable and finding a way to make that meet your criteria.” Interviewee 20 says, “do a project, try it, explore it, and then again some sort of evaluation in the context of a rubric or in the context of a one page summary, a written summary.” Interviewee 14 believes that integrated STEM assessments in UAE should be “assessments that are maybe more project-based.” She goes on to state, “so we do our projects [and] that is actually a part of their grade.” Interviewee 10 believes that “the project itself should be the assessment. That method [of] project-based learning and assessment would be it.”

Many Interviewees responded and considered project-based learning from an integrated STEM curricular standpoint. Interviewee 19 stated this about integrated STEM in UAE, “so rather than learning a science topic just to learn it, you would need to know it to prove a larger point in your experiment, your project, or whatever your quest is.” He further states that teachers must have the “understanding that projects may not be clean.” Interviewee 12 was talking about what resources you might need for integrated STEM in UAE when he stated, “I would say that depending on your projects you would almost need a shop-like environment in which to do this.” Interviewee 15 said this when discussing resources,

> What are the four projects that we are to have the students work on, and what level of math do they need to know, and what’s the science subjects that they’re going to be doing, and what do they have access to for materials? So they think pretty strategically about where they are going to be in the year and which subject and topics within the subject are

going to be covered simultaneously, and how to tie all those into a relevant integrated STEM project in UAE.

Interviewee 18 stated that resources need to change "based on the project they might be doing."

As one respondent (Interviewee 19) stated, "When you look at STEM and STEM research, integration is assumed. So that when you look at STEM programs throughout the United States, they aren't integrated." Another Interviewee (Interviewee 11) said something similar, "So, the assumption of integration really has been happening forever. I think each content area maintains its own kind of unique didactic content but there has been natural spill over." Both of these comments speak to the fact that integration in UAE might not be as prevalent as first thought. The second statement also speaks to the fact that there are natural overlaps in the STEM disciplines in UAE that can be exploited to provide opportunities for learning.

The subject of integration of the STEM disciplines in UAE continued to surface throughout all the interviews. For example, Interviewee 1 said, he sees "integrated STEM technology as a science class using computer science topics and ideas to prove a science fact or do a science experiment. Similarly with math being applied in science, being applied in a technology or engineering as part of their quest, but we have to use these ideas from other areas" and "using technology to further your understanding of science or mathematics or using mathematics to further the understanding of computer science is STEM." He believes that people should come together to create "STEM education with the goal of integrating all their classes together and intertwining their topics" and that "it [integrated STEM] is a class of multiple classes combined together.

Interviewee 2 sees integrated STEM as "taking concepts from a lot of different areas like natural sciences and mathematics in order to design a solution to a problem." Interviewee 3 sees integrated STEM where "students don't learn the subjects independently from each other. That the knowledge that they are learning is all related knowledge toward an end goal" and that students "see the connection and need to use the knowledge from all different subject areas." Further Interviewee 3 believes that teachers need to carefully think about "where they are going to be in the year and which subject and topics within the subject are going to be covered simultaneously, and how to tie all those into a relevant integrated STEM project."

Interviewee 4 defines integrated STEM as "an opportunity for students to see connections among different content areas that previously were 'siloed' out into their own specific categories" and thinks "it's a lot more meaningful if they [students] can have some connections to different content areas that they are currently studying and/or different fields that they might be interested in going into." Interviewee 5 continues the integration theme by defining integrated STEM as "how all the content areas interact and how they are really applied beyond the classroom setting and getting into how the specific set of skills and knowledge are also taught," and expects teachers to "continue to show how content areas are connected and how they would show the application of it beyond the classroom."

Interviewee 6 says integrated STEM "needs to cross disciplines" and that he sees "integrated STEM education as where science, technology, engineering, and mathematics are much more interdisciplinary perspective." Interviewee 7 believes "integrated STEM education is bringing math, science, engineering, and technology into all classes where they apply, and doing that through projects that students do within the class that have math or science STEM topics embedded in them, and also doing focused classroom activities on particular topics." Further, Interviewee 7 thinks, "more integration in the curriculum would be a benefit and more open-ended opportunities for students to investigate in an open-ended manner would be a benefit."

Interviewee 8 states that integrated STEM is where the “subject areas of science, technology, engineering, and math are not isolated within their school day” and that it incorporates “real world topics, real world problems working in collaborative groups in which students have to use their knowledge of science, technology, engineering, and math to come up with potential solutions.” Interviewee 9 believes that integrated STEM is “integrating all the core areas of curriculum into STEM education” and “is the combination of all the knowledge that students are learning at a particular age level and building upon what they have learned through their experiences to be able to apply knowledge and solve real-world relevant problems.” Interviewee 10 believes that integrated STEM is “[where students are] taking knowledge from each one of their classes and they are applying it in their other classes or they are seeing the connection between everything” and that “STEM is not a ‘siloed’ enterprise and all four of those ought to come together.”

Interviewee 11 says, “Integrated STEM education involves the specific use of didactic content from one area to support any or all of the other areas of STEM” and that it should include “the use of one field to bolster content into another and to develop new content.” Interviewee 12 thinks that integrated STEM is “finding out the applications that would bring science, math, and technology together.” Finally, Interviewee 13 believes “integrated STEM education is when you take multiple discipline contents and you use the knowledge that you gain from those content areas and apply them toward problem solving.” The evidence from the interviews regarding subject integration is clear. All participants see STEM education containing some aspect of integration of subjects.

Design-based education is the third leg of the pedagogical model by Kelley (2012). Design-based education is described as education in a “full range of real-life activities and using a hands-on approach to teaching”. This aspect of Kelley’s pedagogy was not nearly as evident as project-based learning or subject integration. In those cases, participants used words like “project,” “project-based,” or “integration” that clearly showed their importance to the Interviewee. Design-based education (DBE) was equally prevalent but it took a semantic analysis of the text to garner the underlying meaning. For the analysis, the researcher coded text related to real life applications, real world experiences, relevance, and other text like demonstrate, explore, etc. that had meaning related to a hands-on approach.

DBE was found in Interviewee 1 when he stated, “you would find applications of that real world or contrived but ways that you can demonstrate the usefulness of this in a more practical application,” and “the teacher must build a culture where they [students] are allowed to define problems, explore the problems, and use you as a guide...use the teacher as a guide and a resource, but not use them as the absolute purveyor of knowledge.” Interviewee 2 was more directly related to DBE. He said “I think it is a much more real world and rich education experience” and when referring to integrated STEM resources, “with the hands on...certainly you need some space.”

Interviewee 3 believes that “integrated STEM is a really great thing for the learner because it finally gives relevance to the stuff that they have just been memorizing.” Interviewee 4 said that integrated STEM teachers are “trying to put them [students] into situations where the line has a meaning and the slope has a meaning and the y-intercept has a meaning” and integrated STEM is a place where, “students that really excel with projects, and really excel through hands-on situations, can still learn the content.” In addition, Interviewee 4 thinks educators need to “give them [students] opportunities to get more of a real world setting, I think project assessments are equally as important, if not more important, than standardised testing.”

Interviewee 5 thinks educators should be “creating authentic experiences for students” and sees integrated STEM as more about how a class “would be taught and how students would apply that beyond the classroom." Interviewee 8 sees students in integrated STEM addressing "real world topics, real world problems, working in collaborative groups in which students have to use their knowledge of science, technology, engineering, and math to come up with potential solutions." In addition, he believes that students should be "thinking critically and doing their best to come up with real-world answers to real-world problems" and that "real-world problems change the nature of how students address the subject matter."

Interviewee 9 thinks a "STEM high school needs to be set up to replicate what is going on out in the industry and the business world" and that teachers need "to be able to create some of these problem-based, relevant, application kind of problems and lessons" where "the kids could apply the knowledge to real world experiences." Interviewee 10 sees integrated STEM as where students "work on a real world issue in their community, in their neighbourhood, their school, or whatever it may be" and "they are applying all that knowledge and it's even taught that way in that it's more experiential." Interview 12 sees integrated STEM as where "students get to explore and see those connections and hopefully see some real life things happening" and that a key component of integrated STEM is "problem solving and seeing real life applications."

Interviewee 13 specifically references the hands on nature of integrated STEM. She says "public education is very good at devaluing hands-on skills, but being able to take an electron microscope and being able to apply that in different areas, that shouldn't be devalued." This implies that we need the hands on nature of DBE. The remaining interviews had a lesser connection to DBE. They all spoke about problem solving and application of knowledge, which is loosely connected, to DBE. Interviewee 6 sees integrated STEM as "Interdisciplinary. Big ideas. Problem solving and inquiry" and says, integrated STEM is "much more of a true problem solving environment where they learn certain concepts." Interviewee 7 says that integrated STEM instructions should "give students project-based experiences that allow them to utilise their STEM knowledge and skills." Interviewee 11 says integrated STEM students should be able to "apply information from a given field that crosses over into another area." Overall, a strong case can be made for the interviews containing evidence to support design-based education as a part of integrated STEM.

In summary, all the Interviewees either mentioned or referred to the pedagogical methods as referenced without being prompted. The emergence of this theme shows strong support for the and strongly infers that project-based learning, subject integration, and design-based education should be included in integrated STEM implementations.

4.3.2.2 Theme 2: "School Leadership"

All participants in the interviews specifically stated some form of leadership is necessary for successful integrated STEM education in UAE. From the literature, leadership, specifically district decision makers, were cited as a key support structure for integrated STEM education. While the participants of the study did discuss the need for strong school leadership, their thoughts on the leadership related to integrated STEM education was far broader in scope. They included such ideas as leadership by teachers, shared leadership, student leadership, and leadership by outside experts.

School leadership can be defined in many ways. For the purpose of the analysis, the researcher had combined comments about school leadership from anyone directly attached to the school except teachers and students. This included building and district level administrators, curriculum specialists, and school board members. Interviewee 1 believes that you must "have an administration that is willing to put trust in the teacher, and teachers that are willing to put trust in the students" and further, that "you have an administration that is allowing this [integrated STEM] to take place." Interviewee 3 said "the administrator has to ‘buy in’.” In addition to facilitating curriculum and teaching, “the administration actually gives the team of the different subject area matters planning time to talk about things, to talk about the students that are in all those classes.” When developing an integrated STEM curriculum, Interviewee 4 believes that you must

> Talk to the administration and go forward from there. So from a teacher’s perspective, if you have the passion for it, go for it, and find people that will support you. From an administrative position, see teachers that are passionate and want something like this [integrated STEM] and just talk to them and see what they’re willing to do.

Interviewee 4 agrees with Interviewee 3 when she said, “If I am an administrator in a building I would want to allow that time for my teachers to work together on a new program such as this [integrated STEM].”

Interviewee 5 said for implementation of integrated STEM, “you may need an instructional coach…someone who’s able to coach and to provide that support in terms of improvement of instruction.” Interviewee 6 thinks that there “needs to be a STEM curriculum director who oversees those departments and has some sort of control over it.”

He further reiterated, “Whether it is someone designated as the STEM leader of the school where they lead an interdisciplinary committee or better, they have a designated curriculum director who is the STEM curriculum director.” Interviewee 8 believes a “collaborative effort is going to be necessary on this [integrated STEM] with good administrators and good leaders at the top.” Interviewee 10 believes that to implement integrated STEM, “administration and curriculum and professional development those three things are needed.” He further believes that STEM certification is needed and that “that can be done with the support of the administration in that building or maybe the school district and the other teachers to provide a course.”

Interviewee 11 believes that staffing will require, “educational leaders in integrated STEM who have a lot of the abilities and knowledge that I have been talking about.” He elaborated teachers need to be, “fully degreed in two or more of the subject areas, or have at least a very good concept of the crossover of how all those really are used from one field to the next.” He also believes that integrated STEM requires “educational leaders who have the ability to very specifically guide teachers in that process.”

Leadership by teachers, students and outside the school was also mentioned as important to integrated STEM. Interviewee 2, feels that teachers need to have leadership experiences. He is a practicing high school teacher who feels he has “enough experience either formally or informally with engineering and mathematics, that I feel pretty comfortable in either leading something or finding out the information I need.” Interviewee 6 thinks, “it [integrated STEM] needs some sort of faculty specialist in STEM with a vision for it. Interviewee 7 strongly believes that “it [integrated STEM] takes leadership from students that are interested in pursuing STEM activities.” He further states that the creation of integrated STEM “takes leadership I think from both the teacher’s perspective and the student’s perspective as well.” Interviewee 9 believes that when professional development is needed, you need to “find community leaders to kind of help out with that training so that you’re on top of it.” Interviewee 12 stated, “[It would be the] Nebraska Association of Teachers of Mathematics [for math]. It would be NETA for technology. It would be NATS for science. I think all of those leadership groups would be the ones who would help disseminate and support the idea of STEM integration.”

Possibly the best way to sum up the leadership needs for integrated STEM, is through shared leadership. Eight of the 13 interviews spoke to the shared leadership needs of integrated STEM. Interviewee 2 said, “it [integrated STEM] takes a lot of cooperation on the part of all the participants the students, the teachers, the administration, the parents etc." Interviewee 4 stated, "The teachers, the teacher organisation, and the administration have to be on the same page and have to make sure that their goals are all the same." Interviewee 5 believes that "it [the leader] is someone taking the lead and saying let's think differently on how we view STEM and let's think differently on how we communicate to our teachers and our students." Interviewee 6 spoke about the importance of leadership when he stated,

> If you don't have any person to develop a STEM course, or an engineering course, or a computer science course, and it counts for university entry requirements and moves from an elective to a required [course], one of the options for required courses, then who does that? Who leads that conversation?

Interviewee 7 believes that integrated STEM takes "leadership, I think from both the teacher's perspective and the student's perspective as well." He further stated this about shared leadership,

> I think you have to have leadership in the school from the adult side and from the student side. From the adult side, you'll see that leadership, possibly you'll see that leadership in the administration, in some cases where an administrator did see the importance of STEM experiences for their students."

Interviewee 8, Interviewee 12, and Interviewee 13 spoke about shared leadership in term of vision and collaboration. Interviewee 8 stated, "I think we need practical visionaries...Practical visionaries...What I mean by that are people who can lead and demonstrate." Interviewee 12 says to implement integrated STEM it "takes a champion." Interviewee 13 summed up leadership related to integrated STEM this way. "It takes partnerships and collaboration and you need people to advise you…the partnership has to go outside the school doors. You have to reach out into the community. Your school board definitely has to be a part of that creative team as well."

The theme of leadership being essential to integrated STEM resounded across all the interviews. Each interview respondent put a unique spin on exactly who and how the leadership must be applied; nevertheless, it appears leadership is an important aspect of integrated STEM.

4.3.2.3 Theme 3: "Outside support and funding of integrated STEM"

The concept of outside support and funding was prevalent in the interview as 10 out of 20 respondents mentioned outside support and funding in various ways. There was general support for different outside of school entities, helping with the creation and implementation of integrated STEM in UAE. Interviewee 9 was concerned about listening to the business communities needs when creating an implemented STEM program. She said, "The educators need to know what the business community people are saying to them." Interviewee 12 said we need to be careful to "not leave the business people out".

One way that outside entities were seen as being able to help schools with integrated STEM is through the possibilities of providing resources. Interviewee 4 said, "I think seeking outside funds is huge" and "I think awareness within the community is huge." Interviewee 10 spoke about business and industry in this way. "The supports, the resources, whether it's human resources community members, professional members coming in to help out." Interviewee 12 spoke about looking for outside investment in an integrated STEM program. She mentioned "the Perkins funding for CTE (Career and Technical Education), they have a bucket load full of dollars you're not going to find those same funds to even have the tools or the resources technology-wise." Also, when speaking about businesses she said, "they [businesses] are willing to cough up and do some investment. So, I think business associations, working with your CTE staff, and seeing what we can leverage." Interviewee 1 said to implement integrated STEM you need "to go and find resources and tools that they [teachers] don't have, learn them, and apply them." This implies the need for outside support and funding for the integrated STEM in UAE.

Outside entities in business and industry as well as higher education were thought to be able to provide input beyond financial resources. Interviewee 9 believes that,

> The educational reform that's going on right now needs to include and incorporate all of the STEM experts that are out there whether it's business or universities, or informal science organisations like the zoo that has the experts, the researchers that are working in STEM education.

Interview 11 thinks schools need "better working partnerships with teacher training institutions" for integrated STEM staffing. Interviewee 12 mentioned, "I think making a connection with your community college" is important for integrated STEM. Interviewee 13 echoed that sentiment when she said integrated STEM could benefit from "involving some of the community colleges to bring that expertise into your school."

Seven of the 13 respondents said that expertise related to integrated STEM could be found in the world of business and industry. Ultimately, they thought educational support by providing expertise was also seen as a way that business and industry can help schools with integrated STEM. Interviewee 2 thought that integrated STEM could benefit from "pulling people from local business to give some insight." He further mentioned students taking field trips to see real world applications and experiences. Interviewee 4 said students need "opportunities to get involved with career focused individuals outside of the classroom. It might be…going on field trips or it might be meeting with people in their industry that they are possibly interested in." Interviewee 5 states for integrated STEM "that is really critically important to…I think just [have] access to experts."

Interviewee 9 says "they [schools] have to open up the doors by really letting in the experts, but there needs to be an understanding from some of the experts out in the field, some of the researchers, some of the other organisations, for example like the zoo that come in." She further stated that schools cannot "be afraid to ask others to come in and kind of help out." Interviewee 10 said this of business expertise,

> The community resources once again would be professionals who can not only come to the class, we're not talking about show and tell, we're not talking about career day, but you truly assist and help that educator with projects and so on to also help expose the students to professionals, working professionals. Then also to get those students out to community and that's also in a sense how those students can see their part in the community.

Interview 12 stated, "we can throw in business to try to help us figure out what the real world is asking for," [schools can] "team up with maybe local businesses that would be interested," and "get the business people that talk about STEM careers and for education." Finally, Interviewee 13 said this of business and industry expertise, "along with that business and industry partnership, they can also bring in people who have expertise that are not always available to a school and likewise they become your partner if you need equipment of any kind."

Several respondents saw collaboration between outside entities as important for successful integrated STEM in schools. Interviewee 4 feels that "it [integrated STEM] may be more of an internship where they work more in collaboration with an organisation or business in the community." Interviewee 8 said, "it [integrated STEM] is going to have be embraced by the community." Interviewee 9 said, "the big picture of integrated STEM education is to bring in all the different components and players and everybody have an open mind by working together on educating our youth." She further stated, "the educational reform that's going on right now needs to include and incorporate all of the STEM experts that are out there whether it's business or universities, or informal science organisations like the zoo that has the experts, the researchers that are working in STEM education."

The final way seen by the Interviewees that outside entities could help with integrated STEM in schools is through training. Interviewee 9 thought businesses could help teachers get training on specific equipment and techniques. She said:

> Partnering with a business partner or an industry partner where they're helping maintain some of that [equipment] or heading out in the next generation when they get the top-level thing. Another piece is the training for the teachers on this equipment. I think that's where you start referring to your business partners and community leaders to kind of help out with that training, so that you're on top of it. You're able to replicate so that the kids can experience.

Interviewee 12 thinks professional groups can help with providing teacher training. She said this when speaking about professional development.

> [It would be the] Nebraska Association of Teachers of Mathematics [for math]. It would be NETA for technology. It would be NATS for science. I think all of those leadership groups would be the ones who would help disseminate and support the idea of STEM integration.

Interviewee 13 believes that "it's so important to have the business and industry and the people in your community involved, because they can help you see and you can help them see how you are training in working with kids to fill their needs within the community with jobs and quality workers and that type of stuff." She further stated that, "it [integrated STEM] takes partnerships and collaboration and you need people to advise you. The partnership has to go outside the school doors."

The concept of outside support and funding for integrated STEM ran throughout all the interviews from their different perspectives. Outside support and funding for training, collaboration, expertise, and providing resources were all cited by multiple Interviewees which showed that outside support and funding is a critical need for integrated STEM in UAE.

4.3.2.4 Theme 4: "Professional development needs"

During the interview, the respondents were asked about professional development as a sub-question. This was specifically done because professional development was identified in the literature as critical to successful integrated STEM in UAE. This means that all respondents were asked to speak to professional development. In doing so, a number of themes related to professional development emerged.

There were some very powerful general responses to professional development needs related to integrated STEM. Interviewee 2 does not think that you need to hire new teachers for an integrated STEM program. He says,

> I think you can train the teachers that you have got, but it is going to take some time and willingness on the part of those people because, for all intents and purposes starting an endorsement in other areas, or touching on at least having a level of expertise, or being willing to cross pollinate with some other teachers, or possibly even co-teach, takes training.

Interviewee 4 stated that to create integrated STEM education "it takes the same skills we are asking our STEM students to do." For the integrated STEM implementation in her school, they received a grant, which allowed them to get some training. Interviewee 5 thinks, "STEM is really about our pedagogical approach to teaching the content and how it can be applied."

Interviewee 8 said, "we need to show them [teachers] tangible examples, and they're hard to find, of what STEM education looks like. What does that classroom look like? What philosophical attitudes should they consider in terms of what it takes?" Interviewee 10 feels that,

> Professional development will be the educational supports that are put in play to help whatever teacher is trying to go into this area, to help them get to the point to where they feel comfortable; they feel credible in the classroom before their students and in the content that they're presenting to their students.

Interviewee 10 further stresses that “getting them [teachers] educated with a proper adequate professional development that they would need” is very important.

Interviewee 11 says that we need “specific teacher training and retraining” including professional development on a broad scale. He believes that for integrated STEM education to be implemented there needs to be,

> Extensive training needing to happen in either a STEM learning cycle model or in specific integrated ideas, in other words how to teach mathematical topics in the context of science engineering or technology. How to teach an engineering topic and to pull out the most critical elements of the math that needs to be used for that.

Interviewee 12 feels that professional development needs to include “sharing of a common definition.” Interviewee 13 specifically spoke to, “professional development that needs to take place…Safety is one. Ethics is two” and “you have to get the professional development specific for the teacher who is in STEM.”

Interviewee 6 believes that “integrated STEM education requires a variety of experiences.” This is echoed by Interviewee 7 who stated, “teachers need to be given the experience of doing some kind of integrated project.” Interviewee 8 spoke about teachers and said, “the students who are coming through our university in the college of education don’t have any hooks to latch onto based on their educational experience and that’s what these kids come here with.” Interviewee 9 feels that non-traditional teachers have experiences that make them better at integrated STEM than career teachers.

Several Interviewees specifically mentioned that professional development needs to occur in project-based learning. This type of training would seem to be very applicable to getting teachers experience in integrated environments as stressed in the previous section.

Interviewee 2 has learned project-based learning by doing it in the classroom. He said this when referring to other teachers that are interested in teaching in an integrated STEM environment.

> I think training. You have got to have a teacher who is really comfortable with a lot of different materials. If your background is simply that of a mathematics teacher, or a science teacher you may not feel comfortable enough in some of the other areas that you are going to be pulling in. I know certainly, I have learned a lot about project-based learning, or problem-based learning and that has been really useful when it comes to trying to develop new ideas.

Interviewee 9 agreed with the need for project-based learning professional development. She believes that teachers need "professional development training to get them onto the same page as that problem-based learning, or project-based learning, or experiential learning, or however you want to define it."

Collaboration was also mentioned as an area needing professional development. Interviewee 4 stated, "the training, I think, comes in constantly collaborating and adapting to the change that is happening around us." She further said that, "I think consistently revisiting your curriculum is a must. Constantly collaborating with a community is a must." Interviewee 2 thinks professional development needs to include situations for "educators when they get a chance to come together and discuss things and share their ideas." Interviewee 5 echoed this sentiment when he said, "you need professional development. I think that another key resource, is the time to collaborate in the PD."

The manner of professional development was also a point of discussion. Five respondents felt professional development was needed to be ongoing, focused, and driven. Interviewee 1 said, "making sure that it [professional development] is actually focused and driven and I think that kind of training, work-shopping, experience is necessary for teachers to feel comfortable and be effective STEM educators." Interviewee 9 said:

> Professional development is a constant and it cannot be a one hit wonder where you come in and have an eight-hour day or a two a day session. I think it is something that

> needs to be ongoing throughout the year as a constant, almost like a cohort that goes through. I think the professional development needs to look like whatever industry the teacher is trying to replicate, or whatever component of the STEM education career path. I think they need to go out and get those experiences. They have to be immersed in it so they have a better understanding, so that they can actually teach from their experiences by referring to their experiences working in those different industries.

This speaks not only to the constant, on-going nature of needed professional development, it also stresses the importance of the experiential nature of professional development that can help teachers understand and instruct in an integrated STEM environment. Interview 10 feels that there needs to be a "clearly defined consistent professional development process, a program which would include certification and training, on-going availability, and to also provide the teachers with credit" and that "there needs to be something that is kind of standardised, something that is consistent." Interviewee 11 agrees and stated that a key is to "focus on professional development, but it would need to be sustained rather than just kind of 'here's your professional development for the day, now go and do this stuff.' It needs to be kind of a sustained really kind of a habitual sort of arrangement."

The nature of the conversations around professional development and integrated STEM education has implications related to this study. All the participants spoke to professional development because it was identified as an integrated STEM support structure. However, their comments related to the nature, content, and delivery of professional development should help provide a frame of reference for those school leaders who want to implement integrated STEM.

4.3.2.5 Theme 5: "Non-traditional assessment"

Each participant was asked about assessment related to integrated STEM in UAE and several participants spoke about the difficulty with assessment. Interviewee 1 said that, "it [assessment] is the hardest part." Interviewee 3 stated, "I ultimately think that [assessment] is what is going to stop it because no one is going to be able to figure out how to assess it."

Interviewee 11 said, “I don’t think there is a great way to assess integrated STEM yet.” Other participants spoke to how the assessment process will need to change. Interviewee 9 believes that “we need to get creative and redefine what we consider assessment” and that assessment of integrated STEM is “totally different then what is occurring now.” Interviewee 10 stated, that we “have to think in a non-traditional manner of assessment when it comes to STEM.” Interviewee 10 said, “In STEM education, you have a great opportunity to have non-traditional assessment of students.” Interviewee 12 thinks that assessment is “definitely something that would be a thing in progress.” Finally, Interviewee 13 stated, “we haven’t thought of all the possible assessment that we really can use.”

Some non-traditional assessment methods did surface during the interviews. Interviewee 2 believes that teacher developed rubrics would be beneficial. He also said that, “I also see a real strong value in student self-evaluation.” In assessment, we are really looking at the higher levels, application and synthesis. He stated that “evaluation in the context of a rubric or in the context of a one page summary, a written summary, or asking a student to reflect on mathematics that you needed to complete the activity,” might be possible assessment strategies. Ultimately he thinks that, “student evaluation gives a lot of chance for real metacognition about what I know, what I had to do. Really getting them to reflect is crucial.” Interviewee 3 agrees when she said that, “it [assessment] would be best if they were not paper and pencil, and in a way that the students could interact with either an individual or a system to explain, justify, rationalise, their knowledge about something.” Interviewee 13 thinks assessments “need to also take the questioning and put it at different levels, different thought levels through their students, and they need to know which ones address the higher learning, so that they are able to assess students in that.”

Interviewee 4 thinks the "soft skills that we are trying to develop, I think need to be assessed in some way." Interviewee 4 also mentioned soft skills specifically as "we think about career readiness skills that students will learn through STEM experiences, the problem solving, the critical thinking; I think that those become more difficult to assess."

There were other non-traditional assessments cited by the Interviewees. Interviewee 7 thinks that a possible assessment could be "how much work has a student been able to share and make public for others to use? How much have they engaged in a community?" Interviewee 10 mentions an assessment of "service learning where the students actually go out and they work on a real-world challenge." Two interviews mentioned possible attitudinal surveys as assessment possibilities. Interviewee 10 thought about assessment as:

> Assessing that like pre/post, how did you feel going into it? How did you feel coming out of it? Those types of things. Do you feel like you gained knowledge? Just very broad general things. What did you expect to learn? Did you learn it? Kind of like those KWL (knows, wants to know, learned) type of things.

Interviewee 12 echoed this as a possible assessment technique when she said, "you could do an inventory with whether the students like it in this format better than they do in a traditional format." She also thought that integrated STEM could "use some traditional testing, test content questions, and then I think the other assessment would be attitudinal and how they feel about liking math, science, and technology."

Aside from integrated STEM being difficult and non-traditional, the interviews did have some consensus as to what assessment might look like or contain. Eight of the Interviewees specifically mentioned that assessment of integrated STEM should contain a project. Interviewee 1 said that, "general assessments will be projects" which should include "interviews, talking to people about their [student's] project, talking about what they think the value point-wise or grade-wise of what they did is and was." Interviewee 2 thinks, "there is some sort of product [project]" and that "there is some assessment going on through the project in the form of journaling or discussion with teachers." Interviewee 4 stated that, "assessments that are maybe more project-based" when referring to integrated STEM. She said that would "facilitate their learning in a way that is different than a traditional high school test would look like" and that "project assessments are equally as important, if not more important, than standardised testing." Interviewee 6 said that integrated STEM assessments should be "project-based, problem solving based and higher level inquiry." He thinks this is the best way to assess integrated STEM "because a project gives a student [the chance] to really demonstrate their connections and their understanding." Interviewee 7 said that assessment should be "project-based activities and competition based activities."

Interviewee 8 agrees with the project nature of integrated STEM assessment and what the project should entail. He said:

> The types of assessments that we need to be more invested in are product based, project-based, outcome-based. Show me what you know. Demonstrate what we have been talking about for the last 3 weeks. Build me something. Create me something. Change something. Adapt something. Envision something. Develop a philosophy. Give me something that demonstrates integrated higher-order thinking skills on your part as a student.

He thinks this type of assessment creates "a healthy overall learning environment for kids that's much more exciting than sitting in rows and being addicted to a textbook." Interviewee 9 says that assessment of integrated STEM should be:

> Capstone projects. I think it should all be project-based, problem-based where the kids are exploring and asking questions, or trying to solve a problem, or come up with a new technology, or come up with something innovative to help solve a problem in the world and there's different levels and different degrees so they're building up all those skills and knowledge to hit this major project.

Interviewee 11 stated that the assessments should be "project-based, design based, and inquiry based." In fact, "I think the project itself should be the assessment."

Five of the Interviewees felt that the assessment of integrated STEM should be portfolio-based. Interviewee 1 feels that the assessment should be "student defined and student solved real world or contrived problems that they have come up with, that they have found solutions to. I think that it is much more of a portfolio of work rather than individual tests." Interviewee 7 said the end assessment would be "their portfolio of work. Their resume of work. Their online presence and how integrated STEM is included in their online presence." He went on to say "I think what I'm talking about really goes beyond the portfolio into community presence, virtual community, and real community presences of the students in their projects." Interviewee 9 said that the assessments should be "portfolio and project-based." Interviewee 13 believes that the assessment should be "portfolio development." She went further stating "portfolios-- those are huge, physical and electronic" and "portfolio assessment…that is done throughout, but also as a final product."

Six of the interviews believed that the assessment of integrated STEM must be authentic and competency based. Interviewee 3 discussed the competency that students need to display related to integrated STEM when she said:

> The best assessment strategies would probably be ones that allowed for students to show some level of reasoning or logic or approach so either one-on-one discussions with students, or maybe some virtual interactive thing where they are manipulating things, and saying why they are doing what they are doing.

She further stated that students should "be able to argue from evidence or use modelling, mathematical modelling, or physical modelling of things, or software modelling to demonstrate knowledge" and "you have to have very fluid ways for them to demonstrate or discuss their approaches and thoughts." Interviewee 5 agreed and stated, "It [assessment] is definitely a movement to more of a competency-based model." He went on to say that assessment would be "competency-based models or authentic assessments such as portfolios. Performance assessments, moving beyond the traditional as we think of tests, but definitely competency-based." Interviewee 8 said, assessment needs to be like "real-world environments...On the job training." He elaborated on what assessment should look like when he said,

> The types of assessments that we need to be more invested in are product based, project-based, outcome-based. Show me what you know. Demonstrate what we have been talking about for the last three weeks. Build me something. Create me something. Change something. Adapt something. Envision something. Develop a philosophy. Give me something that demonstrates integrated higher-order thinking skills on your part as a student.

Interviewee 10 said integrated STEM assessment needs to be,

> Something that you can explain. Something that you can present. Something that you can demonstrate that does what it is supposed to do…Shows its function, so to me it doesn't have to be an assessment outside of the project itself.

Interviewee 11 said that assessments need to ask, "can kids ask very appropriate pointed questions and can they employ didactic content from one area into another without being taught specifically to do that?" Students need to,

> Look at the appropriate use of technology to solve bigger types of problems in science or in engineering, but use science and engineering content and synthesise information from math and science to create some new sort of idea for a problem that they're trying to solve.

He went on to state; assessments need to have "a focus on higher level thinking and an earnest attempt to find good ways to measure critical thinking through the implementation and integration of didactic content from the different STEM areas." Interviewee 13 said that integrated STEM needs "authentic assessment with teachers asking why…you have to have authentic assessment all the time."

It can be argued that both project-based assessments and portfolio-based assessments fit as authentic and competency based models for assessment. In fact, several of the interviews used project-based or portfolio-based models in their description of authentic, competency-based assessments. Ultimately, the assessments of integrated STEM are going to be non-traditional where students create a product that demonstrates their skills in a real life authentic setting.

4.4 Results of Research Question 3 - Stakeholder Interviews

This section specifically analyses the responses from stakeholders' interviews in light of third research question. During the course of the research study, 5 leaders and stakeholders in UAE were interviewed either in person or over the phone at three UAE schools in Al Ain, Dubai, and Abu Dhabi. The interviews were transcribed in their entirety. Initial data analysis of the interviews began in three different stages. First, the big ideas from the raw interview data were compiled and sent to the Interviewee for feedback along with the entire interview transcription. Next, Interviewees were allowed to add, detract, and clarify information from the interview. Second, each question was analysed using the raw data to generate initial codes related to integrated STEM education. These codes were grouped together to identify themes that emerged from each question. Third, the data was analysed to remove all names and questions from within the raw interviews and to generate coding of the raw text.

Given the small sample size, the researcher did not engage in the in-depth coding of interviews and therefore briefly analysed each interview and focused on the four pre-established themes: leadership domain, curriculum domain, pedagogical knowledge and engagement domain, and community domain. Through this technique, the researcher confirmed the already established themes rather than searching or forming new themes.

4.4.1 Theme 1: "Leadership Domain"

Leadership Domain is also the highly frequent theme found in the analysis of teacher interviews. From the literature, leadership, specifically district decision makers, were cited as a key support structure for integrated STEM education. School leadership can be defined in many ways. For the purpose of the analysis, the researcher had combined comments about school leadership from anyone directly attached to the school except teachers and students. This included building and district level administrators, curriculum specialists, and school board members.

All participants in the interviews specifically stated some form of leadership is necessary for successful integrated STEM education in UAE. The leadership domain has played an important role in designing the vision for STEM education. Six questions were asked related to leadership domain and their responses are analysed individually. In the question asked regarding whether there is a vision at their organisation for STEM education and whether this vision for STEM field informed by the latest research and based on exemplary practices, almost all the participants showed the affirmation. The stakeholders gave the impression that STEM is the future of UAE education and it is the integral part of their vision now. Stakeholder 1, Stakeholder 3 and Stakeholder 4 indicated that there is a vision in his organisation and is updated and informed by latest research. Similarly, stakeholder 2 expressed that the STEM department in his school has adopted this slogan “a building of four walls with the future inside”. The vision of his school is based on recent researches especially in the field of technology in education and Arts integration in STEM classes and several consultations offered by leaders of STEM education in Jeddah. Stakeholder 5 also expressed that his organisation has used a few innovation projects run by Abu Dhabi Education Council (ADEC) but have not yet broken in to a fully-fledged STEM project. He also expressed that they have had science projects, run as booster sessions in their school and this year they hope to have their first STEM project. He also affirmed that their work will be informed by the latest research and exemplary process. The responses of stakeholders are further outlined in the following table for the purpose of comparison.

Stakeholders also expressed that what they want to accomplish through embedding STEM in their organisation and basically how they will fuel their accomplishment of their vision. Stakeholder 1 indicated that their organisation wants to increase students' interests in STEM fields and develop their skills in order to prepare them for jobs that do not exist. Catering the education needs of UAE students in his school, Stakeholder 2 indicated they want the UAE Kids to develop high cognitive skills as critical thinking and problem solving. They want to prepare them for labour market to face the challenges UAE Arabia is facing. Stakeholder 3 suggested that they want to improve student skills to meet the global work force requirements, improve teachers teaching skills, and integrate teaching and learning. Stakeholder 4 indicated that they want to introduce interdisciplinary learning and teaching while stakeholder 5 indicated that they want to enable students to access the higher order thinking skills involved as well as access STEM careers. The responses of stakeholders are further outlined in the following table for the purpose of comparison.

Regarding the question that by what ways STEM can contribute to lead the development of the overall ethos of their organisation, majority of the stakeholders (3 out of 5) indicated that the element of innovation in STEM can effectively contribute to this cause. Stakeholder 1 indicated that "STEM is considered to be curriculum innovation where students have opportunities to apply what they have learned into new situations". Similarly, stakeholder 4 indicated that "[They] embrace innovation and creativity in a structured and robust way". Stakeholder 5 has also shared similar thoughts by indicating that "The ethos of the school is 'passion for learning, compassion for life' and this is really relevant to STEM and the UAE as it continuous to develop into a world class destination. Students will learn that through STEM learning they are able to develop technologies to help tackle the issues of today and help shape a better future for the UAE". Stakeholder 3 suggested that element of supporting team working, critical thinking, problem solving in STEM while stakeholder 2 believed that modernity, dynamicity and diversity in STEM can effectively contribute to the development of the overall ethos of their organisation. The responses of stakeholders are further outlined in the following table for the purpose of comparison.

Regarding the question that how they will involve all the stakeholders at all levels in planning for STEM implementation, majority of the stakeholders in interviews indicated they will engage all the stakeholders though involvement, collaboration and communication. Stakeholder 1 indicated that “All head of departments and coordinators are involved in the STEM planning where they decide together the important topics to be covered when having a theme of STEM.” Stakeholder 3 indicated that they will engage all the stakeholders through regular meetings, conferences, and workshops regarding STEM in UAE. Stakeholder 5 expressed that they will bring all individuals with genuine passion for their career and a desire to share this passion, whether this is a teacher or an engineer, and bring them together under one roof. On the other hand, stakeholder 2 and stakeholder 4 indicated other means of engaging the stakeholders. Stakeholder 2 indicated that they will conduct interviews, surveys, trends on social media in the field of education in order to bring the awareness among stakeholders and pressing the need of STEM education in UAE. Stakeholder 4 indicated that they will engage stakeholders through embedding real world problem solving by involving industry and experts from the community. The responses of stakeholders are further outlined in the following table for the purpose of comparison.

Regarding the question of the possible reasons of low participation in STEM-related disciplines in the UAE of the tertiary education sector in UAE in absolute terms and in comparison with other comparable nation, stakeholders pointed out towards lack of interest of students in STEM career paths, lack of awareness of STEM, lack of working culture supporting STEM learning, conservative approach to timetables and curriculum delivery of UAE schools, challenges for teachers to fulfil STEM requirements into already packed curriculum, lack of curriculum planning, lack of resources, knowledge, and support for teaching and learning STEM, lack of subject specialists, lack of experimental and kinaesthetic activities, among others. The responses of stakeholders are further outlined in the following table for the purpose of comparison.

Regarding the question that how can the consistence of STEM reform efforts with other school/district reforms enhance public attitudes toward STEM reform, the stakeholders indicated that they are positive about the progress in the form of increasing awareness and interest of students and parents, removing the fear and burden among stakeholders regarding the effectiveness of STEM among students by making them more engage and more productive, building teacher's capability, improving school's infrastructure, restructuring school's curriculum, acceptance of STEM among schools through visible efforts of leadership for integrating STEM in curriculum delivery and timetabling, and promoting the STEM in wider scale thereby connecting through STEM network meetings, workshops, seminars regarding how STEM can be integrated into curriculum. The responses of stakeholders are further outlined in the following table for the purpose of comparison.

4.4.2 Theme 2: "Curriculum Domain"

The second theme in the stakeholder interviews is related to curriculum domain. Five questions were asked from stakeholders related to curriculum domain in STEM. One of the reforms in science education is currently focused on infusing scientific inquiry (i.e., thinking like a scientist), technological and engineering process (i.e., thinking like a designer), and computational thinking (i.e., thinking like a mathematician or computer scientist) into the K-12 science curriculum. The rise of science, technology, engineering, and math (STEM) education is evidence of this desire to integrate the disciplines (Breiner et al. 2012). Subject matter content knowledge and critical thinking skills are both needed to produce scientifically literate citizens in a complex world with complex problems to be solved (Symonds, Schwartz & Ferguson 2011).

Regarding the question whether their schools have systematic planning for STEM integration, practice and students' experiences in order to inform innovative curriculum design, majority of the stakeholders denied that currently their schools do not have such systematic planning for STEM integration. Stakeholder 1 indicated that although there is no such systematic planning, however, "the school uses different approach in planning and designing the curriculum. The co-planning with students is important as they will plan their projects based on their interests". Stakeholder 2 indicated although he is not sure about such systematic planning for STEM by schools themselves, their organisation do provide a plan for deployment and change management for schools that designs STEM curriculum. Stakeholder 4 also indicated that although there is no systematic planning for STEM in their schools, they have a desire to implement a more flexible timetable to allow time for STEM, but this also must be something that is integrated into the regular class timetable and should be integrated into the normal classroom subject and not be a stand-alone subject. Stakeholder 5 indicated that they have science developed models as an intervention project that was the closest they got to STEM. He expressed that the new MOE curriculum in UAE seems to lend itself a little bit further to STEM projects at the moment this is just being integrated in the school. He suggested that they are hoping that in the future they could develop a STEM committee of subject experts and help embed this in to the curriculum.

Regarding the question whether their schools have access to a wide variety of resources that support cross curricular integration in a STEM context, some participants indicated that they do have such resources, while some indicated that there are plans to reserve funds for such activities. Stakeholder 3 specifically mentioned that their school does not have access to a wide variety of resources that support cross curricular integration in a STEM context.

Regarding the question whether their schools receive extra funds for purchasing equipment and supplies for STEM, majority of participants denied that they do not receive extra funds for this purpose. Only stakeholder 1 indicated that they do receive extra funds whenever necessary. In expressing the reason of not receiving the extra funds for purchasing equipment and supplies for STEM, stakeholder 4 indicated that STEM is perceived is an expensive option to set up in their school, even though, he personally does not think so.

Regarding the question whether there are any National/District curriculum frameworks for STEM/ level of integration at their organisation, majority of the stakeholders denied that there are no such national or district level curriculum frameworks for STEM/ level of integration at their organisation. Only stakeholder 1 indicated that they there is an interdisciplinary framework for STEM/ level of integration at their organisation. Stakeholder 5 also indicated that their school has received innovation packs previously and these have helped to develop projects.

Regarding the question whether they think having a proposed STEM framework can support the country National agenda in advancing STEM fields or disciplines from professional associations and industry group's perspective, all of the stakeholders affirmed that such initiative would definitely promote the agenda of STEM integration at national level. Stakeholder 1 indicated that "[Such initiative] definitely will support as it will help students to have higher grades in TIIMSS and PISA". In addition, Stakeholder 2 expressed that "[Such initiative] will enable the whole education body to push towards the same goals". Similarly, stakeholder 4 indicated that "[Such initiative] would assist schools to see that STEM is taken seriously and support the schools to implement STEM, and give the needed justification for

STEM to the community". Stakeholder 5 also expressed that "I definitely think this will help as it will guide schools in a direction in which the country would like to go. This will also encourage the stake holders to think of innovative of providing STEM to the learners as well as developing quality resources that are needed".

4.4.3 Theme 3: "Pedagogical Knowledge and Engagement Domain"

The third theme in the stakeholder interviews is related to pedagogical knowledge and engagement domain. Six questions were asked from stakeholders related to pedagogical knowledge and engagement domain in STEM. The literature on an interdisciplinary approach to teaching and learning has reported that helping students to develop knowledge, insight, problem-solving skills, and self-confidence are considered pedagogical skills demonstrated by teachers concerning their ability to plan and organise a lesson (Repko 2009). It is suggested that peer observation improve the content and pedagogical knowledge in technology and can add valuable information to the knowledge and learning. Learning from each other is beneficial because everybody benefits and the strategy serves as a vehicle for professional growth and development rather than for evaluation. The previous literature indicated that teachers acknowledged that there were benefits to acquiring an understanding and knowledge of interdisciplinary approaches to teaching not only for themselves but also for the students in their classroom. The teachers expressed that there were benefits for students such as helping them develop critical thinking skills. Peer collaboration and deep thinking exercises resulted in understanding problem-solving methods. Engagement in the process of science, mathematics, technology, and engineering resulted in developing skills required for the transfer of learning from multiple disciplines. The process allows for cognitive, physical, and emotional engagement. Examples of active learning activities include problem-solving, teacher collaboration and discussion, joint planning, observing other teachers, being observed by other teachers, and coming up with possible interventions and solutions (Garet et al. 2001; Roth et al. 2011).

Regarding the question whether they think STEM/STEAM teachers in the school are well supplied with materials for investigative instruction inherent in STEM, majority of the stakeholders indicated that they are teachers are well supplied with materials which makes them capable of such pedagogical knowledge and skills. Stakeholder 1 indicated that “[Teachers] are well supplied as I believe also that STEM doesn’t require huge materials. The recycled materials can be used. It depends on the needs. The most important is the proper design of the projects”. In addition, Stakeholder 5 indicated that their teachers are adequately supplied with the projects they can run. However, he also believed that this can be improved if there was a STEM framework with guided activities. These similar thoughts were also shared by stakeholder 4 who suggested that this is happening slowly and it takes time for teachers to accumulate resources and also for the school to set up the required systems and processes, e.g. parents donating recycled materials for STEM on a regular basis. Notably, as a STEM researcher and within the limits of STEM integration, I do not see the urge to change the STEM to STEAM education. For instance, far across the board, the needs of the so called STEM workers outweigh the urge for professional artists. Besides, powerful organisations such as NASA together with other prominent establishments have programs focused on the promotion of STEM and not STEAM. Moreover, the careers in STEM are dominated by men; hence, a focus on this conception can positively impact this notion.

Regarding the question whether they think that teachers feel supported by colleagues to try out new ideas in teaching STEM teachers in this school, majority of the stakeholders indicated that they do believe that teachers feel supported by colleagues to try new ideas and innovation in teaching STEM teachers. Stakeholder 4 indicated that STEM, like any other new initiative, will take time for teachers to get used the idea of integrating STEM into their classrooms. Stakeholder 5 further revealed that science was given fantastic support with the timetable being rearranged and resources being provided in the modelling projects.

Regarding the question whether teachers have time during the regular school week to work with peers on STEM curriculum and instruction, majority of the stakeholders affirmed that teachers do have time during regular school week to balance with both their curriculum and work with peers on STEM curriculum and instruction. Only stakeholder 2 denied that teachers do not have this much time to dedicate themselves to such activities. Stakeholder 4 indicated that there is room for improvement and if it is introduced gradually and expectations are realistic. Stakeholder 5 indicated that a committee needs to be developed to allocate time for such activities.

Regarding the question whether they believe the STEM program in their organisation is strongly supported by local organisations, institutions, and/or business, majority of the stakeholders affirmed that they do have support from local community, organisations, businesses, and other direct and indirect stakeholders to integrate STEM programs in UAE. Stakeholder 1 indicated that STEM framework in their school is appreciated by the Knowledge and Human Development Authority (KHDA) in Dubai. In addition, stakeholder 4 indicated that people are beginning to become more familiar the term STEM, and businesses and the community are starting to understand that for jobs in the 21st century students need to be learning in a more integrated and multi-disciplinary way.

Regarding the question whether there is a wide range of high quality ICT integration that has a strong impact on students' and teachers' overall digital competencies, majority of the stakeholders indicated that yes there is such high quality ICT integration support which is impacting students' and teachers' overall digital competencies. Stakeholder 4 expressed that student and teachers are now more digitally literate and most are open to using digital learning in problem solving based learning.

Regarding the question on the quality of available instruction materials, majority of the stakeholders indicated that there are many high quality instruction materials available which can support the STEM curriculum in the culture of UAE schools. Stakeholder 1 indicated that their school has revised and evaluated instructional materials to match the standards of high quality global education. Stakeholder 3 and Stakeholder 5 also indicated that there are highly sophisticated materials available and lot of information and material on this innovation project, however, there is room for more improvements in this regards.

4.4.4 Theme 4: "Community Domain"

The third theme in the stakeholder interviews is related to community domain. Three questions were asked from stakeholders related to community domain in STEM. It takes commitment from school districts to support the initiative by providing teachers the necessary professional development, time and resources, as well as commitment from the community in terms of providing support and resources (personal, physical, and financial). To create integrated STEM, it takes an individual decision to attempt STEM education with a push to go ahead and start. To implement integrated STEM, it takes all stakeholders supporting it, school leaders, teachers, parents, and community members. As teachers, the need to constantly educate and talk about why and how to do integrated STEM. Invite parents into the classroom. Take pictures. Post blogs. Start by writing a goal, getting people on-board, and stick to your clear-cut goals for what schools want their outcomes to be for their students. Then, constantly revisit the curriculum and structures to make sure that they are geared toward your goal. Schools need to reach out to the community for expertise while looking to form partnerships with business and industry. More immediate assessments can be conducted through student resumes, student portfolios, amount of shared work, and community presence and engagement. Community members and working professionals and organisations through public and private investment are an additional resource that is necessary for integrated STEM. These professionals can assist the teacher with the projects and expose students to real life situations, where the knowledge they are learning applies. Internships and service learning is a good way for students to apply their skills and to work on real world challenges facing their community. Integrated STEM needs the support of the administration and all the teachers in the building. Anyone can teach integrated STEM, provided they have been given the proper professional development. The expense related to integrated STEM does not have to be prohibitive. If financial resources are available, upper grade levels could utilise access to technology being used within the business world. Certification and standards need to be developed for the implementation of integrated STEM.

Regarding the question regarding the one way of supporting STEM in UAE through sustained public and private investment at an appropriate level to keep it comparable with the best performing nations, the participants suggested promoting STEM and building networks for public and private sectors as the key for supporting such initiative. Stakeholder 1 indicated that using the themes of EXPO (by inviting industry and schools representatives) would be effective to support STEM in UAE through sustained public and private investment at an appropriate level to keep it comparable with the best performing nations. Stakeholder 3 indicated that involving public and private sectors in planning and executing STEM programs would be effective for such supporting STEM in UAE. Stakeholder 4 indicated that the economy for the UAE needs to diversify from being oil dependent, so STEM supports the movement of the economy into other industries like manufacturing, media and technology based industries. Similarly, stakeholder 5 indicated that with so much development and progress taking place in the UAE, having large companies such as EMAAR and ADNOC into partnerships with schools, would develop nationwide projects and competitions that would definitely provide the STEM reform with an opportunity.

Regarding the question whether how to ensure the community's confidence in the UAE's STEM enterprise and the acceptance by the community of the outcomes from STEM, majority of the stakeholders suggested bringing more awareness and knowledge of STEM benefits among community. Some stakeholders also suggested following the other countries program as benchmark to set the standards and also following the programs which has profound effects on the community through STEM education. Stakeholder 2 indicated that raising awareness, and organising public events before targeting schools themselves are effective in ensuring community's confidence towards STEM education in UAE. Stakeholder 3 indicated that increasing number of education system graduates who met the working requirements will be effective in ensuring community's confidence towards STEM education in UAE. Stakeholder 4 indicated that STEM initiatives need to be well publicised and it needs to be strongly emphasised that the leadership of the country are driving STEM to be part of the education of young people in the country. Similarly, stakeholder 5 indicated that acceptance will only be given, in my point of view, when the public can see the benefits of such programs.

Regarding the question that to what extent politicians and researchers look ahead to the grand challenges of society and identify key and long-term research problems, majority of stakeholders indicated that politicians and researchers need to play key role in integration of STEM in UAE and they need to support in raising the awareness identifying the challenges related to the issue. Stakeholder 1 indicated that usually the challenges and problems are identified and interpreted in the OECD reports. In addition, stakeholder 4 indicated that there is a growing awareness that the UAE needs to diversify its economy and the STEM jobs will be the main source of employment in the future. Stakeholder 5 indicated that successful politicians and researchers have to play key role and in order to be successful, they must research a number of hypotheses and evaluate the methods they use to do this.

4.5 Results of Research Question 3 - Classroom Observations

This section specifically analyses the classroom observations in light of third research question. Data collection included many classroom observations in random classes at three schools in Al Ain, Dubai, and Abu Dhabi. In perspective, random classes, in this case, are those classes selected studied without systematically chosen by the researcher. These observations involved field notes, reflections, and tentative interpretations of classroom lessons to gather data. For observations of the classroom, the researcher used an unstructured-observational tool with the focus of the study written on the tool to ensure targeted observations. The researcher kept and recorded track of the times between classroom activities, interactions between teachers and students, and check for actions that reveal self-regulating behaviours and cues that signal confidence levels. The researcher also looked for signs of growing or diminishing self-efficacy of teachers when engaged in the STEM subjects. Out of five categories, four checklists were observed frequently higher by the researcher. Table 26 shows the results of the classroom observations while subsequent paragraphs provided their analysis.

Table 26: Components of STEM Policy in UAE

Components of STEM Policy in UAE	**Document Analysis**	**Teacher Questionnaire**	**Teacher Interviews**	**Stakeholder Interviews**	**Classroom Observations**	**Literature Review**
Policy Planning	✓	✓	✓	✓	✓	✓
UAE vision 2021 and strategic planning	✓	✓	✓	✓	✓	✓

Policy makers/educators/workforce board and economic sectors/government entities	✓	✓	✓	✓		✓
Leadership	✓	✓	✓	✓	✓	✓
Leadership and management	✓	✓	✓	✓		✓
Implementation planning /Staffing and facilities		✓	✓	✓	✓	✓
Dissemination and scalability		✓		✓		✓
Establishing STEM	✓	✓	✓	✓		✓
Institutionalization	✓		✓	✓		✓
Pipeline K-12 and beyond legitimise efforts to scale and network/Sustainable educational partnership	✓		✓	✓		✓
Research projects	✓	✓		✓		✓
Professional Development of Teachers	✓	✓	✓	✓	✓	✓
Teacher Education programs and professional development(pre-service and in service)	✓	✓	✓	✓		✓
Communities and Businesses' Role	✓	✓	✓	✓		✓
Community, networking and industry	✓	✓	✓	✓		✓
Authentic and collaborative projects	✓		✓	✓		✓
Investment and business	✓	✓	✓			✓
Outreach centres	✓		✓	✓		✓
Technology and Resources	✓	✓	✓	✓	✓	✓
Technology, Resources and funding	✓	✓	✓	✓	✓	✓
Access to knowledge and innovation hubs	✓	✓	✓	✓	✓	✓
Curriculum Design and Assessments	✓	✓	✓	✓	✓	✓
Curriculum and assessment	✓	✓	✓	✓	✓	✓
Standards integration	✓	✓	✓	✓	✓	✓
Built in assessment plans	✓	✓	✓	✓	✓	✓
UAE context	✓	✓	✓	✓	✓	✓
Pedagogy and Learning	✓	✓	✓	✓	✓	✓
STEM pedagogical content knowledge	✓	✓	✓	✓	✓	✓

Project based learning/problem based learning/design based learning	✓	✓	✓	✓	✓	✓
College readiness and labour competency	✓	✓	✓	✓	✓	✓
Capacity Building and Motivation	✓	✓	✓	✓	✓	✓
Capacity building for success and efficacy	✓	✓	✓	✓	✓	✓
Impact for transformation/internship /mentorship/Students interest and competency in STEM	✓	✓	✓	✓	✓	✓
Awareness and Promotions	✓	✓	✓	✓	✓	✓
Recognition and exhibition		✓	✓	✓		✓
Campus and regional showcases	✓	✓				✓
Society's Adaptation	✓	✓	✓			✓
Societal attitude and willingness		✓	✓			✓
Business awareness/society awareness		✓	✓			✓
Exposure and Employment	✓	✓	✓	✓	✓	✓
Industry exposure and innovation	✓	✓	✓	✓	✓	✓
STEM jobs	✓	✓	✓	✓	✓	✓
STEM stream schools	✓	✓	✓	✓	✓	✓
SEND attitudes and willingness		✓	✓			✓
SEND effective learning		✓	✓	✓		
SEND relevant training for teachers		✓	✓	✓	✓	

4.5.1 Project-Based Learning

The findings indicated that project-based learning was effective between students and teachers. Project-based learning with integrated content across STEM subjects was highly evident in the classroom. The researcher also observed that there were collaborative opportunities, interactions between students were effective, feedback for adjusting learning were effective, interactions between teachers and students were effective, and rubrics and success criteria are clear.

Capraro et al. (2013) found that "STEM Project Based Learning (PBL) required a professional teaching force empowered with the skills necessary for designing learning experiences that maximise student potential" (p. 1). Multiple researchers agreed that undergraduates at risk of attrition benefitted from a closer interaction with their professors, a project based learning approach and mentors (Daempfle 2003; Litzler & Young 2012; Ulriksen et al. 2015). In the case of this study, these highly efficacious students were provided with empathic teachers who had high content knowledge and taught using project based learning, they also had mentors. Before they can be in danger of attrition while in college, their motivation and self-image has been bolstered not only by the kind of teachers they have had in this school but also by the types of projects that they have participated in. The students continued learning and engaging with STEM projects because they learned that learning can also be fun and interactive, an important realisation that should be reiterated to teachers as they construct their lessons. These students' recollections were many and varied but all of them remembered the projects with a smile and as something that inspired them to go into a STEM field.

The projects these students engaged in were many. Most of their experiences were due to being enrolled in a STEM based high school, a choice made in conjunction with their parents. According to Barron and Darling-Hammond (2008), students who engaged in PBL had gains in factual learning that were equivalent or superior to students who engage in traditional forms of instruction, those same PBL gains were transferable to new situations and problems. Not only were there gains in knowledge but also, according to Bandura's theory of self-efficacy (1997), there are benefits in increased confidence in academic skills which leads to a greater sense of self-efficacy, a notion with which Barron and Darling-Hammond (2008) agreed.

4.5.2 Inquiry-based learning

Inquiry-based learning is emphasised, along with the teaching of critical thinking and the scientific method. The researcher observed that students displaying various questioning techniques from teachers, the teachers were encouraging curiosity among students, the teachers were giving positive affirmation to students, the students were engaging in safe learning environment for making mistakes, the students were provided opportunities for think pair share, the students were planning through reasoning skills, and teachers' assessment for learning is embedded at various levels. The focus of the study involved four main unit projects (Straw Rockets, Solar System Computer Models, Mars EDL, and Mars Cars) that required students to develop artefacts using the data they gained from scientific experimentation and supporting science content that they learned throughout. Table 27 summarises and illustrates the four units.

Table 27: Summary of integrated units

Unit Title	Summary
Straw Rockets	Student conduct small inquiry-based investigations to determine how mass affects rocket distance. Using the results of the investigations, students then design straw rockets that will go the farthest distance using design process.
Solar System Computer Models	Students explore a solar system creation simulator and then conduct two different inquiry-based investigations to test two different independent variables (Mass of planet and distance from star). Using the results of the investigations, students design their own solar system.
Mars EDL (Entry, Descent, and Landing)	Student conduct small inquiry-based investigation to determine how different shapes affect fluid friction. Using the results of the investigations, students design Mars EDL device (egg drop) that protects the egg and navigates constraints.

Mars Cars	Student conduct inquiry-based investigations to explore three independent variables (mass and gravity, sliding friction, and fluid friction/aerodynamics) that may or may not affect an inertia car's distance. Using the results of the investigations, students design a Mars Car device that slides along the floor and travels the farthest distance using a set amount of force.

The researcher believed that a better understanding of the experiences, engagement, and motivation would allow her, and/or other curriculum designers and science educators to proceed from a more informed perspective concerning curricular units that were based on the Next Generation Science Standards. Five major findings emerged from my analysis of the data generated from this study:

1. A majority of students reported positive attitudes towards all of the inquiry powered project-based units.
2. Most students appeared to be motivated to design a successful product.
3. The majority of students thought that the design phase was more motivating than the research (experimentation) phase.
4. A majority of male and female students indicated that competition was the most motivating factor of the design phase of the units.
5. A majority of female students, who preferred designing artefacts to experimentation, were motivated by creativity rather than competition.

The scientific practice of inquiry was woven into the design-based units. The authors of the NSES (NRC 1996) state that, "Inquiry instruction is its own standard describing how good science teaching should be accomplished. …Students at all grade levels in every domain of science should have the opportunity to use science inquiry and develop the ability to think and act in ways associated with inquiry" (p. 105). The Next Generation National Science Frameworks (NRC 2010) state that, "K-12 science and engineering education should focus on a limited number of disciplinary core ideas and crosscutting concepts, be designed so that students continually build on and revise their knowledge and abilities over multiple years, and support the integration of such knowledge (p. ES-1).” The students in this research were frequently exposed to how scientists and engineers work together to find solutions to their questions and problems.

4.5.3 Classroom Culture

The findings indicated that the classroom culture domain fosters teacher’s ability to create and facilitate a classroom environment. The researcher observed that components of classroom culture such as physical learning environment, resources, positive relationships, culture of creativity, effective feedback, learning environment, and success celebration were all important for fostering teacher’s ability to create and facilitate a classroom environment

Holmegaard, Ulriksen, and Madsen (2015) saw attrition as more than an academic preparedness problem or a sociological problem having more to do with the interaction between students and the institution, bringing the notion that students who leave STEM do not integrate into the dominant culture of the institution where the integration must be both social and academic. Like Holmegaard et al. (2015), Beasley and Fischer (2012) saw the sociological detriments for minority and female STEM undergraduates, Easley, Bianco, and Leech (2012) saw the problem as a “stereotype threat” where “the anxiety caused by the expectation of being judged based on a negative group stereotype” (p. 1). Easley et al. (2012) posited that minority STEM undergraduates suffer from anxiety, from the knowledge that they belong to a ‘stigmatised group’ whose behaviour is being scrutinised based on group stereotypes and that the fear both to themselves and to others that those stereotypes may be affirmed as a result of their academic achievement is what causes the anxiety and eventual attrition. Camacho et al. (2009) saw STEM majors as an “exclusionary space” or an “exclusionary culture” describing STEM/Engineering programs as one of the last exclusionary and segregated spaces that remain in academia and citing that as an attrition factor. Camacho et al. (2009) and Easley et al. (2012)

both pointed to the stereotype threat as an area that needs to be addressed to in order to impact attrition rates. Camacho et al. (2009) and Easley et al. (2012) believed that issues that affect minority STEM undergraduates include the stereotype threat, biases, social isolation and the "chilly climate" of engineering.

The students' understanding of success and failure is then coloured by this process and is parallel to what Engineers do in the industry on a daily basis. The students re-learned their belief system in terms of failure because of all the projects that they were engaged in. The student participants in this study developed a sense of STEM agency and grit due in part to their interactions with teachers, physical learning environment, resources, positive relationships, culture of creativity, effective feedback, learning environment, and success celebration.

4.5.4 Student motivation

Curricula are delivered to students in ways that encourage curiosity and reflection. The students were provided with opportunities for reflection, wait time, differentiated instructions, planning for language, feedback, thinking for oneself, the sequencing of instructional activities is planned for. In addition, the teacher gives attention to the pace of the lesson. All these elements were showing the student motivation during observations. The most obvious example of students being motivated to complete design-based artefacts is the observation that the students had higher completion rates for projects than other daily assignments. These artefacts seemed to be much better in quality and substance than I had seen in the past.

4.5.5 Curricula and the corresponding syllabi

Curricula and the corresponding syllabi reflect the moderate transient and evolving character of the factual knowledge of STEM and provide a strong focus on the practice of

STEM. This is reflected across curriculum modification, curriculum adaptation, intervention plans, mid-term planning, scope and sequences, enrichment resources, long term planning, and continuity and progression of teachers, administrators, and overall schools observed by the researcher in UAE.

4.5.6 Linking the findings with the theoretical framework

As illustrated, the current study utilised a wide range of theories to depict the theoretical framework concept. The theories indicated encompass the integrative, institutional, and socio scientific issues models. In addition, more theories are explicated in appendix 10, which add to the conception of the theoretical framework including evidence based management, sociocultural or social development theory, and the global economy or post modernity model. These theories provide a broader view of the theoretical framework, which is established to theorise STEM policy education and its respective implementation framework in the UAE context. As evinced from the study findings, the researcher analysed the information gleaned using quantitative and qualitative techniques. Through the theoretical foundations, the researcher was able to establish 10 main themes, which can be grouped into either interpersonal or structural in light of developing and implementing the STEM education policy framework in the UAE. The themes identified are in line with the conception of institutional, evidence-based management, and other models of the theoretical framework. Further, all the factors identified in connection to research question two find their basis on evidence-based analysis, integrative, and socio scientific issues models, which align to the STEM policy education in the alluded context. Moreover, as depicted by the research participants, it is explicit that a variety of resources, technology, assessment, and leadership should be integrated to yield a better model towards implementing STEM policy in the UAE. Further, from the teachers and coordinators, school leaders' opinions about STEM education; it is important to indicate that they have a basis on the theories expounded in the theoretical model. Finally, it is undoubted that the explicated theories align the pedagogy, curriculum, assessment and professional development within the realm of implementing STEM policy in the UAE.

4.5.7 Summary of Research Question 3 - Interview with Stakeholders and Classroom Observations

This section examined the results related to third research question: *"In the light of the proposed policy, what are stakeholders' (teachers, coordinators, school leaders, and administrators) knowledge and perception about STEM future implementation?"* The findings from teachers and coordinators' interviews indicated that five major themes related to STEM future implementation. These five major themes are: "subject integration/project-based learning/design-based education, school leadership, outside support and funding of integrated stem, professional development needs and non-traditional assessment". The findings from stakeholders' interviews indicated that four major themes related to STEM future implementation. These four major themes are: "leadership domain, curriculum domain, pedagogical knowledge and engagement domain, and community domain". Lastly, the classroom observations five major areas: project-based learning, inquiry-based learning, classroom culture, student motivation, curricula and the corresponding syllabi. The findings indicated that project-based learning and inquiry based learning was effective between students and teachers. In addition, the classroom culture domain fosters teacher's ability to create and facilitate a classroom environment. There was also student motivation in learning STEM related content. Lastly, curricula and the corresponding syllabi showed that curriculum needs the structural changing.

4.5.8 Main Findings of the Study in line with Research Questions

According to the findings of the research and in relation to study question one; it is evident that the researcher identified a number of themes, which helped in elucidating the international common models regarding effective instructional practices together with the STEM policies in education. The themes, as depicted include subject integration, STEM content, professional development, time, assessment, outside support from the organisation, collaboration, and willingness. In addition, there were themes of authenticity, leadership, and dissent. Ideally, all these themes denoted are, at the same time, the findings for research question.

Cognizant of research question two, the main findings indicated that major differences do not exist between the aspects of sector, gender, and campus in lieu of the STEM perceptions. For instance, those teachers that had at least 2 years of experience showcased positive responses regarding STEM education. Notably, when checking between the public and private institutions, the public school teachers had slightly high positive attitudes attached to resources and technology than those from private schools. Moreover, those instructors from Ras Al Khaimah, Ajman, and Al Ain had more positive attitudes compared to the ones from Dubai, Sharjah, and Abu Dhabi. Further, teachers of math, Education and science degrees depicted more positive attitudes in comparison to their counterparts from engineering, computer science and other subjects. Besides, male teachers highlighted more positive attitudes than the females. Ideally, the respondents indicated more positive attitudes with regard to integration of pedagogical content knowledge, curriculum integration, and delivery factors. As denoted from the findings, all the factors identified had a positive statistical correlation; however, technology and resource were strongly related.

With regard to research question three, the researchers drew five core themes including project-based learning, school leadership, outside funding and support of the integrated STEM, non-traditional assessment, and professional development needs. It was indicated, from the interview, that four major themes were notable. The themes according to the interviews were curriculum domain, leadership domain, community, and pedagogical knowledge and engagement aspect. Further, the observations from the classroom highlighted five themes including inquiry-based learning, project-based learning, classroom culture, curricula and corresponding syllabi, and student motivation. Accordingly, the findings insinuated that inquiry and project-based learning techniques are effective between the learners and instructors. Additionally, classroom culture bolsters the ability of the instructors to create and facilitate an appropriate classroom environment. Motivation among the learners also boosted the learning experience while curricula and corresponding syllabi required structural changes.

Notably, the most interesting findings from the analyses are the manner in which the themes were drawn from the information presented. As showcased, several themes emerged indicating the varied parameters with regard to the development and integration of a STEM policy into the schools in the UAE.

4.6 Summary of All Results in Chapter 4

This chapter of the study analysed the results for each research question using both qualitative and quantitative methods. The findings of first research from document analysis regarding the international common models of effective instructional practices and policies of the STEM education indicated 10 themes which can be categorized in to structural and interpersonal implementation. These themes are considered effective and important in relation to integrated STEM implementation. The findings of second research question from questionnaire analysis indicated that important factors associated with STEM are Assessment, Connection, Curriculum and Delivery, Leadership, Pedagogical Content Knowledge, and Technology and Resources. Out of these six factors, leadership, technology and resources, and assessment are found more robust and statistically significant with STEM integration and implementation in UAE schools. The findings of third research question indicated several themes from teachers' and coordinators' interviews, school leaders, and classroom observations. Overall, the findings indicated that curriculum, pedagogy, leadership, professional development, and assessment are important elements associated with STEM integration and implementation in UAE schools. The next chapter of the study now presents the discussions and conclusions of these findings.

CHAPTER 5

DISCUSSION AND CONCLUSION

This section, chapter 5, of the study presents the discussions and conclusions. The chapter discusses the findings from each research question and then interprets the combined findings of all research questions. Based on the discoveries of the study, the chapter, further, highlights the policy recommendations framework for implementation and integration of STEM in K-12 education in the UAE schools. The researcher then discusses the possible limitations of the current study and suggests future research implications where more studies could be conducted while addressing the possible limitations. Lastly, the researcher presented the conclusions of the findings.

5.1 Discussions

The purpose of this study was to develop a policy and implementation framework in the UAE by identifying critical elements of an integrated STEM education key factor related to the implementation of an integrated STEM curriculum in K-12 schools in the UAE. The researcher employed Exploratory Sequential Mixed Methods for this study. The findings of this study are based on document analysis, teacher questionnaire survey, teacher and coordinators' interview surveys, school and district leaders' interview survey, and classroom observations. Three research questions were established, which were examined from the findings from the above research instruments. The subsequent sections provided the discussions related to each research question.

5.1.1 Discussions of Results of Research Question 1

The researcher, first, examined and interpreted data and drew frequent themes related to the international common models of effective instructional practices and policies of STEM education. The researcher used thematic analysis and applied six steps of Braun and Clarke's (2006) strategy to analyse and report themes (patterns) within data. The researcher used Content Analysis on MS Word qualitative software for thematic analysis. The findings of this research identified 10 global themes from the document analysis that can be considered both a critical component and key implementation factor for integrated STEM education. All these themes emerged as *the international common models of effective instructional practices and policies of the STEM education.*

Through the findings of this study, the analysis and synthesis identified 10 global themes that can be considered both a critical component and key implementation factor for integrated STEM education. The structural implementation global theme was termed systematic, not because they are structures (even though some of them are), but because these global theme represents factors that must be in place either from the schools or outside influences. The global implementation theme was regarded as interpersonal because it included activities done by the people (teachers, students, outside experts). This global theme is more connected to the people involved in the integrated STEM process where the structural global theme are more about needs for integrated STEM education. This is in line with Sadler (2011) who contends that there are several factors that are needed for effective implementation of STEM education; often, these are those factors that form the environment around the implementation and integration of STEM.

The identified global theme works in concert to produce something that is more than the sum of its parts. This is an important consideration for measuring the performance of existing integrated STEM programs or when attempting to begin a new program. Not only does it incorporate the integration of multiple disciplines as content, it incorporates multiple structural and interpersonal aspects as part of that process. This, in turn, makes integrated

STEM very complex. Fundamentally, the complexity of the integrated STEM education is highlighted by Drake and Burns (2004) when they elucidate on the concept of multidisciplinary. As such, these findings align with the conception showcased by these researchers, Drake and Burns (2004).

The real question is can you create and implement integrated STEM without all the global themes identified in the research study? The findings of this study confirmed nearly universal responses of the qualitative and quantitative survey responses related to these global themes made a strong argument that they must all be included. The literature agrees and details to that effect can be found in the next section. A primary difference between the identified global theme in the literature and the identified global theme in the research study, was that the global theme identified in the study were much more highly interconnected than the literature appears to indicate. The literature tends to list global themes that are important to integrated STEM, but does not necessarily explore the interconnectedness between them. As such, this finding, to a larger extent, acts as a contribution of the current study. It is, therefore, explicit that the global theme acts as a fundamental international model for effective instructional practices and policies with regard to STEM integration. As depicted by Farokhi (2014), STEM education is grounded on global competition; besides, his study focused on developing a scheme for STEM-based financial prosperity framework, which holds aims at reversing the deepening economic trend across the globe. Moreover, this theme provides a leeway to ensure benchmarking of varied SETM programs on a global standing and then use the structures and theories presented in the theoretical framework to ensure a STEM policy that will yield the desired objectives in the UAE.

In the literature, research identified many essential components for the successful implementation of integrated STEM education. Effective STEM instruction was identified in research as a critical element for student achievement. This type of instruction utilises students' interests and experiences. It identifies and builds on their prior knowledge, and gives them educational experiences that engage them in STEM coursework and sustains their interests (Herschbach 2011; National Academy of Engineering 2014; National Research Council 2011). This incorporates two global themes found in the findings: authentic/relevant/real world experiences and the professional development, which is required for teachers to be effective STEM instructors.

The results of this study show that professional development designed to guide teachers through the change process is feasible. Professional development is likely to make the change in teacher instructional practices easier if needs are supported, if they have time to plan, practice, and reflect, and if they have time to collaborate amongst themselves and use the resources that are provided. Changes in instructional practices may also result if teachers are provided with access to research-based recommendations considered and implemented in the research design. This finding is backed by Sunyoung et al. (2015) who allege that professional development has the potential to ease the evinced challenges during transition from traditional educational methods to STEM programs.

With this realisation, the categories that were identified in the synthesis from qualitative and quantitative results can be considered both critical components for the definition and implementation factors of STEM in UAE schools. There are two broad classes of implementation categories: structural and interpersonal. The structural implementation categories include: "subject integration/project-based learning/design-based education, non-traditional assessment, STEM content, time, professional development, and outside support (from businesses and industry). The interpersonal implementation categories include: leadership, collaboration, willingness, authentic/meaningful/relevant experiences for participants, and outside support (from people in business and industry)". In this case, the researcher found out the global themes supporting the integration of STEM education; in so doing, the investigator realised that other models that should be present for successful implementation of STEM education include collaboration, leadership, willingness, and relevant experienced. Through these variants, STEM can be appropriately implemented in the UAE. In reality, these themes relate or connect to the theoretical framework as the model identifies varied theories that back the integration of STEM model. For instance, the integrative theory, institutional model, evidence-based management, and post modernity and global economy link to the concept of global theme where such elements are essential to successful implementation of programs such as STEM education. The interconnectedness of these categories is shown in Figure 18.

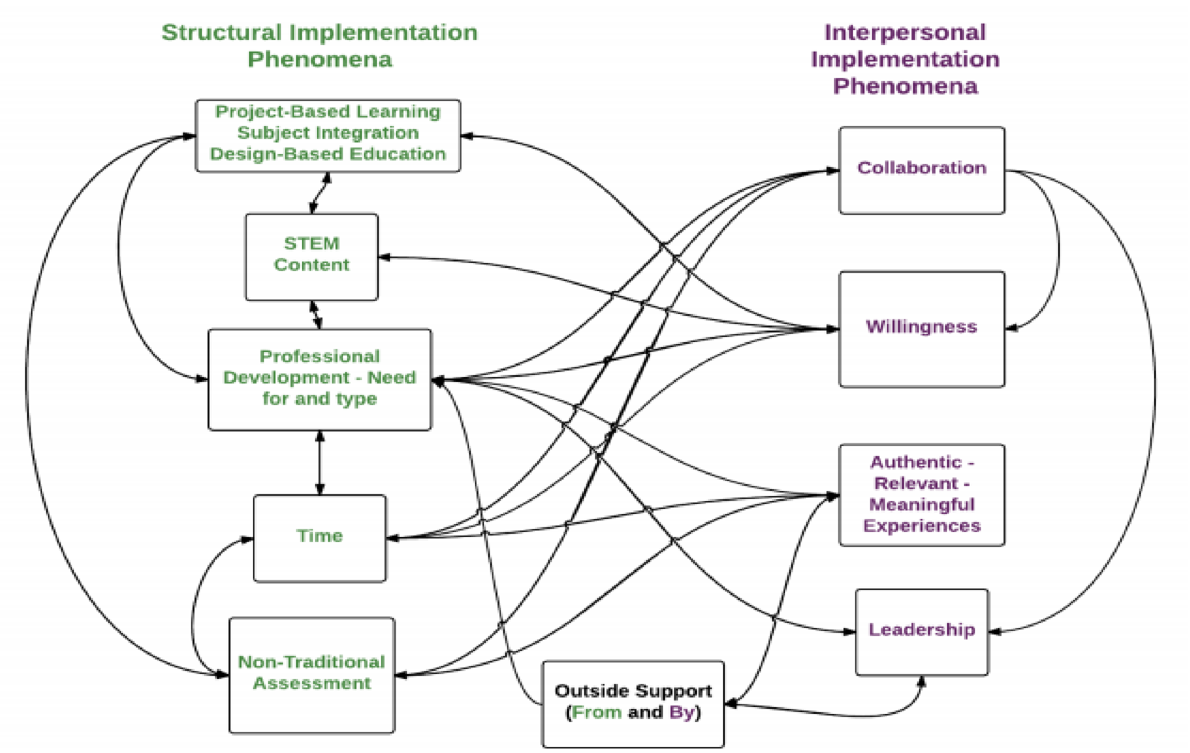

Figure 17: Integrated STEM categories

5.1.2 Discussions of Results of Research Question 2

Subsequently, the researcher analysed the responses of teachers from the questionnaire survey to explore the factors associated with STEM integration and implementation in UAE schools. The researcher used both descriptive and inferential statistics to determine those factors which are significant with STEM integration and implementation in UAE schools. In this regards, the researcher used IBM SPSS Statistics and IBM SPSS AMOS software to compute descriptive statistics, Pearson correlation, Explanatory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), Structural Equation Modelling (SEM), Analysis of variance (ANOVA), and Multiple regression analysis (MLR) to reach the concluding points.

The purpose of second research question is to analyse factors associated with STEM integration and implementation in UAE schools. The findings from the questionnaire survey of teachers indicated that six factors: Assessment, Connection, Curriculum and Delivery, Leadership, Pedagogical Content Knowledge, and Technology and Resources are significantly associated with STEM integration and implementation in UAE schools. While all these six factors are important, the research identified that leadership, technology and resources, and assessment are found to be more robust and statistically significant with STEM integration and implementation in UAE schools; however, it is critical to note that not all schools depict all of the themes mentioned. For instance, some schools showcase a section of the themes, for instance, the public schools while private schools implicated nearly all of them.

As discussed earlier, there is a rise in interest related to providing students with learning that makes connections across STEM disciplines in UAE; however, there is little research and/or consensus on what integrated STEM means and how to create integrated STEM offerings for student learning (Brown et al., 2011; Householder & Hailey, 2012; NAE, 2014). Householder and Hailey (2012) state that there is a need for clarity in the outcomes that may be expected, and the arrangement of developmental sequences related to integrated STEM, and that there are few organised efforts that include engineering experiences in high school STEM courses. According to the National Academy of Engineering and National Research Council report, *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research*, there is little research on how to best conduct integrated STEM, or what factors make the integration of STEM subjects increase student learning, interest, retention, achievement, or other outcomes (NAE, 2014). This study attempted to address these needs identified in the literature, by answering the following research questions. First, what were the critical components of an integrated STEM definition and second what critical factors were necessary for an integrated STEM definition's implementation.

The National Research Council report, "*Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics"* (2011), identified another critical component of integrated STEM education, which is adequate instructional time. The NRC report states that the current No Child Left Behind legislation has changed the time allotted for science, technology, engineering, mathematics teaching, and learning in the K-12 curriculums. K-12 schools are focusing more on mathematics and English because these are tested annually, at the expense of losing time for science, technology, and engineering education. This decrease in educational time for science education is a problem, because research indicates that interest in science careers develop in K-12 schools (National Research Council, 2011).

The relationship to this study is that time was identified universally by the both qualitative and quantitative survey participants, as essential to integrated STEM. The survey participants spoke directly to instructional time when discussing longer class periods, as well as providing students with time to think and process. The survey participants also spoke about time for teachers to work, collaborate, and learn, which directly affects the teacher's ability to instruct quality integrated STEM. Time, from the standpoint of the study, is definitely important to integrated STEM for multiple uses and from multiple perspectives.

Equal access to high-quality STEM learning opportunities was cited as another critical component for integrated STEM education in the literature. These learning opportunities must have an inclusive STEM mission, where goals are stated clearly to prepare students for STEM careers, to support students from minority and underrepresented population groups, and to have an emphasis on recruiting students from these underrepresented population groups (DeJarnette 2012; National Research Council 2011; Peters-Burton et al. 2014; Stone et al. 2017).

Equal access to high-quality STEM learning opportunities, just like providing effective STEM instruction, relates to the study-identified category of authentic/relevant/real world experiences for students. Providing these types of experiences for students will help prepare students for STEM careers and help with motivation and recruiting. Another component related to integrated STEM education found within the literature is having real world partnerships, research opportunities, and internships. In literature, identified STEM schools provide extensive research opportunities for students.

These opportunities allow students to connect with businesses, industry, and the world of work via internships, mentorships, and projects, both within the school day and outside the school day/school year. These research experiences provide hands-on experience for students and have the possibility of increasing interest in STEM career fields (Ejiwale 2012; Peters-Burton et al. 2014; Pfeiffer et al. 2010; Scott 2012).

The importance of this category was clearly defined in the survey participants when speaking about outside support from structures and from people. The survey participants discussed exactly these types of experiences for students of integrated STEM. The survey participants went one step further when they thought outside support for resources and expertise related to instruction was essential for integrated STEM education. For there to be successful integrated STEM, there is evidence that outside support is needed.

Collaboration between teachers of all disciplines was seen as a critical integrated STEM component. Teachers from all disciplines should meet to analyse lesson plans and student work, to improve future learning (Peters-Burton et al. 2014). STEM education requires collaboration, since teachers have not been trained in all STEM curricular areas. The time allocated to teacher training needs to be dedicated and collaborative (Brown et al. 2011; Peters-Burton et al. 2014; Sanders 2009; Scott 2012).

Collaboration was a universal category that surfaced in the survey participants as being important for integrated STEM. The cited evidence from literature confirms that collaboration is important. The survey participants again went further when discussing the collaborative nature of integrated STEM from the students' perspective. The data and literature showed that collaboration's many facets are essential to integrated STEM.

Professional development/teacher support was another key component of integrated STEM education identified in the literature. According to the National Academy of Engineering, (2014) very few teacher education programs are preparing prospective teachers with appropriate knowledge in more than one STEM curricular area. Rockland et al. (2010) claimed that to increase the presence of engineering in the K-12 classroom, teachers must be exposed to training on engineering concepts, and how to integrate those concepts into the classroom. Professional development of teachers allow them to become more comfortable with their own knowledge of STEM, and as teachers learn more about math and science they become more comfortable teaching STEM (Nadelson et al. 2012). The implementation of integrated STEM education in all educational settings will require additional content and pedagogical knowledge beyond which teachers currently are trained, therefore schools currently attempting to have an integrated STEM curriculum must provide professional development for its teachers and leaders (Nadelson et al. 2012; National Academy of Engineering 2014; National Research Council 2011; Rockland et al. 2010; Scott 2012; Stearns et al. 2012).

Professional development was clearly identified by the participants as important to integrated STEM, particularly the type of experiences cited in the literature. The data from the study, as well as the literature, highlighted the category that teachers need experience with more than one discipline in integrated environments. Professional development is one way to gain those experiences and is therefore essential to the success of integrated STEM.

The idea of better assessments for integrated STEM is also present in the literature. The National Research Council report, "*Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics"* (2011), identified a supportive system of assessment and accountability as important for integrated STEM. The report states that the current push by governmental oversight agencies toward standardised testing limits the teacher's ability to teach using techniques that are known to increase learning of mathematical and science content and practices (National Research Council 2011).

5.1.3 Discussions of Results of Research Question 3

Following the document analysis and analysis of questionnaire survey responses, the researcher analysed the interview responses of various stakeholders (teachers, coordinators, school leaders, and administrators) to explore possible practices of STEM integration and implementation. The researched used thematic analysis and applied six steps of Braun and Clarke's (2006) strategy to analyse and report themes (patterns) within data. The researcher used Content Analysis on MS Word qualitative software for thematic analysis. Lastly, the researcher examined the data collected from the classroom observation list. The researcher examined all the personal notes, field notes, reflections, and tentative interpretations during classroom lessons. These classroom observations were examined in light of document analysis, questionnaires, and interviews data. The researcher monitored classroom activities, interactions between teachers and students, and check for actions that reveal self-regulating behaviours and cues that signal confidence levels in STEM integration and implementation in UAE schools.

In lieu of third research question regarding stakeholders' (teachers, coordinators, school leaders, and administrators) knowledge and perception about STEM future implementation, the findings of this study identified five major themes from teachers' and coordinators' interviews related to STEM future implementation. These five major themes are: "subject integration/project-based learning/design-based education, school leadership, outside support and funding of integrated stem, professional development needs and non-traditional assessment". The findings from stakeholders' interviews indicated that four major themes related to STEM future implementation. These four major themes are: "leadership domain, curriculum domain, pedagogical knowledge and engagement domain, and community domain". The next chapter of the study now presents the discussions and conclusions of these findings.

The results of the study in terms of the categories generated through the interview analysis align well with the previous studies in the literature review. The "subject integration/project-based learning/design-based education" category was identified by the Interviewees as the primary instructional mechanism for integrated STEM in UAE. This matches the three pedagogical methods outlined by Pitt (2009) that forms one leg. The second leg was STEM content, which was also either explicitly stated or implied by the interview and questionnaire survey participants as being important to integrated STEM education in UAE. The third leg was the support structures identified in the literature as important to integrated

STEM. Two of the six support structures were clearly identified in the results as categories: collaboration and professional development. A third support structure, administrators, was greatly expanded upon within the interviews, in the leadership category. The respondents did mention school leaders. However, they saw leadership as much more than just school leaders in UAE. Leadership from multiple aspects and multiple perspectives were identified in the participants as important to integrated STEM. The other three support structures: counsellors, libraries, and the arts curriculum, were not mentioned by any of the respondents. This does not discount them as important to integrated STEM. Rather, it means that in the course of the surveys they were not mentioned. The participants also included supporting elements for integrated STEM that were not included in the support structures. These include: non-traditional assessment, time, outside support, willingness, and authentic/meaningful/relevant experiences for participants. The fact that the participants' responses matched the literature review validates its construction. The additional categories (supporting elements) that were found, provide additional information related to integrated STEM.

The results revealed participants to have a high level of pedagogical knowledge; however, this pedagogical knowledge was not fully applied in their classrooms, where most of the participants tended to be traditional teachers. Moreover, the results showed that participants had an average level of subject matter knowledge related to STEM disciplines. Participants showed a need for deeper knowledge of "STEM disciplines and systematic support, such as training courses or professional development programs, to be able to implement integrated STEM education in their classes".

The results revealed that participants had a positive attitude toward the value of integrated STEM education. They believed in the need for and strength of integrated STEM education for current and future generations of students. Participants also displayed a reasonable attitude toward integrated STEM education's feasibility, in relation to time required and difficulty. The majority of the participants showed a positive personal desire to be integrative STEM teachers, indicative of their ability to overcome challenges that may impede their transition from traditional teachers to integrated STEM teachers.

Participants reported several obstacles to becoming integrated STEM teachers. Some obstacles were related to the teachers' preparation, motivation, subject matter knowledge, and need for training courses or professional development programs. Other obstacles were related to school setting, such as classroom readiness, lab equipment, and number of students per classroom. Student achievement level and motivation were also mentioned as obstacles. Some teachers believed the current 7th grade curriculum could be suitable for integration with other disciplines, but not 8th and 9th grade curricula. Families, which included parents of the learners and the society, were mentioned as a potential obstacle, as they needed to believe in and support integrated STEM education. The lack of technology support and external resources were raised as another obstacle. One participant also mentioned that the school administration could be an obstacle if the principal did not support and facilitate integrated STEM education.

The survey participants spoke about the non-traditional nature of integrated STEM. Some survey participants felt that integrated STEM would not hinder standardised testing. However, the types of non-traditional assessments that were mentioned in the data were often not standardised. The survey participants did not mention a supportive system of assessment, but the types of assessments which were discussed, would support integrated STEM education. This would effectively create a supportive system of assessment. Ultimately, the data and literature demonstrated the importance of assessment, which will likely be non-traditional for integrated STEM.

The next area in the literature that has connections to theme generated in the survey participants was using engineering design and problem-based learning as a mechanism for integrated STEM education. Project-based learning and problem-based learning is not exactly the same thing, but are often used interchangeably. Engineering design and engineering design challenges in the classroom expand on traditional problem-based learning which is a highly researched instructional technique (Rockland et al. 2010). Strobel and van Barneveld (2009) performed a qualitative synthesising meta-analysis of problem-based learning, and determined that problem-based learning is significantly more effective than traditional instruction to train competent and skilled practitioners, and to promote long-term retention of knowledge and skills acquired during the learning experience or training session. Inquiry learning, problem-based learning, and project-based learning, are teaching methods that are proposed for use in engineering education (Prince & Felder 2006).

The survey participants specifically stated project-based learning needed to be part of an integrated STEM environment. These statements regarding project-based learning made up one third of the "subject integration/project-based learning/design-based education" category that was found in the data from the findings. These three pedagogical methods were grouped into one category because they are the primary instructional methods from the study's conceptual framework.

The above literature discusses engineering design and problem-based learning as well as project-based learning. These concepts together make sense, because project-based learning is made up of smaller problems, that must be addressed though some kind of process. In integrated STEM, the engineering design process can be the driving force to address the problems that make up the larger projects. The amount of literature related to problem-based and project-based learning and the consensus of the survey participants related to project-based learning makes it an important factor for integrated STEM implementation.

Another area in the literature that has connections to theme generated in the findings was subject integration, which is also part of the conceptual framework of the study. In the article "*The STEM Initiative – Constraints and Challenges",* Dennis Herschbach (2011) discusses STEM as a curriculum concept. Herschbach states that there are two types of curriculums: correlated and broad field. In a correlated curriculum, each course retains the identity of each subject and is offered separately. In a broad field curriculum, all courses are integrated together with each course losing its own identity (Herschbach 2011). Math and science tend to be correlated in nature, where technology and engineering tend to be broad field in nature. The broad field curriculums of engineering and technology are a very good way to organise engineering and technology instruction because they are interdisciplinary. Using this model, instruction is built around the integrated use of knowledge from engineering and technology, with supporting knowledge drawn from the correlated fields of science and mathematics (Herschbach 2011).

The National Academy of Engineering report, "*Engineering in K-12 education: Understanding the status and improving the prospects"* (2009) identified a "symbiotic relationship between mathematics, science, and engineering, where engineers use mathematics and science in their work, and mathematicians and scientists use the results from engineering in their work" (p.5). The committee that authored this report found that due to this symbiotic relationship, "engineering could be the vehicle for the development of integrated STEM education" (National Academy of Engineering 2009, p.18). Rockland et al. (2010) believe that the engineering design process can provide a context that supports teachers in teaching scientific inquiry to students, because scientific inquiry and engineering design are parallel processes with both having similar problem solving characteristics. Kimmel, Carpinelli & Rockland (2007) argue that “when engineering and science are taught together, they extend and reinforce each other. The integration of engineering principles into science instruction, presented through problem-solving inquiry/discovery pedagogy, can stimulate students as well as enable them to recognise links between their lessons and tasks performed by engineers in the real world” (Harwood & Rudnistsky 2005, p.65).

The survey participants all discussed the integrated nature of integrated STEM. Several respondents mentioned that integration is sometimes claimed, but when what is actually happening in the classroom is analysed, integration is not occurring. They all felt that subject integration is critical for integrated STEM to occur, and the literature appears to support those feelings. Because of the consensus of survey participants’ opinions related to subject integration, the amount of literature surrounding the importance of subject integration, and the fact that subject integration made up one of the instructional delivery models of the conceptual framework of the study, subject integration can be considered critically important for integrated STEM.

Some other areas in the literature that are cited as important for integrated STEM were not found in the comments of the survey participants. First, the literature stated, high quality integrated STEM educational settings utilise varied technology. Integrated STEM institutions use a wide variety of instructional technology like computers, graphing calculators, calculator-based laboratories, and other digital data instruments to deliver inquiry based lessons, engage in research, and to produce and present projects. The use of “technology has the potential to change the interactions and relationships between students, teachers, and the knowledge that teachers are trying to convey” (Scott 2012, p.11).

The survey participants did mention some specific technology that integrated STEM environments could use. However, as stated earlier, most of the ideas that the respondents spoke about were conceptual rather than “things.” This does not mean that varied technology is not important, rather that the survey participants did not address specific technologies and did not reach a consensus on that matter. Second, a clear and understandable set of standards and curriculum where there are strong course offerings in all STEM areas is important for integrated STEM. Engineering and technology are “explicitly and intentionally integrated into STEM and non-STEM subjects”. Setting rigorous standards and aligning the curriculum to those standards can show gains in student achievement (Brown 2012; National Research Council 2011; Peters-Burton et al. 2014).

In today’s educational climate, standards and curriculum are very important. The survey participants did discuss standards and found much more agreement related to national standards than they did related to state standards. However, there is disagreement among the survey participants related to standards and curriculum, and whether integrated STEM is a core class vs. elective class. The national standards in the eyes of the participants were much broader and process-based than state standards. This might be why they feel that integrated STEM would fit national standards better than state standards. The issue of curriculum and how integrated STEM fits into schools is a more difficult topic.

Third, teachers with a high capacity to teach their discipline are a key component of integrated STEM education that is identified by many researchers. Teachers must teach in ways that inspire all students, and increase their understanding of STEM content and practices (National Research Council 2011; Scott 2012). Teachers must have advanced STEM content knowledge and/or practical experience in STEM career fields and they must be well prepared

(Brewer & Goldhaber 2000; Ejiwale 2012; Monk & King 1994; Peters-Burton et al. 2014; Rowan, Chiang & Miller 1997).

While the survey participants did not specifically mention high capacity teachers, it could be implied in their conversations regarding professional development. They stated that teachers must be willing, excited, and well trained. These are likely traits of high capacity teachers. The fact that the survey participants did not state integrated STEM teachers needed to have a high capacity to teach, does not discount the literature. Rather, the questions in the study might not have been asked in such a way as to elicit this type of response.

The literature aligns well with the findings of the study, which is a confirmation of the findings. There were some theme identified in the survey participants on which the literature is not as clear. The concept of willingness was prevalent in the survey responses. The participants overwhelmingly thought that willing teachers (and to a certain extent, willing students) are essential for successful integrated STEM. This might be a characteristic that could be included in the high capacity teachers' component from the literature. Regardless, this is something that the data from the study shows is important to integrated STEM.

The participants spoke at depth about non-traditional assessment for integrated STEM. While the literature touches briefly on the need for a supportive assessment system, the survey participants were much more specific about the nature of integrated STEM assessment. The survey participants also put emphasis on authentic/meaningful/relevant experiences for participants. Again, the literature touches on this category when it cites real world partnerships, research opportunities, and internships, as important to integrated STEM. However, the survey participants were much more specific about the nature of those experiences.

The final category that the respondents considered very important to integrated STEM is leadership. The literature does speak to leadership related to integrated STEM, which is also a support structure from the conceptual framework. However, the survey participants were much broader in their discussion of the type of leadership, and from whom the leadership needs to originate than the literature.

Throughout the research study, it was evident that the design of professional development for interdisciplinary STEM teaching was effective, and it does have an impact on participating teachers' planning, implementation, and instructional practice. However, changes in classroom practices were not the same for all five teachers. Differences in teachers' instructional practices indicated some change in their beliefs about STEM integration; classroom observations also showed changes in instructional practices. These differences were not surprising because they correspond to the theory of change mentioned earlier in the literature which indicated that there are certain kinds of experiences that result in changes in teachers' instructional methodologies. Therefore, a change in instructional practices would not happen unless teachers had these experiences; these experiences foster a changes in beliefs and understanding. This lesson was important to know about the teachers' professional development experiences because teachers approached the professional development training from different perspectives based on what they already knew and understood about interdisciplinary. As a result, the outcome of this study was heavily influenced by how teachers approached professional development training, and their prior experience affected what they learned.

The study has shown, and research also revealed that teacher collaboration time was essential for sustained change to occur (DePaul 2013). The importance of cooperation in the study was evident in spite of the use of the CAR model, which is also a collaborative approach (Herr 2005), because the expected change required resources such as time for planning, exchange of ideas, and feedback. Consequently, the school was called upon to provide support in creating flexible teacher schedules. Also, because STEM is not a discipline, teachers could collaborate and plan together to make learning authentic, rather than working in isolation (Merrill & Daugherty 2009). The teachers realised that subjects such as science and mathematics had areas in which natural overlap occurred and connected seamlessly.

This study has shown that professional development provides teachers with a variety of opportunities to learn how to use technology tools in the classroom as a means of integrating STEM. For example, three participants collaborated with the technology teacher and gained ideas and techniques on how to use computer tools to enhance science and math instruction. This example shows that changes in teacher instructional practices in the classroom as a result of teacher collaboration are effective in developing a deeper understanding of the innovative methods used in STEM interdisciplinary teaching (Jacobs 2010). The study has also shown that focus on the characteristics of effective professional development, and the needs of teachers, are essential to teachers' experience and to bring about changes in their instructional practices (Porter et al. 2000). For example, Sharon immediately implemented the acquired technology tools for learning in her classroom and remarked: "I think every teacher should experience how technology integration changes the dynamics of instruction and offers different ways of teaching and learning." Another participant expressed that technology-integration provided opportunities for active learning and collaboration practices through the type of learning used (collaboration, and active learning) rather than the techniques employed by the traditional learning model.

The study has shown that interdisciplinary teaching exposes teachers to other methods and pathways to differentiate instruction and engage students. For example, teachers' lesson plans reflected an interdisciplinary approach to teaching and learning after session three of phase one of the professional development training. Teachers who implemented the concept of the interdisciplinary strategies in the lesson plans have shown some positive outcomes for students. Teachers reported that students gained knowledge of problem-solving techniques from more than one perspective. This improved their critical thinking skills in mathematics and science, and they became aware of the interrelationships that existed in other disciplines. Students' demonstrated understanding in solving real-world problems and issues as measured by their class work during the lesson, their engagement in the class activities, and their responses to critical thinking questions related to problem-solving. For instance, students were able to complete tasks and declared them to be interesting approaches to learning math, science, and technology.

These observations agree with research that indicates teachers' learning experiences are reflected in classroom practices and students' learning outcomes (Porter et al. 2000). More importantly, participating teachers commented that they valued the STEM interdisciplinary approach because of the focus on teaching from a broader perspective rather than in isolation. The strategy focused more on whether students are learning and making connections. The findings reveal that deliberately focusing on effective professional development for interdisciplinary STEM teaching will require professional development approaches based on teacher needs, teacher collaboration, and time to plan and reflect on experiences. Given the current state of science education, and the fact that science reformers have been calling for best practices that will enable students of today to become scientifically literate for tomorrow, the findings from this study serve to show:1) that interdisciplinary approaches to teaching and learning can enhance the quality of science teaching; and 2) that effective STEM professional development programs can provide teachers with experiences that afford them skills and knowledge to teach in interdisciplinary ways.

As part of the science and social studies methods course, the teachers were able to apply what they were learning through an authentic, constructivist-based STEM integration teaching experience with K-12 students. The researcher had anticipated that doing so would improve their overall attitudes as the previously mentioned studies had found, which was implied with the directional hypothesis for the study. Upon analysis, when it was determined that no significant change had occurred, the researcher concluded that various factors may have contributed to the findings lending themselves to a rejected hypothesis. The teachers articulated in their qualitative interviews that they believed STEM was a valuable component of K-12 curricula, a finding that is supported by a study on curriculum integration conducted by Koirala and Bowman (2003). In Koirala and Bowman's study of 35 teachers, all participants them came into an integrated math and science course with the belief that integrated teaching was valuable to student learning. As such, all participants in Koirala's and Bowman's study were motivated to utilise integration in their instruction, just as the participants in this study were with regard to integrating STEM. Similar to Koirala and Bowman's findings, however, the teachers this study became quickly discouraged upon the realisation of the compartmentalisation and fragmentation of existing curricula, which made integration difficult. This category was mirrored in the current study in the sense that there was no significant increase in pre-service teacher attitudes as a result of engaging in STEM-based preparation.

As the teachers grappled with compartmentalised curricula and gained exposure to the high pedagogical, instructional, and time demands placed on their cooperation, their attitudes decreased as they realised how difficult it would be to take on the initiative of integrating STEM into the existing curricula. Numerous researchers share the assertion that STEM integration is important at the K-12 level (Achieve Inc. 2013; Alexander et al. 2014; Knezek, Christensen & Tyler-Wood 2011; National Academy of Engineering & National Research Council 2014; Sanders 2009; U.S. Congress Joint Economic Committee 2012). The teachers in this study maintained the attitude in all three phases that constructivist-based STEM integration should begin early; hence, benefiting the learners to acquire the desired skills and knowledge. This may have been influenced by their own understanding that their own background in K-12 and college was not conducive to feeling prepared to engage with STEM content. Upon seeing the lack of STEM present in their field experience curricula, the teachers in this study may have felt discouraged regarding how they could actualise the opportunities for STEM-based integration that they pointed out within their qualitative interviews.

What was surprising to the researcher was that the teachers began Phase I already sharing the assertion that STEM was valuable to the K-12 curricula even though they were not able to define it or articulate its various components. They did not identify any meaningful STEM experiences in K-12 or college, and many of them came into the study only being able to identify what the acronym stood for. It may be true, then, that the teachers were influenced by the fact that STEM was a topic of study within the methods course itself, thus causing them to assume its value based on its inclusion in the course. The researcher's directional hypothesis was a reflection on the researcher's own belief that STEM-based preparation would positively impact teachers' attitudes toward STEM as it had in studies previously mentioned. The lack of significant change in attitudes may be attributed to such factors as changes in attitudes requiring time and consistent experiences to attain. Additionally, as discussed earlier, some of the teachers entered the study with exceptionally high levels of confidence and maintained or exceeded those levels throughout the study, where the levels of ability may refute such a high level of confidence. Given the small sample size for the study, more research is needed to determine if additional experiences, such as those in the methods course and beyond into student teaching or the first year as a practicing teacher, would affect the attitudes of teachers toward STEM.

5.1.4 Interpretation from Combined quantitative and qualitative results

The results from the quantitative and qualitative phases revealed several interesting findings and seeming contradictions. Mathematics teachers showed high levels of pedagogical knowledge, knowledge of different teaching strategies that ranged from traditional, cooperative, student-centred, and active learning strategies, which was consistent with O'Neill et al. (2012), Nikirk (2012), Knapp (2003), and Ejiwale (2012). However, participants showed a tendency to be traditional teachers, which also was consistent with O'Neill et al. (2012). While participants reported using a variety of teaching strategies, none mentioned project-based learning, problem-based learning, or inquiry-based learning, which have been reported as the most effective teaching strategies to deliver integrated STEM education (e.g. Aleman 1992; Darling-Hammond & Youngs 2002; Fajemidagba, Salman & Olawoye 2010; Glasgow 1997; Nikirk 2012). This finding could be related to a difference in the way mathematics teachers think. Wasserman and Rossi (2015) discussed this idea in their article about the difference between inductive and deductive reasoning among mathematics and science teachers. This possibility is important because teaching science within integrative STEM education has been shown to require different skills than teaching mathematics (Wasserman & Rossi 2015).

One of the participants discussed the importance of using different assessment methods and the value of using a rubric during assessment. She also discussed the power of self- and peer-assessment, which was consistent with Teo and Kaijie (2014) and O'Neill et al. (2012). Additionally, some participants mentioned many classroom management skills that are important according to Ejiwale (2012) and Knapp (2003). In terms of subject matter knowledge, participants reported an average knowledge level of different STEM disciplines, which was consistent with Reinsvold et al. (2014). This finding is important because teachers' level of understanding and knowledge of subject matter is linked to their ability to effectively teach the content of a lesson (Nadelson et al. 2012; Halim, Syed Abdullah & Meerah 2014; Ejiwale 2012). These findings showed the need for training courses or professional development programs to prepare mathematics teachers to be integrative STEM teachers, a result consistent with Stohlmann et al. (2012) and Hewson (2007).

Participants reported a positive attitude toward the value of integrated STEM education. This result was consistence with Berlin and White (2012) as they showed reasonable judgment and attitudes toward the feasibility of implementing integrated STEM education, which Berlin and White explained as a "more realistic understanding of what is required to integrate mathematics, science, and technology in the classroom—that it is not simple, nor slow, nor easy but somewhere in between" (p. 27). Teachers' attitudes are essential because they are driven by their self-confidence, self-efficacy, and pedagogical content knowledge. All these elements contribute to teacher and student success (Jones & Carter 2007; Settlage et al. 2009; Nadelson et al. 2013). Regarding personal desire, the majority of participants wanted to be in the field and to become integrated STEM teachers. This is important because personal desire leads to the ability to face challenges and indicates that over time teachers will grow and use suitable teaching strategies and subject matter knowledge. Additionally, they will move easily from traditional teachers to facilitators, an argument supported by Stohlmann et al. (2012).

5.3 Policy Recommendations and Implications

STEM research is rare in UAE; hence, several studies recommended more in-depth research into integrated STEM education in UAE. Therefore, the results from this study are especially significant to UAE decision makers, educators, teachers, and policy makers. Firstly, it attempted to help those in authority make sound and research-based decisions regarding the introduction and implementation of integrated STEM programs in the country with a full knowledge of teacher readiness and attitudes toward STEM education. Decision makers would be able to better understand STEM teacher obstacles and be better equipped to eliminate these obstacles in implementing and teaching STEM disciplines. Secondly, educators may use the findings and recommendations from this study to build suitable professional development programs targeting STEM education for UAE teachers and those seeking to become integrated STEM teachers. Thirdly, teachers will be able to determine their perceived needs, beliefs, and attitudes toward teaching STEM disciplines. Fourthly, the results from this study attempted to help prepare students for 21st century life by equipping them with needed literacy and skills needed in a competitive global market and to contribute to national economic growth.

The implications of this study may influence several different groups focused on educational outcomes. Specifically, policy writers and grant funding agencies, public and private high schools' administrators and teachers, higher education faculty, and educational researchers may all find valid information within this meta-analytic research study. Policy writers and grant funding agencies could benefit from this study by knowing increased research is needed in engineering, higher education STEM student perceptions, and higher education STEM course constructs. Relatedly, the type of research conducted in the area of instructional technology may need to be refined based on the information from this meta-analysis. To reduce the variability inherent with technology implementation and usage in a classroom setting, more research specificity may be warranted. For example, research in which particular attributes of the technology use are coupled with a well-defined, short time parameter, such as two weeks, could produce more generalizable outcomes. Additionally, administrators and classroom teachers in K-12 public and private schools could benefit from these results, which may guide the use of the most effective classroom practices. The most effective classroom practices for STEM disciplines must include activities that promote problem solving coupled with critical thinking opportunities. Higher education STEM faculty could benefit from this study by understanding that the public and private school education system is producing students with a different skill set. These students are more capable in the areas of critical thinking and problem solving, as indicated by the results of this meta-analysis, than students in the past.

As the individuals directly in contact with the students, it is vital that teachers feel comfortable and informed when presenting a STEM-model to their students. This means that they will need appropriate training and time to develop a well-thought curriculum that will challenge students, while also building in the support they need to be successful. Moving forward, I feel that school districts must invest in relevant professional development in order to accommodate the needs of STEM teachers. Additionally, I would suggest that teachers are involved in the process of identifying areas of need for professional development. As evidenced earlier in this document, teachers' perceptions of the program will play a vital role in its success (Pryor, Pryor & Kang 2016). Perhaps one of the most important factors that teachers and school districts alike will need to be conscious of is the value of patience. It will take time for teachers to adjust to a new set of expectations. In the same regard, it will take students time to adjust to their own new set of expectations as set forth by their teachers. Despite the pressures of high stakes assessment, districts should be patient with the development of a STEM program.

The findings of this study provide insight for teacher education programs and K-12 educators at the pre- and in-service levels, including those in leadership or administrative positions. The following two sections provide implications, including both contributions and recommendations, based on the findings of this study. The first list includes recommendations and contributions for teacher education programs. The second list includes recommendations and contributions for K-12 educators, including teachers, in-service teachers, and those in leadership or administrative positions. Based on that, the study proposed the following policy recommendation model for integration and implementation of STEM in UAE schools as shown in figure 19.

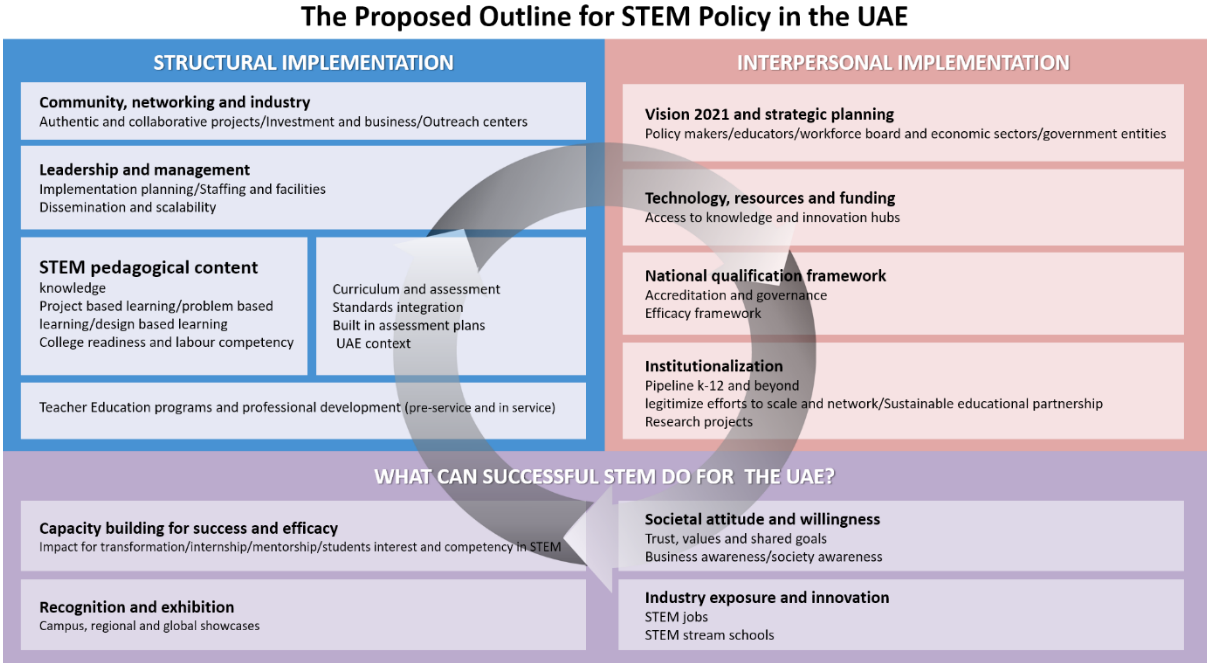

Figure 18: STEM Integration and Implementation Policy Recommendation Framework for UAE Schools

Table 28 further illustrates each component of STEM policies into different categories and the identification of these components and categories from different research instruments of the current study and literature review. In perspective, the components recommended in table 28 fit into both the private and public schools in the UAE in that they suggest the ideology of networked and engaged communities of practice; achieved through early learning programmes, students, and communities engage in Cop to draw knowledge, resources, expertise, and tools to effectively engage STEM learning and teaching. Another way the policy fits to the public and private schools alike is through accessible learning where there is invitation of intentional play (U.S. Department of Education, 2016). Typically, STEM education stresses on benefits of intentional play among the K-12 learners and these play activities are applied through public and private institutions and all levels regarding the education continuum. In so doing, the activities eliminate the barriers for entry and bolster creative ideas and boost engagement of diverse learners in difficult and complex content. Moreover, the educational experiences, which involve interdisciplinary techniques, help in solving grand challenges both in private and public schools in the UAE (U.S. Department of Education, 2016). The concept of STEM education involves learners of all ages when tackling challenges. Thence, the STEM policy framework fits perfectly into both the private and public institutions in the UAE.

These vast recommendations provide imperative ways to enrich further studies. However, if I were to conduct this study again, I could focus more on the STEM integration programs implemented in the UAE rather than delve into the establishment of a policy framework.

5.3.1 Policy Planning

The UAE is the star of the Middle East due to its stable political situation and rapidly growing economy over the past 20 years, which has placed it within the top 20 most competitive economies in the world (Schwab et al. 2013). The UAE is represented by an absolute monarchy led by the tribal leaders of its seven Emirates. Demographically, UAE has relatively similar population sizes, approximately 9.1 respectively (World Bank 2014). UAE is a cosmopolitan country with Emiratis making up only approximately 15 percent of the population (International Consultants for Education and Fairs, ICEF 2013). These developments have been driven by its natural resource wealth in the form of large reserves of oil and gas, located mainly in Abu Dhabi, the capital of the country (Dobbs et. al 2013).

The country leaders in the United Arab Emirates have set a 2021 vision as a strategic plan to lead the country from its reliance on oil to a sustainable environment (UAE Government 2012; UAE Cabinet 2014). The vision includes changes in educational values that were based on traditional methods of teaching through rote learning, memorization, and teacher-centred approaches (Hatherley-Greene 2014).

Leaders are investing in educational technology in the United Arab Emirates (UAE) as part of the country's vision of 2021 in hopes of making their country a knowledge hub (UAE Government 2012). The leaders of UAE have made a budgetary commitment to the higher education of over AED 3.9 billion (approximately over one billion US dollars) in an attempt to improve facilities and support research (Emirates Competitiveness Council 2014). Leaders of countries in the UAE are making considerable investments in educational technology with the largest spending from Saudi Arabia and the United Arab Emirati which was projected at 72.6 million U.S. dollars in 2010 for the United Arab Emirates (Weber 2011). Researchers agree that integration of science and technology in the education for the UAE students would be useful; however, further investigation is still required to understand new education reforms for the Arab learner (Baasanjav 2013; Weber 2011).

The UAE has a booming economy and boasts a GDP per capita approximately at $44,204 per person (World Bank 2013). The data of both public and government expenditure on education unsurprisingly shows that the UAE is spending significantly more on education, although this has so far not materialised in terms of student outcomes. Despite its economic success, the country has overall seen less improvement in its social sectors – education and health – where significant investments have been made to import leading global reforms aimed at developing a thriving knowledge economy (Burden-Leahy 2009).

UAE is engaged in various reforms that emphasise the development of productive citizens who will advance the national economic interests of establishing knowledge economies. These reforms are driven by the belief in the growing mismatch between the labour market needs and the outcomes of the education system (Hanouz & Dusek 2013). The UAE

Ministry of Education has put considerable efforts and investments in bringing improvements in the education system, however, these investments have so far not yielded the anticipated improvements in the public and private education system. Instead, an increasing number of the Emirati population is choosing to enrol their children in private schooling due to its relatively better quality (Knowledge and Human Development Authority, KHDA 2013), however, private schools are also lacking the standards compared to other well-resourced countries. Although students in the UAE are currently the best performers across the region in international assessments, their test scores remain significantly below the international averages in both Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA) and they have seen little change in recent years with students in public and private schools falling behind their peers in private schools (Mullis et. al 2011; Organisation for Economic Co-operation and Development, OECD 2013; KHDA 2013).

A similar discourse surrounds the latest education reform in the UAE, introduced as part of the country's strategy, Vision 2021, which calls for a collective effort to build a knowledge economy by promoting well-rounded citizens and developing a first rate education system (Ministry of Cabinet Affairs, MOCA 2011, p.13, 15). These reforms feed into the global discourse regarding the importance of developing knowledge economy skills and competitiveness among the next generation (Ministry of Education, MOE 2012; MOCA 2011).

According to the policy borrowing and lending literature, aid-dependent countries are considered tied to their donors through programmatic conditionalities (Steiner-Khamsi 2010), however in resource rich countries like the UAE, where education reforms are largely sponsored by the government, they are believed to take on a voluntary process of developing, importing, and implementing education policies like STEM for UAE vision 2021. The independence in the source of funding would arguably promote greater ownership in the reform process in integration and implementation of STEM in UAE schools. However, studies have recently indicated the high dependence of the UAE government on external advisors and private educational organisations in consulting on the import of global education reforms and guiding policymaking (Bahgat 1999; Jones 2013). This calls for an integrated education reforms, involving all the stakeholders including teachers, school leaders, community, businesses, industries, students, parents, researchers, and policy makers, for implementation of global education reforms.

One such integrated framework reforms was introduced by UAE in 2012. In early 2012, the UAE launched the Mohammed bin Rashid Smart Learning Programme (SLP) with a similar, albeit more ambitious, vision. SLP's goal was to provide public and private school students with tablets, teachers with laptops, equip classrooms with interactive smart boards in order to enhance their skills and competencies and as a result improve student learning (Pennington 2014). The program, worth approximately $272,000, is a joint venture between the Ministry of Education, Telecommunications Regulatory Authority (TRA) (a federal authority for Information and Communications Technology), and the Prime Minister's Office (PMO) in partnership with leading technology companies, educational organisations, educational and strategic consultants, and more (ICT Fund 2013). Despite this integrated framework in UAE education system, it has so far not materialised in terms of student outcomes and hence makes the room for integrated STEM framework using well-rounded involvement and engagement of teachers, school leaders, community, businesses, industries, students, parents, researchers, and policy makers in UAE schools. The findings of this research support this notion by calling for integrated STEM education in UAE Vision 2021 in K-12 education.

“Though expectations are high, and challenges are many...I know you have your eyes set on the best: the first place” stated His Highness Sheikh Mohammed Bin Rashid Al Maktoum, Vice President and Prime Minister of the UAE and Ruler of Dubai, during the launch of Dubai’s latest strategic plan (TEC 2015, p.2). It is this vision that has guided the UAE, and Dubai specifically, to where it is today – a country, in which the discovery of oil brought forth decades of growth, wealth, and ambition. Despite becoming the most important business and economic hub in the region in recent decades, the UAE’s development has largely overlooked the social sector, and in particular education. Behind the aura of modernity and Westernization is a citizenry that is underachieving and underproductive and that ultimately remains dependent on its government for jobs, welfare, and security.

5.3.2 Leadership

In recent years it has become evident that the renter system on which the UAE has been built due to its oil wealth has strengthened feelings of entitlement among the country’s small population of nationals (Jones 2013). This has been due to misplaced incentives introduced by the government, such as lucrative employment opportunities in the public and private sector for young Emiratis lacking post-secondary education, assured job security and benefits for all, inflated salaries (as compared to expatriates holding the same qualifications), large subsidies on government-provided services, and more (Jones 2013).

Concerned about the consequences of this situation, the leadership has recognised the urgency of addressing the weaknesses and gaps in the education system so Emiratis can take greater responsibility for their nation’s development and find a more sustainable model for growth. Earlier this year, General Sheikh Mohammad Bin Zayed Al Nahyan, Crowne Prince of Abu Dhabi and Deputy Supreme Commander of the UAE, conceded in his speech at the Government Summit that the country has been late to address the issue of education, “However, knowing that you are late and working on it is what matters.” He then added, In this period, while we have the resources and wealth, we must invest in education. If we do so correctly now, in 50 years, when we ship off the last barrel of petrol, we will not be sad. I promise you, my brothers and sisters, we will be celebrating (Nazzal 2015).

This vision has been articulated in the UAE’s overarching strategy, Vision 2021 that is currently guiding the nation’s transformation to be ‘among the best countries in the world.’ It focuses on six priority areas – society and national identity, judiciary, economy, education, health, and environmental sustainability (PMO 2010). More specifically, the national agenda for education calls for establishing a ‘first rate education system’ by improving student literacy and numeracy skills; raising enrolment rates in higher education; developing creativity; instilling responsibility and ambition among students; and raising the standard of schools including that of teachers and principals. To monitor the level of progress in these areas, the Vision 2021 website published a number of Key Performance Indicators (KPIs) with baseline data and ambitious targets set for 2021. In the context of education, these include improving UAE’s standing in international assessments, raising the quality of teaching, and leadership, among others.

In light of the structural weaknesses facing UAE’s public educational system, numerous challenges lay ahead to achieve these targets without dismantling the current systems in place. As result, the country’s leadership chose to embark on the largest, most expensive and ambitious reform effort to date – the STEM– in the hope that it would comprehensively transform its education system and put it on the map, among the world’s leading countries in education.

5.3.3 Establishing STEM

This research study provides a clear definition and purpose of STEM for K-12 students aligned with ample research literature. Pre-service, in-service, and administrative leaders can use this information to clearly articulate the meaning, goal, and purpose of STEM within their K-12 school's curricula. Doing so will allow for better collaboration and less confusion among the in-service teachers within the schools and better mentoring of teachers. The articulation could be completed within a teacher in-service in preparation for the implementation of STEM in UAE, during which the meaning, goal, and purpose of STEM could be presented by administrators and further developed with input from the teachers as the STEM in UAE are implemented.

On a global level, STEM in UAE has served the strategic goal of presenting the country as modern, competitive, and innovative among the world's educational leaders. Given the size of the government bureaucracy and the lack of capacity within the national cadre to address this challenge, a new entity built on private sector ideals was established to bring about changes that traditional government institutions were unable to introduce. Non-state actors in the form of technology companies, advisors, and other educational institutions were brought on as partners to support the policy process and bring about this transformational change. Notwithstanding the role of private and other external actors, particularly in the implementation phase, and the potential influence they may have behind closed doors, national policymakers continue to preserve their central role in decision-making and to maintain strong ownership of the program. This is critical to strengthening the country's national identity among its small national population. These factors allow it to determine the model and content of the partnership to best suits its needs.

Contrary to partnerships that strive to promote collaboration to establish win-win situations for all parties, this partnership fosters fierce competition among private actors to promote innovation and to increase their accountability. The case of STEM also illustrates that the availability of resources is a significant contributor to the country's decision to attempt such an ambitious and risky initiative while providing some semblance of continuity and stability for the reform to this date. However, only time will tell whether nature of the political system in the country and the dependence on external expertise will aid the country in achieving its goal of making sustainable improvements in the quality of its public and private educational system.

Despite the high need for capacity building on part of UAE public and private sector, there is little evidence of this taking place, whereas STEM incorporated it into its policy model. This can be explained by the different mentality surrounding the role of external actors across the two countries. The priority of UAE actors is not to establish a locally sustainable model, but rather to draw on the best global expertise (regardless of their level of understanding of the local context) to ensure the implementation of the model. However, in Jordan, due to the country's limited resources, greater emphasis rested on gaining the knowledge and skills of external actors in an effort to localise the initiative and ensure its longevity, which it arguably succeeded in doing over the past eight years, albeit with new objectives.

The implementation of the STEM at a national scale has so far been expensive. According to anecdotal evidence, the original strategy of rolling it out across all public and private schools in the country (except for Abu Dhabi, which has its own educational system and has introduced a smaller pilot of the model) from grades K-12 (although only students in grades 6-12 would be given electronic tablets) is likely to be reconsidered. It is possible that the whole program may be reassessed or even shelved if the economic situation does not improve, effectively leaving it more vulnerable to date.

In the case of STEM, although some limited impact on student outcomes has been observed over the years and there was evidence of a change in school culture (Alnoaimi 2011; EDC 2012). Hence, policymakers should continue to question why the Initiative did not succeed in achieving its goal of rolling out the program nationally and whether it unintentionally reinforced inequality across students by supporting the better off schools rather than students from less well-resourced parts of the country.

Also, K-12 education in the UAE is challenged by a scarcity of high-quality research that would improve the quality of higher learning in the region (Issa &Siddiek 2012). For example, educational leaders at the Beirut Institute Summit discussed the challenges of understanding how to engage the UAE student in education and reported that problems of engagement remain the biggest challenge for higher education in the UAE world because of the cultural differences of learners in this region (Pennington 2015). The UAE Ministry of Education is encouraging research studies that are both lacking and new to the Gulf region (Ministry of Higher Education and Scientific Research 2015).

5.3.4 Professional Development of Teachers

Based on the findings of this study, it is recommended that teacher education programs implement a series of recommendations that will allow teachers to develop professionally with regard to STEM integration. The recommendations include providing authentic teaching experiences, linking programmatically to 21st -century learning, providing integrated learning experiences within the teacher education and general education courses, integrate STEM pedagogy within relevant education courses, provide pedagogy within the methods courses that articulates the importance of hands-on learning and inquiry in content areas in and beyond STEM, and provide opportunities for teachers to engage in collaboration.

It is recommended that teacher education programs, specifically the methods courses, provide pedagogy for teachers that highlights the importance of hands-on learning and inquiry in STEM and other content areas. Within the qualitative interviews, all of the teachers noted the importance of hands-on learning and inquiry in designing their STEM Units, and they all noted how exciting and engaging the subsequent learning experiences were for the K-12 students. Hands-on learning and inquiry-based learning, while they are important aspects of STEM learning, are not exclusive to the STEM content areas. Methods instructors should expose teachers to the opportunities that exist in other curricula, such as social studies, or English language arts, to engage in inquiry or hands-on learning. For example, in a social studies class, students may construct and maintain a model of a traditional longhouse village, navigating a local park using a topographical map, or sculpting landforms on a make believe island.

Based on the findings of this study, it is recommended that K-12 educators, specifically the teachers themselves as well as in-service teachers and leaders (administrators, curriculum coordinators, etc.), engage in a series of recommendations that will further the professional development of all parties with regard to STEM integration. The recommendations include developing a clear definition and purpose of STEM in the K-12 curricula, developing a model (or series of models) appropriate for integration at the beginning, intermediate, and advanced levels, providing professional development for integration of STEM and the Next Generation Science Standards (Achieve Inc. 2013) into the K-12 curricula, and providing and engaging in opportunities for educator collaboration, specifically with regard to the integration of 21st - century learning.

Linking practicing STEM professionals with teachers in professional development is critical to helping teachers increase in STEM career awareness and understanding local STEM career pathways. STEM professionals should share real-world problems, solutions, application of their knowledge, and practices of their daily work. These examples from professionals in STEM fields help teachers connect what and how they are teaching STEM content and practices with a relevant context which students may encounter in the future. Practicing STEM professionals should be involved in teacher professional development to provide this context and to form networks with teachers where they might be directly involved in the schools and serve as guest speakers to inform teachers and students of STEM career paths.

5.3.5 Communities' and Businesses' Role

Collaborating and partnering with global technology companies and world-renowned experts was seen by UAE policymakers as a ticket to be a part of the leaders driving STEM reforms in education, rather than being the recipients of reforms. Interestingly, however, what makes this case even more unique is that policy decisions seem to be driven more by perceptions than by real life outcomes, where the evidence to date indicates that the STEM is not as concerned with the quality and impact of the program implementation, but rather with the stakeholder awareness of its efficient adoption and their perceptions and that of other global educational actors of its success.

This study contributes to the policy studies literature, which despite offering a range of different frameworks for studying the policy process, has been largely rooted in policy environments primarily based in Western contexts. These contexts have different governance systems than those in autocratic countries in the Middle East, and therefore do not reflect the unique structures, processes, and balances of power among the various actors.

In the UAE despite strong internal political divisions across emirates, the political structure of the country ensures that these internal fissures do not impact high-level decision-making, which is ultimately made by the ruler of the country. This makes the situation less complex and presents an aura of strong cohesion and balance of power within the top leadership. In addition, the government needs to ensure that the small local population remains satisfied and acquiescent through the provision of financial and other economic incentives. This has made decision-making less challenging. The medium to long-term impacts of that remain to be seen.

Finally, in light of the contexts of the UAE as oil-rich and aid-dependent state, it suffers from limited human resources. Unsurprisingly, this study showed fell short of determining the extent of the influence of these global private companies, donors, and NGOs in local decision-making, and in particular Western consultants and advisors, in decision-making in the UAE, although there is evidence that they are drawn on at every stage of the policy process. These national differences have important and expected influences on ownership and alignment, which are limited in the case of UAE due to the growing human capacity of local actors. Importantly, the lack of investment in capacity building of STEM in the UAE points to a continued dependence on these actors, which can be problematic in cases where policymakers do not have a thorough understanding of the needs of the education system and how to effectively address them.

5.3.6 Technology and Resources

It is recommended that teacher preparation programs make every effort to mirror the resources (i.e. technology, materials, manipulatives) within the public and private schools in which teachers will be placed. This will allow faculty to model the use of the resources in practice. Additionally, it will allow the teachers to become familiar and comfortable with the resources prior to entering the field, where their cooperating teacher may not be comfortable with the resources. The resources may not be available in certain schools, as indicated by some of the teachers from this study, who described lacking resources to teach STEM to K-12 students, specifically. As a result, the teachers noted that practicing teachers were often paying for hands-on learning experiences out of pocket in their own classrooms. Gaining exposure to quality STEM resources, especially technology, allows the teachers to use and apply them within the teacher education courses, whether as part of course projects that are implemented with peers or as borrowed, non-consumable, materials that could be taken into the field for practice. Access to STEM education materials may increase the probability that the teachers will be more aptly prepared to utilise the resources beyond their field experiences.

It is recommended that institutional leaders should train faculty in instructional design of STEM so that faculty will be able to teach STEM courses that meet the context they are teaching. Institutional leaders are also recommended to invest in training faculty in the experiential learning approach strategies so they can plan their lessons based on a clear set of procedures. Leaders are further urged to invest in video technology devices and game-based learning methods because these tools appeared important in motivating students in STEM courses. Leaders could also invest in professional development and collaborative trainings for faculty they could collaborate with other teachers in order not only teach UAE students but also those who are coming from different cultural and educational backgrounds.

Another recommendation regarding the learning structure is for institutional leaders to set policies for STEM course structure to be followed on the institutional level. Institutional leaders are also recommended to set the flex class model as an opportunity for STEM and as a model best suited for meeting effective learning goals. Institutional leaders should offer students the options to choose the course structure they enrol in whether it is offered in a blended learning format or traditional classroom-based instruction in STEM.

Another recommendation is in regards to the finding concerned with the importance of reflective practices of teaching STEM. Institutional leaders could establish venues for faculty to share best practices for teaching STEM and have communities of practice that directly relate to the context they are teaching in different UAE Emirates. Furthermore, leaders may assign faculty to teach subjects that they are informed with to explain to their students. If there is a shortage of faculty to teach certain STEM subjects, the recommendation is to either hire adjunct specialised faculty or to create an affiliation with other institutions where students could take online courses that could fill the gap in their STEM program. The concern for the quality of the education in the STEM learning approach was evidenced in this research.

All of these initiatives require additional funding. Few school initiatives are free, but some are worth the cost. The findings of this study provided a glimpse into how school policy makers may influence their choice to pursue STEM, makes the case that such spending would provide real gains in the nation’s STEM education, STEM literacy, and grow the STEM degree attainment of UAE citizens.

5.3.7 Curriculum Design and Assessments

According to Hall, Wallace, and Dossett (1973), there should be a collaborative link between adopters (faculty) and an effective support system (institution) that can assess and intervene. Put differently, providing the technology, or the innovation, is not enough to ensure proper adoption. Higher education institutions need to treat the implementation of education reforms, such as STEM, as a developmental process, and therefore implement structured training programs to help all faculty, from younger faculty who may embrace STEM to more experienced faculty who may not want to give up the traditional face-to-face lecture and interactions with students. This will be the way in which teachers are moved from the awareness stage to the higher level stages of concern that will be necessary for them to understand the importance of embracing STEM curriculum in their teaching practices. Another recommendation that can be made from the findings of this study is that higher education institutions must intervene in order to help their teachers resolve concerns about actually managing STEM curriculum. There was some concern on the part of the participants about not having enough time to organise themselves, and about managing all of the tasks and responsibilities that STEM requires. It must be assumed that if the teachers feel as though they cannot manage STEM curriculum, they are not going to be concerned about the higher level issues of consequences, collaboration, and refocusing associated with STEM integration and implementation.

Hall (2010) discussed three types of change facilitators: initiators, managers, and responders. While initiators push the innovation, and managers support it, it is the responders who listen to the concerns of the adopters and intervene accordingly. Higher education institutions in the UAE seem to be focused on the issues and concerns in stages 3 and 4 with regards to STEM integration and implementation, while forgetting that teachers need to be helped with the lower level stages because they can focus on the higher stages of concern. In this regard, a one-time educational intervention for higher education teachers may not be enough. Instead, higher education administrators may need to truly demonstrate to faculty why implementing STEM curriculum can provide a competitive advantage. Even more, administrators may need to provide assistance and support for implementing STEM curriculum, such as guidance about how to effective and efficiently uses the STEM subjects given the time constraints and many duties that teachers must undertake.

5.3.8 Pedagogy and Learning

Educators and researchers are improving curricula in K-12 Engineering and Technology Education (ETE) to create a more effective integrated STEM education program and increase the flow of students into STEM careers (Prevost et al. 2009). Yet STEM education often remains limited to science and math, being mostly taught disconnected from one another with little emphasis given to engineering or technology (Hoachlander & Yanofsky 2011). Secondary teachers struggle to locate authentic contexts for teaching integrated STEM, lack pedagogical context and content knowledge, and lack awareness of current STEM workforce practices (NAE 2014).

It is recommended that K-12 teacher education programs provide experiences in which pre-service teacher candidates must apply 21st -century learning skills to answer questions and solve problems. For example, a general education science course should allow ample opportunity for authentic inquiry and problem-solving from a real-world perspective (i.e. for students who are concerned about the dying honeybee population, a possible inquiry may include examining which type of flowers are most conducive to bee pollination and honey production to determine landscaping options for the university). This will allow the teachers to draw from their own schema and connect their prior experiences to the K-12 curricula to teach skills and apply concepts they have had the opportunity to master from a constructivist-based viewpoint, such as by teaching lessons or integrated units such as the STEM Unit outlined within this study.

It is recommended that K-12 teacher preparation programs encourage teachers to take courses that integrate curricula, specifically technology and engineering, as those are the areas in which the teachers in this study felt least prepared, as noted within the qualitative interview findings as well as during analysis of the general education courses that the teachers had taken leading up to the methods course. It is also recommended that general education courses, specifically those in math and science, which have traditionally been compartmentalised, should integrate other areas of STEM wherever applicable. This recommendation is supported by the assertions of the teachers in this study, who articulated that they were confused as to why their K-12 and college experience were compartmentalised despite the fact that they will be required to teach in an integrated way in the field. University general education instructors should explicitly draw students' attention to the connectivity between the content areas, allowing the students a frame of reference and experience from which to draw when planning and implementing STEM-based curricula as teachers in the field. Through professional development opportunities in which content area faculty can learn about the various aspects of curriculum integration and how their content area overlaps meaningfully with others, collegiate level courses should mirror the expectations of the K-12 field in terms of providing students with opportunities to engage in hands-on, inquiry-based learning.

It is recommended that K-12 teacher education programs better include STEM integration pedagogy for K-12 teachers in order to better prepare them to successfully integrate STEM into an already full daily schedule. Certainly math and science methods courses should explicitly discuss strategies for planning and implementing STEM-based lessons, but educational foundations courses such as educational technology should model the integration of technology with the areas of science, engineering, and math as much as possible. This study provides a model for providing STEM-based preparation to K-12 teachers, as detailed in the course syllabus for the science and social studies methods course syllabus. K-12 teachers should also be engaged in opportunities to apply STEM based pedagogy through the design and implementation of authentic STEM experiences for K-12 students, such as the Integrated STEM Unit, which was completed by the teachers are part of the methods course.

5.3.9 Capacity Building and Motivation

The UAE Vision 2021 seeks to improve and develop education in UAE, to accommodate structural changes, and to educate new generations that can help shift the UAE dependency on oil to industry and investment. Integrated STEM education would help in accomplishing that goal. To ensure that any educational innovations succeed, it is needed to prepare the teachers to guide and implement those innovations.

Since UAE teachers are only qualified to teach certain courses, especially Mathematics and English, and not all STEM courses, it is recommended that an integrated STEM education degree, where teachers can take intensive courses to deepen their knowledge of different STEM disciplines beyond mathematics and English. Additionally, this degree should provide pedagogical classes to ensure that teachers can deal with inductive and deductive reasoning, which is important to be able to teach multiple disciplines at the same time. This degree should be provided from special institutions and capable educators who can help the transition from traditional teachers to integrative STEM teachers.

It is recommended that teacher preparation programs decrease pre-service teacher isolation from one another during field experiences by encouraging co-teaching, co-reflection, and increasing faculty involvement and support with teachers, supervisors, and cooperating teachers in the field to provide more fluidity between the methods courses and the field experiences. This recommendation was echoed by the teachers who were interviewed throughout the study, as they all noted that collaboration, and especially co-teaching, with their peers allowed their confidence to develop more so than if they were to complete the project alone. Essentially, the power of socialisation, as noted within the qualitative data, helps the teachers to feel more supported and more confident in their STEM-based planning and instruction. This can be accomplished through establishing a monthly, social meeting schedule at varying locations (i.e. at the university or at one of the partnering field placement schools) for the teachers with university faculty, supervisors, and cooperating teachers as they are able to attend. A formal gathering will provide a designated time amidst a very full schedule for the teachers to convene and receive support, both from their peers and from faculty.

Also, getting students interested in STEM fields as early as possible is of primary importance to school officials interested in increasing STEM interest. It is clear from the findings and the literature that students make up their minds as young adults to like STEM and to pursue it or to look elsewhere for a favourite subject. The findings are suggestive that professional development for teachers designed to influence their STEM education methods are needed. Keeping STEM curricula hands-on and centred on real-world application is as important at this level as well, perhaps more so.

5.3.10 Awareness and Promotions

The Ministry of Education, Education Administration, and educators need to start an awareness campaign to educate people, businesses, community, and politicians about STEM literacy and its importance for the country’s future. The campaign should also target parents, students, teachers, and administrators. Additionally, the Ministry of Education and Education Administration, as decision makers, need to facilitate the implementation of integrated STEM education and meet educators’ needs, including fully quipped labs and supplies, technology support and specialists, and higher salaries to encourage teachers to go through the training process. Professional development programs need to provide continuous and long-term support to help teachers make the right decisions regarding their teaching experience and dealing with students.

5.3.11 Society's Adaptation

Societal and businesses attitudes and willingness play major role in implementation of integrated STEM in UAE public and private schools. The society and businesses need to accept and adapt the STEM literacy. Many researchers in the STEM field connect 21st-century learning themes into the realm of STEM literacy. STEM literacy is defined as learning that goes beyond basic STEM content knowledge and extends into the application of learning associated with local and global issues, ultimately advances the goals of STEM education (Bybee 2013). These goals include becoming aware of societal issues pertaining to STEM, being willing to engage in these issues as a reflective citizen, and advancing the knowledge, skills, and attitudes needed to develop solutions for the issues for the greater good of society (Rising Above the Gathering Storm Committee 2010). What remains to be seen, however, is a coherent scope and sequence for the purposes of STEM and models for its implementation for teachers to follow. In other words, *how* STEM is to be implemented within K-12 curricula, specifically at the K-12 level, must be addressed prior to preparing pre-service and in-service teachers alike to integrate STEM content into their K-12 classroom.

5.3.12 Exposure and Employment

Legislators and experts in education policy should continue to encourage students to pursue a STEM career, they should also consider both the economic and psycho-sociological factors that these future STEM employees-that is, if they do make it through the first stage of the pipeline-will eventually face as they enter the STEM workforce and pursue their careers. If industry and the federal government are serious about increasing the number of scientists and engineers in the UAE, then every effort should be made to recruit as many men and women possible into the STEM professions. That means their campaign to do so starts aggressively at the educational level and should not end once the student has his or her degree.

5.4 Limitations of the Study

A range of procedures were applied in order to conduct a proper study however several limitations may exist or appear while running the study which were out of control from the researcher. For example, findings were based on a particular context within the public and private schools in five emirates of UAE (Abu Dhabi, Ajman, Al Ain, Dubai, Ras Al Khaimah, and Sharjah) which resulted in context-specific data hence limiting the generalising the data of this context. Therefore, a similar study may yield different findings if run in a different context.

Given the saturation strategy applied by the researcher, the number of responses by participants in both primary data collection instructions for both qualitative and quantitative phases depended on the participants who were available during the time of the study. This may influence the findings to certain behaviours of the individuals which can skew the data in certain direction. This strategy however applied in order to ensure the maximum response rate.

The study also measured different stakeholders' perceptions at a certain stage of the study. This might give incomplete picture about perceptions and commitment to best practices being practiced at that particular period of time, at particular contexts, and context and hence additional examples will have required time and again in future to test those perceptions and practices over time and with different populations.

Lastly, the fact that STEM has no clear policy of implementation nor monitoring for accountability by the mangers of UAE public and private schools to make a compelling case for raising competence and confidence to develop, through a consultative process with key stakeholders, strategies, policies and guidance documents, and to support improvements in teaching and learning within the area of STEM. This can result in different perceptions and practices across the public and private schools and may need to widen the scope of research to enable the researcher to tell a story from a representative number of instructional leaders.

Moreover, STEM specialist is not an existing position in the private and public schools in UAE and hence there is a potential of having a variety of scenarios of practices within the public and private educational system of UAE. This might also have affected the findings of best practices by the researcher when observing classroom instructions and reporting the full picture to inform designing the STEM framework.

5.5 Implications for Future Research

The implications for future research are numerous. One area of consideration is to explore the interconnectedness of the findings identified in the surveys. Is one category more important than another is? Are all the global theme necessary, or can one or more be left out to determine the distilled minimum amount of key components/implementation factors for integrated STEM in UAE? Are some of the connections between the global theme more important than others? This has implications for implementation, because if some connections are more important, leaders and practitioners in UAE schools need to be aware of it, and concentrate effort on building that connection versus another.

Another area for further research is to explore the value each category specifically contributes to integrated STEM, and to further identify the specific characteristics of the category. This would involve an in depth look at a single category using quantitative and qualitative methods to see how a particular category relates to integrated STEM, as well as specifically what that category represents. For instance, is one particular area of leadership important or is one aspect of outside support more important than another is?

A third area to consider for future research is to analyse existing STEM implementations in the context of the identified global theme, to see if the study's global theme are present. This research study can serve as a gauge for the quality of a STEM education curriculum and suggest ways to improve STEM education by incorporating global theme that were identified as important, but which might not be present.

5.6 Conclusions

The UAE government has concerted efforts to reshape its economy from being market-based to becoming innovation-based. In doing so, it has deliberately invested its national revenues to diversify and strengthen its oil-based economy. Following the lead of other innovation-based economies (e.g. Singapore, Finland, etc.), the UAE has decided to concentrate its reform energies into overhauling the school system's teaching STEM subjects in K-12 education. Unfortunately, the recent trend of UAE students graduating with STEM-related degrees has been on a downfall and this will ultimately negatively affect the aspirations of the UAE attaining an innovation-based economy, thus deliberate speed must be taken to provide all the facilities and expertise needed to increase successful and competent completion of STEM programs by national students. Although STEM subjects in K-12 education may be taught with utmost vigour and high aspirations, this does not guarantee that students will major in STEM fields and become innovation and productive members in related professions. This calls for the need of integrated STEM framework in K-12 education in UAE that should be placed well-rounded by brining every stakeholder of STEM i.e. teachers, school leaders, students, parents, community, society, businesses, district authorities, administrators, researchers, policymakers, politicians and the like.

The purpose of this study was therefore to develop a policy and implementation framework in the UAE by identifying critical elements of an integrated STEM education and by identify key factors related to the implementation of an integrated STEM curriculum in K-12 schools in UAE. In lieu of the purpose of this research, the findings of this study proposed the policy recommendation framework for integrated STEM implementation in UAE schools.

From the findings of document analysis, teacher questionnaire survey, teacher and coordinators' interview surveys, school and district leaders' interview survey, and classroom observations, it can be concluded that implementation can be categorized into structural and interpersonal implementation dimensions. In addition, Assessment, Connection, Curriculum and Delivery, Leadership, Pedagogical Content Knowledge, and Technology and Resources are important factors associated with STEM integration and implementation in UAE schools. The findings also suggested that curriculum, pedagogy, leadership, professional development, and assessment are important elements associated with STEM integration and implementation in UAE schools. These findings proposed the policy recommendation framework for integrated STEM implementation in K-12 education in UAE. The components of this policy recommendation is policy planning, leadership, establishing STEM, professional development of teachers, communities and businesses' role, technology and resources, curriculum design and assessments, pedagogy and learning, capacity building and motivation, awareness and promotion, society's adaptations, and exposure and employment.

In concluding thoughts, for effective implementation of STEM in K-12 education in UAE, it is important to inform educational administrators at both state and federal levels, as well as local school administrators, to advise future decisions on policy and standards concerning integrated STEM courses. School district administration should encourage and support STEM programs at the K-12 level because it can potentially increase the number of STEM courses that can be offered at the high school level. Business and industry leaders, as well as universities, should become more invested in assisting K-12 schools with resources and teacher training. School districts should provide extensive, compensated professional development for current in-service K-12 school STEM teachers on best practices in planning and implementing integrated STEM courses in the K-12 grades, and provide continued support and training in subsequent years. Teacher education programs should provide specific training at the university level to train pre-service teachers in planning and implementing quality integrated STEM courses. School administrators should have training in what STEM education is and what quality integrated STEM courses should look like at the K-12 level. School districts should provide apprenticeship opportunities for STEM teachers to work with scientists or engineers. More authentic ways to assess students in these courses need to be developed. This includes assessing the process and skills involved in integrated STEM courses. K-12 school administrators should allow for more freedom of teachers to control how they perceive the best ways to implement curriculum in teaching integrated STEM courses. K-12 school teachers should be provided with more time during the school day to collaborate in developing integrated STEM courses.

REFERENCES

Abend, G. (2008) The Meaning of Theory. Sociological Theory 26; 173–199.

Achieve, I. (2013). Next generation science standards. The Next Generation Science Standards.

Adelman, C. (2000). Over two years, what did froebel say to pestalozzi? History of Education, vol. 29(2), pp. 103-114.

Ahmed, H. O. K. (2016). Strategic Future Directions for Developing STEM Education in Higher Education in Egypt as a Driver of Innovation Economy. Journal of Education and Practice, vol. 7(8), pp. 127-145.

Aldosari, H. M. (2015). The reality of Saudi Arabian experience in STEM education in light of the international experiences. The First Excellence Conference in Science and Mathematics Education: STEM, vol. 1, pp. 599-640.

Aleman, M. P. (1992). Redefining “teacher.” Educational Leadership, 50(3), 97.

Alexander, C., Knezek, G., Christensen, R., Tyler-Wood, T. & Bull, G. (2014). The impact of project-based learning on pre-service teachers’ technology attitudes and skills. Journal of Computers in Mathematics and Science Teaching, vol. 33(3), pp. 257-282.

Allaire, F. S. (2017). Navigating Uncharted Waters: First-Generation Native Hawaiian College Students in STEM. Journal of College Student Retention: Research, Theory & Practice, vol. 0(0), pp. 1-21.

Al-Muhaisin, I. A. & Khaja, B. B. (2015). Professional development for sciences teachers in light of integration of science, technology, engineering and mathematics. The First

Excellence Conference in Science and Mathematics Education: STEM, vol. 1, pp.13-37.

Alnoaimi, T. (2011). Case Study: Jordan. In UNESCO (Ed.) Transforming Education: The Power of ICT Policies (pp. 93-122). Paris: UNESCO.

Alterio, M. & McDrury, J. (2003). Learning through storytelling in higher education: Using reflection and experience to improve learning. Routledge.

Althauser, K. (2015). Job-embedded professional development: Its impact on teacher self-efficacy and student performance. Teacher Development, vol. 19(2), pp. 210-225.

Alyammahi, S., Zaki, R., Barada, H. & Al-Hammadi, Y. (2016, April). Overcoming the challenges in K-12 STEM education. In Global Engineering Education Conference (EDUCON), 2016 IEEE (pp. 951-960). IEEE.

American Association for the Advancement of Science (AAAS) (2012). AAAS Annual Report 2012. Retrieved from https://www.aaas.org/page/aaas-annual-report-2012

Anderson, J. C. & Gerbing, D. W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. Psychological Bulletin, vol. 103(3), p. 411.

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry. Journal of Science Teacher Education, vol. 13(1), pp. 1-12.

Anderson, R., Cissna, K. N. & Arnett, R. C. (1994). The reach of dialogue: Confirmation, voice, and community. Cresskill, NJ: Hampton Press.

Anderson, R.D. (2007). Inquiry as an organising theme for science curricula. In S. K. Abell & N. G. Lederman (Eds.), Handbook of research on science education (pp. 807-830). Mahwah, NJ: Taylor & Francis.

Andres, L. (2012). Designing and doing survey research. London: Sage Publications Ltd.

Arabian Business Consultants for Development (2017). The Jordan STEM Education Landscape. A Report for the British Council. Retrieved from https://www.britishcouncil.jo/sites/default/files/STEM_4.0.pdf

Aronson, J. (1994). A pragmatic view of thematic analysis. The Qualitative Report, 2 (1), Retrieved from http://www.nova.edu/ssss/QR/BackIssues?QR2-1/aronson.html.

Asunda, P.A. & Mativo, J. (2015). Integrated STEM: A new primer for teaching technology education. Technology & Engineering Teacher, vol. 75(4), pp. 8-13.

Atkinson, R. D. & Mayo, M. J. (2010). Refueling the US innovation economy: Fresh approaches to science, technology, engineering and mathematics (STEM) education.

Augustine, N. R., Barrett, C., Cassell, G., Grasmick, N., Holliday, C., Jr, Jackson, S. A., . . . Mote, C. D., Jr. (2010). Rising above the gathering storm, revisited: Rapidly approaching category 5. Retrieved from National Academies Press website: http://www.nap.edu/catalog.php?record_id=12999

Avery, Z. (2013). Developing effective STEM professional development programs. Journal of Technology Education, vol. 25(1), pp. 55-69.

Baasanjav, U. (2013). Incorporating the experiential learning cycle into online classes. Journal of Online Learning & Teaching, vol. 9(4), pp. 575-589.

Bahgat, G. (1999). Education in the Gulf monarchies: Retrospect and prospect. International Review of Education, vol. 45(2), pp. 127-136.

Bahrum, S., Wahid, N. & Ibrahim, N. (2017). Integration of STEM Education in Malaysia and Why to STEAM. International Journal of Academic Research in Business and Social Sciences, vol. 7(6), pp. 645-654.

Ball, S. J. (2016). Subjectivity as a site of struggle: refusing neoliberalism?. British Journal of Sociology of Education, vol. 37(8), pp. 1129-1146.

Bamberger, Y. & Cahill, C. (2013). Teaching design in middle-school: Instructor’s concerns and scaffolding strategies. Journal of Science Education and Technology, vol. 22(2), pp. 171-185.

Bandura, A. (1997). Self-efficacy: the exercise of control. New York: W.H. Freeman and Company.

Bansal, P., Bertels, S., Ewart, T., MacConnachie, P. & O’Brien, J. (2012). Bridging the research-practice gap. Academy of Management Perspectives, vol. 26(1), pp. 73-92.

Baran, E., Canbazoglu Bilici, S., Mesutoglu, C. & Ocak, C. (2016). Moving STEM beyond schools: Students’ perceptions about an out-of-school STEM education program. International Journal of Education in Mathematics, Science and Technology, vol. 4(1), pp. 9-19.

Barron, B. & Darling-Hammond, L. (2008). Teaching for Meaningful Learning: A Review of Research on Inquiry-Based and Cooperative Learning. Book Excerpt. George Lucas Educational Foundation.

Beane, J. A. (1997). Curriculum integration: Designing the core of democratic education. New York, NY: Teachers College Press.

Bear, L. K., Dickens, T. A., Krebs, J. R., Liu, J. & Traynin, P. (2005). Integrated velocity model estimation for improved positioning with anisotropic PSDM. The Leading Edge, vol. 24(6), pp. 622-634.

Beasley, E. M. & Fischer, M. J. (2012). Why they leave: the impact of stereotype threat on the attrition of women and minorities from science, math and engineering majors. Social Psychology of Education, vol. 15(4), pp. 427-448.

Beede, B., Julian, T., Langdon, D., McKittrick, G., Khan, B. & Doms, M. (2011). Women In STEM: A Gender gap to innovation. U.S Department of Commerce, Economics and Statistics Administration. Retrieved from www.gse.harvard.edu/%7Euk/otpd/final

Belland, B. R., Walker, A. E. & Kim, N. J. (2017). A Bayesian Network Meta-Analysis to Synthesise the Influence of Contexts of Scaffolding Use on Cognitive Outcomes in STEM Education. Review of Educational Research, vol. 87(6), pp. 1042-1081.

Bennett, A., Kepes, S. & McDaniel, M. (2014). Evidence-based management and the trustworthiness of our cumulative scientific knowledge: Implications for teaching, research and practice. Academy of Management Learning & Education, vol. 13(3), pp. 446-466.

Bennett, C. A. & Ruchti, W. (2014). Bridging STEM with mathematical practices. Journal of STEM Teacher Education, vol. 49(1), pp. 17-28.

Berkeihiser, M. & Ray, D. (2013). Bringing STEM to life. Technology & Engineering Teacher, vol. 72(5), pp. 21-24.

Berlin, D. F. & White, A. L. (2012). A longitudinal look at attitudes and perceptions related to the integration of mathematics, science, and technology education. School Science & Mathematics, vol. 112(1), pp. 20-30.

Bernard, H.R. (1988). Research methods in cultural anthropology. Sage Publications.

Birkland, T. (2010). An introduction to the policy process: Theories, concepts, and models of public policy making. Armonk, NY: M. E. Sharpe.

Blank, R. K. & de las Alas, N (2009). Effects of teacher professional development on gains in student achievement. Washington, DC: Council of Chief State School Officers.

Bodrova, E. & Leong, D. J. (2005). High Quality Preschool Programs: What Would Vygotsky Say? Early Education & Development, vol. 16(4), pp. 435-444.

Bodrova, E., Germeroth, C. & Leong, D. J. (2012). Play and Self-Regulation: Lessons from Vygotsky. American Journal of Play, vol. 6(1), pp. 111-123.

Bogdan, R. & Biklen, S. (2007). Qualitative research for education: An introduction to theory and practice.

Boix-Mansilla, V. (2000). Historical understanding: Beyond the past and into the present. Knowing, teaching, and learning history: National and international perspectives, pp. 390-418.

Boix-Mansilla, V. (2010). MYP guide to interdisciplinary teaching and learning. vol. 19 (1), pp. 163-174. Retrieved from http://balimy.files.wordpress.com/2010/05/mypguide-to-interdisciplinary psychology

Bok, D. (2009). Universities in the marketplace: The commercialization of higher education. Princeton University Press.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. Educational Researcher, vol. 33(8), pp. 315.

Borowczak, M. M. (2015). Communication in STEM education: A non-intrusive method for assessment & K20 educator feedback. Problems Of Education In The 21St Century, vol. 65, pp. 18-27.

Bosworth, D., Lyonette, C., Wilson, R., Bayliss, M. & Fathers, S. (2013). The supply of and demand for high-level STEM skills (No. 77). UKCES: UK Commission for Employment and Skills

Bottge, B. A., Rueda, E., Kwon, J. M., Grant, T. & LaRoque, P. (2009). Assessing and tracking students' problem solving performances in anchored learning environments. Educational Technology Research and Development, vol. 57(4), pp. 529-552.

Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, vol. 3(2), pp. 77-101.

Breiner, J. M., Harkness, S. S., Johnson, C. C. & Koehler, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. School Science and Mathematics, vol. 112(2), pp. 3-11.

Brewer, D. & Goldhaber, D. (2000). Does teacher certification matter? High school teacher certification status and student achievement. Educational Evaluation and Policy Analysis, vol. 22, pp. 129-145.

Briner, R. & Walshee, N. (2014). From passively received wisdom to actively constructed knowledge: Teaching systematic review skills as a foundation of evidence-based management. Academy of Management Learning & Education, vol. 13(3), pp. 415-432.

Briner, R., Denyer, D. & Rousseau, M. (2009). Evidence-based management: Concept cleanup time. Academy of Management Journal, vol. 23(4), pp. 19-32.

Brophy, S., Klein, S., Portsmore, M. & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. Journal of Engineering Education, vol. 97(3), pp. 369-387.

Brosterman, N. (1997). Child's play. Art in America, vol. 85(4), pp. 108-111.

Brown, J. (2012). The current status of STEM education research. Journal of STEM Education: Innovations & Research, vol. 13(5), pp. 7-11.

Brown, J. D. (2011). Quantitative research in second language studies. In E. Hinkel (Ed.), Handbook of Research in Second Language Teaching and Learning (vol. II) (pp. 190-206), NY: Routledge.

Brown, R., Brown, J., Reardon, K. & Merrill, C. (2011). Understanding STEM: Current perceptions. Technology & Engineering Teacher, vol. 70(6), pp. 5-9.

Burden-Leahy, S. M. (2009). Globalisation and education in the postcolonial world: the conundrum of the higher education system of the United Arab Emirates. Comparative Education, vol. 45(4), pp. 525-544.

Butz, W. P. & Science and Technology Policy Institute (Rand Corporation). (2004). Will the scientific and technology workforce meet the requirements of the federal government?. Santa Monica, CA: RAND.

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. Technology & Engineering Teacher, vol. 70(1), pp. 30-35.

Bybee, R. W. (2013). The case for STEM education: Challenges and opportunities. Arlington, VA: National Science Teachers Association.

Byrne, B. M. (2013). Structural equation modelling with AMOS: Basic concepts, applications, and programming. London, UK: Routledge.

Camacho, M., Layton, R. A., Lord, S. M., Long, R. A., Ohland, M. W. & Wasburn, M. H. (2009). Who's persisting in engineering? A comparative analysis of female and male Asian, black, Hispanic, Native American, and white students. Journal of Women and Minorities in Science and Engineering, 15(2).

Cantrell, P., Pekcan, G., Itani, A. & Velasquez-Bryant, N. (2006). The effects of engineering modules on student learning in middle school science classrooms. Journal of Engineering Education, vol. 95(4), pp. 301-309.

Capobianco, B. & Rupp, M. (2014). STEM teachers' planned and enacted attempts at implementing engineering design-based instruction. School Science and Mathematics, vol. 114(6), pp. 258-270.

Capps, D.K. & Crawford, B.A. (2009). Is science inquiry professional development effective? A critical review of empirical research. Retrieved from http://wwwfocilfinders.org/upload/about/NARST

Capraro, R., Capraro M., and Morgan J. (2013). STEM Project-based Learning. An Integrated Science, Technology, Engineering, and Mathematics (STEM) Approach. 2rd ED.

Carmichael, C. C. (2017). A State-by-State Policy Analysis of STEM Education for K-12 Public Schools (Doctoral dissertation, Seton Hall University).

Carnes, M., Devine, P. G., Isaac, C., Manwell, L. B., Ford, C. E., Byars-Winston, A. & Sheridan, J. (2012). Promoting institutional change through bias literacy. Journal of Diversity in Higher Education, vol. 5(2), pp. 63-77.

Carnevale, A. P., Smith, N. & Strohl, J. (2010). Help wanted: Projections of jobs and education requirements through 2018. Retrieved from Georgetown University Centre on Education and the Workforce website: http://www9.georgetown.edu/grad/gppi/hpi/cew/pdfs/FullReport.pdf

Cavanagh, S. (2008). States heeding calls to strengthen STEM. Education Week, vol. 27(30), pp. 10-16.

Cavanaugh, J. M., Giapponi, C. C. & Golden, T. D. (2016). Digital technology and student cognitive development: The neuroscience of the university classroom. Journal of Management Education, vol. 40(4), pp. 374-397.

Chalmers, C., Carter, M. L., Cooper, T. & Nason, R. (2017). Implementing “big ideas” to advance the teaching and learning of science, technology, engineering, and mathematics (STEM). International Journal of Science and Mathematics Education, vol. 15(1), pp. 25-43.

Charette, R. N. (2013). The STEM crisis is a myth. IEEE Spectrum, vol. 50(9), pp. 44-59.

Charleston, L. J., George, P. L., Jackson, J. L., Berhanu, J. & Amechi, M. H. (2014). Navigating underrepresented STEM spaces: Experiences of Black women in U.S.

computing science higher education programs who actualise success. Journal of Diversity in Higher Education, vol. 7(3), pp. 166-176.

Chernus, K. & Fowler, D. (2010). Integrating curriculum: Lessons for adult education from career and technical education. Washington, D.C.: National Institute for Literacy.

Chew, E., Jones, N. & Turner, D. (2008). Critical review of the blended learning models based on Maslow’s and Vygotsky’s educational theory. Hybrid learning and education, 40-53.

Chittum, J. R., Jones, B. D., Akalin, S. & Schram, Á. B. (2017). The effects of an afterschool STEM program on students’ motivation and engagement. International Journal of STEM Education, vol. 4(1), p. 1-16.

Chiu, J., Malcolm P., Hecht, D., DeJaegher, C., Pan, E., Bradley, M., Burghardt, M. (2013). WISEngineering: Supporting precollege engineering design and mathematical understanding. Computers & Education, vol. 67, pp. 142-155.

Christians, C. G. (2011). Ethics and politics in qualitative research. The SAGE Handbook of Qualitative Research (4th ed.). (pp. 61-80).

Chute, E. (2009). STEM education is branching out: Focus shifts from making science, math accessible to more than just brightest. Pittsburg Post-Gazette. Retrieved from http://www.post-gazette.com/pg/09041/947944-298.htm

CIA (2014). United Arab Emirates. World Fact Book. http://www.cia.gov/library/publications/the-world-factbook/geos/ae.html

Clark, V. L. P. & Creswell, J. W. (2014). Understanding research: A consumer's guide. Pearson Higher Ed.

Cohen, D. (2007). The very separate worlds of academic and practitioner publications in human resource management Reasons for the divide and concrete solutions for bridging the gap. Academy of Management Journal, vol. 50(5), pp. 1013-1019.

Cohen, R. & Swerdlik, M. (2010). Psychological testing and assessment. Boston: McGraw-Hill Higher Education.

Colebatch, H. K. (2009). Policy, (3rd Ed.). New York: Open University Press.

Coleman, D. (2008). Long before Legos, wood was nice and did suffice. The New York Times, 11.

Common Core Curriculum standards (CCSS) (2012). Common Core State Standards Systems Implementation Plan for California. Retrieved from https://www.cde.ca.gov/re/cc/documents/ccsssimplementationplan.pdf

Comparini, L., Douglas, E. M. & Perez, S. N. (2014). The Development of Social Cognition: Preschoolers' Use of Mental State Talk in Peer Conflicts. Early Education and Development, vol. 25(7), pp. 1083-1101.

Cooper, J., Mitchell, D., Jr., Eckerle, K. & Martin, K. (2016). Addressing perceived skill deficiencies in student affairs graduate preparation programs. Journal of Student Affairs Research and Practice, vol. 53(2), pp. 107-117.

Crayton, J. E. (2010). STEM art education movement: A creative approach to education in innovation for the 21st Century. Retrieved from http://janedapain.net/files/STEM_Art_Education_Movement_crayton.pdf

Creswell, J. (2009). Research design: Qualitative, quantitative, and mixed methods approaches. (3rded.). Thousand Oaks, CA: SAGE Publications, Inc.

Creswell, J. W, Clark, V. L., Guttmann, M. L. & Hanson, E. E. (2003). Advanced mixed methods research design. In A. Tashakkori and C. Teddlie (Eds.), Handbook of mixed methods in social and behavioural research (pp. 209-240). Thousand Oaks, CA: Sage.

Creswell, J. W. (2013). Research design: Qualitative, quantitative, and mixed methods approaches. Sage publications.

Creswell, J. W. (2015). Educational research : Planning, conducting, and evaluating quantitative and qualitative research. 5th edition.

Creswell, J. W. & Clark, V. L. (2011). Designing and conducting mixed methods research (2nded.). Thousand Oaks, CA: Sage.

Creswell, J. W. & Clark, V. L. P. (2007). Designing and conducting mixed methods research.

Croft, S. J., Roberts, M. A. & Stenhouse, V. L. (2016). The perfect storm of education reform: High-stakes testing and teacher evaluation. Social Justice, vol. 42(1), p. 70.

Custer, R.L., Daugherty, J.L. & Meyer, J.P. (2009). “Formulating a conceptual base for secondary level engineering: A review and synthesis,” Research in Engineering and Technology Education.”

Daempfle, P. (2003). An analysis of the high attrition rates among first year college science, math, and engineering majors. Journal of College Student Retention: Research, Theory & Practice, vol. 5(1), pp. 37-52

Dale, R. (1999). Specifying globalization effects on national policy: A focus on the mechanisms. Journal of Education Policy, vol. 14(1), pp. 1-17.

Danielson, C. (2014). Teacher leadership that strengthens professional practice. Alexandria, VA: Association for Supervision and Curriculum Development.

Darling-Hammond, L. & Youngs, P. (2002). Defining 'Highly Qualified Teachers': What Does 'Scientifically-Based Research' Actually Tell Us?. Educational Researcher, vol. 9. p. 13.

Darling-Hammond, L., Wei, R. C., Andree, A., Richardson, N. & Orphanos, S. (2009). Professional learning in the learning profession. Washington, DC: National Staff Development Council.

Daugherty, J. & Custer, R. (2014). High school teacher professional development in engineering: research and practice. In S. Purzer, J. Strobel & M. Cardella (Eds.), Engineering in pre-college settings (pp. 35-59). West Lafayette, IN: Purdue University Press.

Daugherty, M. K. (2013). The prospect of an "A" in STEM education. Journal of STEM Education: Innovations & Research, vol. 14(2), pp. 10-15.

Davies, M., McNulty, C. P. & Maddox, M. A. (2011). Turn the kaleidoscope: fifteen strategies to shift perspectives when learning. Childhood Education, vol. 87(3), pp. 154-160.

Davis, D. & Mason, L. L. (2017). A behavioural phenomenological inquiry of maker identity. Behaviour Analysis: Research and Practice, vol.17(2), pp. 174-196.

de la Paz, K. & Cluff, K. (Eds.). (2009). The overlooked STEM imperatives: Technology and engineering K-12 education.

Dejarnette, N. K. (2012). America’s children: Providing early exposure to STEM (science technology, technology, engineering and math) initiatives. Education, vol. 133(1), pp. 77-84.

DeLeon, P. (1998). The evidentiary base for policy analysis: Empiricist versus postpositivist positions. Policy Studies Journal, vol. 26(1), pp. 109-113.

Deloitte Consulting LLP. (2005). Skills gap report: A survey of the American manufacturing workforce. National Association of Manufacturers: Washington, DC.

Denson, C., Kelley, T., Wicklein, R. (2009). Integrating engineering design into technology education: Georgia’s perspective. Journal of Industrial Teacher Education, vol. 46(1), pp. 81-102.

DePaul Science Working Group. (2013). Implementing The Next Generation Science Standards: Hallmarks of a Fully Realised School System. Chicago STEM Education Consortium, Chicago, IL.

Dewey, J. (1938). Experience and Education. Macmillan, New York.

Diamandis, P. (2010). The best way to predict the future [Video file]. Retrieved from http://www.youtube.com/watch?v=1KxckI8Ttpw

DiMaggio, P. J. & Powell, W. W. (Eds.). (1991). The new institutionalism in organisational analysis (Vol. 17). Chicago, IL: University of Chicago Press.

Dobbs, P., Oppenheim, J., Kendall, A., Bratt, M. & van der Marel, F. (2013). Reverse the Curse: Maximizing the potential of resource-driven economies. McKinsey Global Institute.

Dollaghan, C. A. (2004). Evidence-based practice in communication disorders: What do we know, and when do we know it?. Journal of communication disorders, vol. 37(5), pp. 391-400.

Donna, J. (2012). A model for professional development to promote engineering design as an integrative pedagogy within STEM education. Journal of Pre-College Engineering Education Research (J-PEER), vol. 2(2), pp. 1-8.

Drake, S. M. (2012). Creating standards-based integrated curriculum: The Common Core State Standards edition. (3rd ed.). Thousand Oaks, CA: Corwin Press.

Drake, S. M. & Burns, R. C. (2004). Meeting standards through integrated curriculum. Alexandria, VA: Association for Supervision and Curriculum Development.

Duff, M. L. (2012). 10 steps to creating a cutting-edge STEM school library. Young Adult Library Services, vol. 10(2), pp. 24-28.

Dugger, W. & Fellow, J. (2011). Evolution of STEM in the United States. International Technology and Engineering Educators Association and Emeritus Professor of Technology Education Virginia Tech.

Dugger, W.E. (2010). Evolution of STEM in the United States. Paper presented at the 6th Biennial International Conference on Technology, Surfers Paradise, Gold Coast, Queensland, Australia.

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D. & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. Journal of Engineering Education, vol. 94(1), pp. 103-120.

Easley, N., Bianco, M. & Leech, N. (2012). A Qualitative Study Examining Mexican Heritage Students' Motivation to Succeed in Higher Education. Journal of Hispanic Higher Education, vol. 11(2), pp. 164-178.

Easton, D. (1953). The political system: An inquiry into the state of political science. New York: Alfred A. Knopf.

Education Development Center Inc. (EDC) (2012). Technology Teaching and Learning Research, Experience, and Global Lessons Learned. Developing Rehabilitation Assistance to Schools and Teacher Improvement (D-RASATI) Project. Beirut: EDC.

Edwards, S. (2007). Theoretical transitions and professional learning. NZ Research in Early Childhood Education Journal, vol. 10, pp. 131-144.

Eger, J. (2013). STEAM... Now! The STEAM Journal, vol. 1(1), p. 8.

Ejiwale, J. A. (2012). Facilitating teaching and learning across STEM fields. Journal of STEM Education: Innovations & Research, vol. 13(3), pp. 87-94.

Elias, N. (2006). The difference between multidisciplinary, transdisciplinary, and cross disciplinary approaches? Clin Invest Med. 2006 Dec; 29 (6):351-64.

Gaad, E. (2011). Inclusive education in the Middle East. New York: Routledge.

Emirates Competitiveness Council. (2014). Policy in action. The heart of competitiveness: Higher education creating the UAE's future. Retrieved from http://www.ecc.ae/docs/default-source/Document-Library/ecc-2014-english_final_for-website.pdf?sfvrsn=0

English, L. D. (2016). STEM education K-12: Perspectives on integration. International Journal of STEM Education, vol. 3(3), pp. 1-8.

Erez, A. & Grant, A. M. (2014). Separating data from intuition: bringing evidence into the management classroom. Academy of Management Learning & Education, vol. 13(1), pp. 104-119.

Ernst, J. V. & Glennie, E. (2015). Redesigned high schools for transformed STEM learning: Performance assessment pilot outcome. Journal of STEM Education: Innovations and Research, vol. 16(4), pp. 27-35.

Faber, M., Unfried, A., Wiebe, E. N., Corn, J., Townsend, L. W. & Collins, T. L. (2013). Student attitudes toward STEM: The development of upper K-12 school and middle/high school student surveys. In the Proceedings of the 120th American Society of Engineering Education Conference.

Fajemidagba, M. O., Salman, M. F. & Olawoye, F. A. (2010). Laboratory-based teaching of mathematics in a Nigerian university. Edited Conference Preceding. Retrieved from http://www.academia.edu/2254525/Reading_Instruction_by_OLAJIDE_Stephen_Billy_Ph._D._.._208

Falk, J. & Dierking, L. (2010). The 95 percent solution: School is not where most Americans learn most of their science. American Scientist, vol. 98(6), pp. 486-493.

Feilzer, M. (2010). Doing mixed methods research pragmatically: implications for the rediscovery of pragmatism as a research paradigm. Journal of Mixed Methods Research. 4(1), 6-16.

Ferraro, J. M. (2000). Reflective practice and professional development. Washington, DC: ERIC Clearinghouse on Teaching and Teacher Education. (ERIC Document Reproduction Service ED 449120).

Fisch, K., McLeod, S. & Brenman, J. (2013). The information age - we are living in exponential times! (ShiftHappens 2013) [Video file]. Retrieved from http://www.youtube.com/watch?v=fR_dvE3eEIs

Fischer, F. (1998). Beyond empiricism: Policy inquiry in postpositivist perspective. Policy Studies Journal, vol. 26(1), pp. 129-146.

Fischer, S., Frese, M., Glaub, M. & Hoppe, M. (2014). Increasing personal initiative in small business managers or owners leads to entrepreneurial success: A theorybased controlled randomised field intervention for evidence-based management. Academy of Management Learning Education, vol. 13(3), pp. 354-379.

Fishman, B. J., Marx, R. W., Best, S. & Tal, R. T. (2003). Linking teacher and student learning to improve professional development in systemic reform. Teaching and Teacher Education, vol. 19(6), pp. 643-658.

Flores, M. A. (2005). How do teachers learn in the workplace? findings from an empirical study carried out in portugal [1]. Journal of in-service education, vol. 31(3), pp. 485-508.

Fogarty, R. (2009). How to integrate the curricula. (3rd ed.). Thousand Oaks, CA: Corwin Press.

Fortin, S., Long, W. & Lord, M. (2002). Three voices: Researching how somatic education informs contemporary dance technique classes. Research in dance education, 3(2), 155-179.

Foster, P. (1994). Must we MST? Journal of Technology Education, vol. 6(1). Retrieved from http://scholar.lib.vt.edu/ejournals/JTE/v6n1/foster.jte-v6n1.html

Fowler, F. C. (2000). Policy studies for educational leaders: An introduction. Upper Saddle River, NJ: Prentice-Hall, Inc.

Freeman, S., Eddy, S.L., McDonough, M., Smith, M.K., Okoroafor, N., Jordt, H., & Wenderoth, M.P. (2014). Active learning increases student performance in science, engineering, and mathematics. PNAS, 111(23); 8410-8415Adams, P. (2006). Exploring social constructivism: Theories and practicalities. Education, vol. 34(3), pp. 243-257.

Frees, W. & Bouckaert, G. (2014). The sustainability of public sector innovations: the role of feedback, accountability and learning. EGPA Conference. Retrieved from https://lirias.kuleuven.be/handle/123456789/473436

Freire, P. (2000). Pedagogy of the oppressed. Bloomsbury Publishing.

Friedman, T. (2007). The world is flat 3.0. A World History.

Frykholm, J. & Glasson G. (2005). Connecting science and mathematics instruction: Pedagogical context knowledge for teachers. School Science and Mathematics, vol. 105(3), pp. 127-141.

Fulton, K. & Britton, T. (2011). STEM teachers in professional learning communities: From good teachers to great teaching. National Commission on Teaching and America's Future. 2100 M Street NW Suite 660, Washington, DC 20047.

Gardner, D. P., Larsen, Y. W., Baker, W., Campbell, A. & Crosby, E. A. (1983). A nation at risk: The imperative for educational reform (p. 65). United States Department of Education.

Garet, M.S., Porter, A. C., Desimone, L., Birman, B.F. & Yoon, K.S. (2001). “What makes professional development effective? Results from a national sample of teachers.”American Educational Research Journal, vol. 38 (4), pp 915-945.

Gehrke, S. & Kezar, A. (2017). The Roles of STEM Faculty Communities of Practice in Institutional and Departmental Reform in Higher Education. American Educational Research Journal, vol. 20(10), pp. 1-31.

Gerston, L. N. (1997). Public policy making: Process and principles. Armonk, NY: M. E. Sharpe.

Gewertz, C. (2013). Standards Worrying Teachers. Education Week, vol. 32(22), pp. 1-12.

Gilmer, T. C. (2007). An understanding of the improved grades, retention, and graduation rates of STEM majors as the Academic Investment in Math and Science (AIMS) program of Bowling Green State University (BGSU). Journal of STEM Education, 8(1, 2), pp. 11-21.

Glasgow, N. A. (1997). New curriculum for new times: A guide to student-centred, problembased learning. Thousand Oaks, CA: Corwin Press.

Glaze, A. L. (2017). Bridging the Gaps: Evolution and Pre-service Science Teachers. In Evolution Education in the American South (pp. 103-119). Palgrave Macmillan US.

Glenn, J. (2000). Before it’s too late: A report to the nation from the national commission on mathematics and science teaching for the 21st Century. The National Commission on Mathematics and Science Teaching for the 21st Century.

Gnilka, P. B. & Novakovic, A. (2017). Gender Differences in STEM Students' Perfectionism, Career Search Self-Efficacy, and Perception of Career Barriers. Journal of Counseling & Development, vol. 95(1), pp. 56-66.

Goddard, Y. L., Goddard, R. D. & Tschannen-Moran, M. (2007). A theoretical and empirical investigation of teacher collaboration for school improvement and student achievement in public elementary schools. Teachers college record, vol. 109(4), pp. 877-896.

Goldkuhl, G. (2012). Pragmatism vs interpretivism in qualitative information systems research. European Journal of Information Systems, vol. 21(2), pp. 135-146.

Gonzalez, H. B., & Kuenzi, J.J. (2012). Science, Technology, Engineering, and Mathematics (STEM) Education: A Primer. Congressional Research Service. Retrieved from https://fas.org/sgp/crs/misc/R42642.pdf Accessed on December 22, 2017 Warner, R. S & S. Burton, G. J. S. (2017). A Fertile Oasis: The Current State of Education in the UAE. Mohammed Bin Rashid School of Government (MBRSG). Retrieved from http://www.mbrsg.ae/getattachment/658fdafb-673d-4864-9ce1-881aaccd08e2/A-Fertile-OASIS-The-current-state-of-Education-in

Gouia-Zarrad, R. & Gunn, C. (2017). Modifying the flipped experience to enhance the learning of calculus in the United Arab Emirates. Learning and Teaching in Higher Education: Gulf Perspectives, vol. 14(1), pp. 1-13.

Govindasamy, T. (2001). Successful implementation of e-leaming: Pedagogical considerations. The Internet and Higher Education, vol. 4(3), pp. 287-299.

Graen, G. B. (2009). Educating new management specialists from an evidence-based perspective: A proposal. Academy of Management Learning & Education, vol. 8(2), pp. 255-258.

Graham, E. (2013, April 25). A nation at risk' turns 30: Where did it take us? Retrieved from NEA Today website: http://neatoday.org/2013/04/25/anation-at-risk-turns-30-where-did-it-take-us/

Graves, A. W., Gersten, R. & Haager, D. (2004). Literacy instruction in multiplelanguage first-grade classrooms: Linking student outcomes to observed instructional practice. Learning Disabilities Research & Practice, vol. 19(4), pp. 262-272.

Green, A. & Sanderson, D. (2017). The Roots of STEM Achievement: An Analysis of Persistence and Attainment in STEM Majors. The American Economist, vol. 0(0), pp. 1-15.

Greene, J. C., Caracelli, V. J. & Graham, W. F. (1989). Toward a conceptual framework for mixed-method evaluation designs. Educational Evaluation and Policy Analysis, vol. 11, pp. 255-274.

Grigg, W. S., Lauko, M. A. & Brockway, D. M. (2006). The Nation's report card: Science 2005 (NCES 2006-466). Washington, D.C.: U.S. Government Printing Office.

Grimm, M. J. (2005, October). Work in progress-An Engineering Bridge Program-The foundation for success for academically at-risk students. In Frontiers in Education, 2005. FIE'05. Proceedings 35th Annual Conference (pp. S2C-8). IEEE.

Guba, E. G. & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. Handbook of qualitative research, vol. 2(163-194), .p.105.

Guskey, T. R. (2002). Does it make a difference? Evaluating professional development. Educational Leadership, vol. 59(6), pp. 45-51.

Guzey, S. S., Harwell, M., Moreno, M., Peralta, Y. & Moore, T. J. (2017). The Impact of Design-Based STEM Integration Curricula on Student Achievement in Engineering, Science, and Mathematics. Journal of Science Education and Technology, vol. 26(2), pp. 207-222.

Haghighi, K., Smith, K. A., Olds, B. M., Fortenberry, N. & Bond, S. (2008). The time is now: Are we ready for our role. Journal of Engineering Education, vol. 97(2), pp. 119-121.

Halim, L., Syed Abdullah, S. I. S. & Meerah, T. S. M. (2014). Students' perceptions of their science teachers pedagogical content knowledge. Journal of Science Education Technology, vol. 23(2), pp. 227-237.

Hall, G. E. (2010). Technology's Achilles heel: Achieving high-quality implementation. Journal of Research on Technology in Education, vol. 42(3), pp. 231-253.

Hall, G. E. & Hord, S. M. (2006). Implementing change: Patterns, principles, and potholes. Boston, MA: Pearson Education, Inc.

Hall, G.E., Wallace, R.C., Jr. & Dossett, W.F. (1973). A developmental conceptualization of the adoption process within educational institutions. Austin, TX: University of Texas at Austin, Research and Development Center for Teacher Education.

Hamilton, L. S., Stecher, B. M. & Yuan, K. (2017). Creating an Indicator of K-12 Classroom Coverage of Science, Technology, Engineering, and Math (STEM) Content and Practices. RAND Corporation, Santa Monica, Calif. Retrieved from https://pdfs.semanticscholar.org/0550/16c0ac0f779cd7295dc9a1034a7ddf4bd5b9.pdf

Hanouz, M. D. & Dusek, M. (2013). The Employment Competitiveness Nexus in the Arab World: Findings from the Global Competitiveness Index. In The Arab World Competitiveness Report 2013. Geneva: World Economic Forum and EBRD.

Hanover Research. (2011). Innovative practices for improving student performance in college level mathematics. Washington, D.C.

Hansen, M. & Gonzalez, T. (2014). Investigating the relationship between STEM learning principles and student achievement in math and science. American Journal of Education, vol. 120(2), pp. 139-171.

Hargreaves, A. & Shirley, D. (2009). The fourth way: The inspiring future for educational change. Thousand Oaks, CA: Corwin Press.

Harris, S. Y. (2017). Undergraduates' assessment of Science, Technology, Engineering and Mathematics (STEM) information literacy instruction. IFLA Journal, vol. 0(0), pp. 1-16.

Harwood, J. & Rudnitsky, A. (2005). Learning about scientific inquiry through engineering. Proceedings of the 2005 ASEE Annual Conference, Portland, OR.

Hassan Al Marzouqi, A. & Forster, N. (2011). An exploratory study of the under-representation of Emirate women in the United Arab Emirates' information technology sector. Equality, Diversity and Inclusion: An International Journal, vol. 30(7), pp. 544-562.

Hatherley-Greene, P.J. (2014). The Cultural Border Crossing Index: implications for higher education teachers in the UAE. Learning and Teaching in Higher Education: Gulf Perspectives, vol. 11(2).

Hattie, J. & Yates, G. C. (2013). Visible learning and the science of how we learn. Routledge.

Hayden, K., Ouyang, Y., Scinski, L., Olszewski, B. & Bielefeldt, T. (2011). Increasing student interest and attitudes in STEM: Professional development and activities to engage and inspire learners. Contemporary Issues in Technology and Teacher Education (CITE Journal), vol. 11(1), pp. 47-69.

Hazen, N. L. & Black, B. (1989). Preschool peer communication skills: The role of social status and interaction context. Child development, pp. 867-876.

Heck, R. (2004). Studying educational and social policy. Mahwah, NJ: Lawrence Erlbaum Associates.

Heller, J. I., Daehler, K. R., Wong, N., Shinohara, M. & Miratrix, L. W. (2012). Differential effects of three professional development models on teacher knowledge and student achievement in elementary science. Journal of Research in Science Teaching, vol. 49(3), pp. 333-362.

Hendricks, C. C., Alemdar, M. & Ogletree, T. (2012). The Impact of Participation in VEX Robotics Competition on Middle and High School Students' Interest in Pursuing

STEM Studies and STEM-related Careers. In American Society for Engineering Education. American Society for Engineering Education.

Herr, K., (2005). The action research dissertation: A guide for students and faculty. Sage Publications,Thousand Oaks, London & New Delhi.

Herschbach, D. R. (2011). The STEM initiative: Constraints and challenges. Journal of STEM Teacher Education, vol. 48(1), pp. 96-122.

Hewson, P. (2007). Teacher professional development in science. In S. K. Abell & N. G. Lederman (Eds.), Handbook of Research on Science Education (pp. 1179-1203). Mahwah: Lawrence Erlbaum.

Hill, R. A. (2013). Narrative nonfiction for STEM (Science, Technology, Engineering, and Math) reading: one option for common core literacy. Teacher Librarian, vol. 3, p. 31.

Hoachlander, G. & Yanofsky, D. (2011, March). Making STEM real: by infusing core academics with rigorous real-world work, Linked Learning pathways prepare students for both college and career. Educational Leadership, vol. 68(3), pp. 60-65.

Holmegaard, H. T., Ulriksen, L. & Madsen, L. M. (2015). A narrative approach to understand students' identities and choices. In Understanding student participation and choice in science and technology education (pp. 31-42). Springer Netherlands.

Holzer, H. J. & Lerman, R. I. (2007). America's forgotten middle skill jobs: Education and training requirements in the next decade and beyond. Washington D.C.: The Workforce Alliance, Skills2Complete.

Honey, M., Pearson, G. & Schweingruber, H. (2014). STEM integration in k-12 education: Status, prospects, and an agenda for research. Washington, DC: The National Academies Press.

Householder, D. L. & Hailey, C. E. (2012). Incorporating engineering design challenges into STEM courses. National Centre for Engineering and Technology Education. c/o Department of Engineering Education Utah State University, 4160 Old Main Hill, Logan, UT 84322.

Howard, P., Liang, Z. & Rasa, J. (2011). Evidence informed managerial decisionmaking: What evidence counts? (Part One). Asia Pacific Journal of Health Management, vol. 6(1), pp. 23-29.

Howell, D. C. (2002). Statistical methods for psychology (5th ed.). Pacific Grove, CA: Duxbury.

Howes, E. V., Hamilton, G. W. & Zaskoda, D. (2003). Linking science and literature through technology: Thinking about interdisciplinary inquiry in middle school. Journal of Adolescent & Adult Literacy, vol. 46(6), pp. 494-504.

Hsieh, H. & Shannon, S. E. (2005). Three approaches to qualitative content analysis. Qualitative Health Research, vol. 15(9), pp. 1277-1288.

Hu, L. T. & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modelling, vol. 6(1), pp. 1-55.

Hudson, P., English, L., Dawes, L., King, D. & Baker, S. (2015). Exploring links between pedagogical knowledge practices and student outcomes in STEM education for primary schools. Australian Journal of Teacher Education, vol. 40(6). Retrieved from http://ro.ecu.edu.au/ajte/vol40/iss6/8

Humphrey, G. (2003). Inquiry-based learning: What does it look like? Connect, vol. 8(4).

Iannaccone, L. (1967). Politics in education. New York: The Center for Applied Research in Education, Inc.

ICT Fund (2013). About Smart Learning. The Smart Learning Program. Dubai, United Arab Emirates. Retrieved from http://ict.clientacumenadagency.com/page/about-smart-learning

International Consultants for Education and Fairs (ICEF). (2013). UAE Educational Prospect. Retrieved from: http://docplayer.net/1532990-Uae-educationprospect-icef-dubai-2013.html

Issa, A. & Siddiek, A. (2012). Higher education in the Arab world & challenges of labour market. International Journal of Business and Social Science, vol. 3(9).

ISTE standards (2007). ISTE Standards Students. Retrieved from https://www.iste.org/docs/pdfs/20-14_ISTE_Standards-S_PDF.pdf

Jacobs, H. H. (1989). Interdisciplinary curriculum: Design and implementation. Association for Supervision and Curriculum Development, 1250 N. Pitt Street, Alexandria, VA 22314.

Jacobs, H. H. (1997). Mapping the big picture: Integrating curriculum & assessment K-12. Alexandria, VA: Association for Supervision and Curriculum Development.

Jacobs, H. H. (2010). Curriculum 21: Essential education for a changing world. Alexandria, VA: Association for Supervision and Curriculum Development.

Jacobs, J., Salas, A., Cameron, T., Naguwa, G. & Kasuya, R. (2005). Implementing an online curriculum management database in a problem-based learning curriculum. Academic Medicine, vol. 80(9), pp. 840-846.

James, S. M. & Singer, S. R. (2016). From the NSF: The National Science Foundation's Investments in Broadening Participation in Science, Technology, Engineering, and Mathematics Education through Research and Capacity Building. CBE-Life Sciences Education, vol. 15(3), fe7.

Jessop, B. (2002). Liberalism, neoliberalism, and urban governance: A state-theoretical perspective. Antipode, vol. 34(3), pp. 452-472.

Johnson, B. & Christensen, L. (2012). Sampling in quantitative, qualitative, and mixed research. In Educational research: Qualitative, quantitative, and mixed approaches (pp. 215-242). Thousand Oaks, CA: Sage Publications.

Johnson, C. (2013). Conceptualising integrated STEM education. School Science and Mathematics. vol. 113(8), pp. 367.

Johnson, C. A., PhD., Dodor, B. A., PhD. & Ball, E., M.A.Ed. (2015). Integrating math Common Core standards into the family and consumer sciences curriculum. North Carolina Association For Middle Level Education Journal, vol. 29(1), pp. 1-10.

Johnson, C. C., Kahle, J. B. & Fargo, J. D. (2007). Effective teaching results in increased science achievement for all students. Science Education, vol. 91(3), pp. 371-383.

Jolly, J. L. (2009). The national defence education act, current STEM initiative, and the gifted. Gifted Child Today, vol. 32(2), pp. 50-53.

Jones, B. D. & Baumgartner, F. R. (2005). The politics of attention: How government prioritizes problems. Chicago, IL: University of Chicago Press.

Jones, C. (2010). Interdisciplinary approach-advantages, disadvantages, and the future benefits of interdisciplinary studies. ESSAI, vol. 7(1), p. 26.

Jones, C. (2013). Bedouins into Burgeouis? Social Engineering for a Market Economy in the United Arab Emirates (Unpublished doctoral dissertation). Yale University, United States.

Jones, M. G. & Brader-Araje, L. (2002). The impact of constructivism on education: Language, discourse, and meaning. American Communication Journal, vol. 5(3), pp. 1-10.

Jones, M. G. & Carter, G. (2007). Science teacher attitudes and beliefs. In S. K. Abell & N. G. Lederman (Eds.), Handbook of Research on Science Education (pp. 1067-1104). NJ: Lawrence Erlbaum Associates.

Jones, V. V. (2014). Teaching STEM: 21st century skills. Children’s Technology & Engineering, vol. 18(4), pp. 11-13.

Jordan, N. C., Kaplan, D., Ramineni, C. & Locuniak, M. N. (2009). Early math matters: Kindergarten number competence and later mathematics outcomes. Developmental Psychology, vol. 45(3), pp. 850-867.

Justice, L. M., Petscher, Y., Schatschneider, C. & Mashburn, A. (2011). Peer effects in preschool classrooms: Is children’s language growth associated with their classmates’ skills?. Child Development, vol. 82(6), pp. 1768-1777.

Katehi, L. (2009). Engineering in K-12 education. Retrieved from http://science.house.gov/publications/Testimony.aspx?TID=15242

Katehi, L., Pearson, G. & Feder, M. Eds. (2009). Engineering in K-12 education: Understanding the status and improving the prospects. Washington, DC: National Academies Press.

Katz, L.G. (2010). STEM in the early years. Paper presented at STEM in early education and development conference. Beyond this Issue. Retrieved from http://ecrp.uiuc.edu/beyond/seed/katz.html

Katzenmeyer, C. & Lawrenz, F. (2006). National science foundation perspectives on the nature of STEM program evaluation. New Directions for Evaluation, vol. 2006(109), pp. 7-18.

Kelley, T. & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. International Journal of STEM Education, vol. 3(1), pp. 1-11.

Kelley, T. R. (2012). Voices from the past: Messages for a STEM future. Journal of Technology Studies, vol. 38(1), pp. 34-42.

Kenny, D. A., Kaniskan, B. & McCoach, D. B. (2015). The performance of RMSEA in models with small degrees of freedom. Sociological Methods & Research, 44(3), 486-507.

Kentucky Department of Education. (2013). Competency-based education: Helping all Kentucky students succeed. Retrieved from education.ky.gov/school/innov/documents/ky_cbe_final_hr1-10-13.pdf

Khadri, H. O. (2014). Planning for establishing stem education department within faculty of education - Ain Shams University an interdisciplinary model. European Scientific Journal October 2014 edition vol.10, No.28 ISSN: 1857 – 7881.

Kilpatrick, W. H. (1918). The project method: The use of the purposeful act in the educative process (No. 3). Teachers college, Columbia university.

Kimmel, H., Carpinelli, J. & Rockland, R. (2007, September). Bringing engineering into K-12 schools: A problem looking for solutions? Paper presented at International Conference on Engineering Education, Coimbra, Portugal.

Knapp, M. S. (2003). Professional development as a policy pathway. Review of Research in Education, vol. 27, p. 109.

Knezek, G., Christensen, R. & Tyler-Wood, T. (2011). Contrasting perceptions of STEM content and careers. Contemporary Issues in Technology and Teacher Education, vol. 11(1), pp. 92-117.

Knezek, G., Christensen, R., Tyler-Wood, T., Periathiruvaldi, S., Alexander, C., Mayes, G. & Moagoun, D. (2012). Measurement of STEM dispositions in K-12 school students. In Society for Information Technology & Teacher Education International Conference, vol. 1, pp. 1052-1059.

Knight, P., Tait, J. & Yorke, M. (2006). The professional learning of teachers in higher education. Studies in higher education, vol. 31(03), pp. 319-339.

Knowledge and Human Development Authority (KHDA) (2013). Dubai School Inspections Bureau Annual Report. Dubai: United Arab Emirates. Retrieved from: http://www.khda.gov.ae/En/Reports/Publications.aspx

Koehler, A., Feldhaus, C. R., Fernandez, E. & Hundley, S. (2013). Alternative certification programs & pre-service teacher preparedness. Journal Of STEM Education: Innovations and Research, vol. 14(4), pp. 45-55.

Koehler, M. & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? Contemporary Issues in Technology and Teacher Education, vol. 9(1), pp. 60-70.

Koirala, H. P. & Bowman, J. K. (2003). Preparing middle level preservice teachers to integrate mathematics and science: Problems and possibilities. School Science and Mathematics, vol. 103(3), pp. 145-154.

Kolata, G. B. (1977). Aftermath of the new math: Its originators defend it. Science, vol. 195(4281), pp. 854-857.

Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., ... & Ryan, M. (2003). Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting learning by design (tm) into practice. The journal of the learning sciences, vol. 12(4), pp. 495-547.

Kolsto, S. (2001). Scientific literacy for citizenship: Tool for dealing with the science dimension of controversial socio-scientific issues. Science Education, vol. 85, pp. 291-310.

Köymen, B., Rosenbaum, L. & Tomasello, M. (2014). Reasoning during joint decision-making by preschool peers. Cognitive Development, vol. 32, pp. 74-85.

Kuhlthau, C. C. (2010). Guided inquiry: School libraries in the 21st century. School Libraries Worldwide, vol. 16(1), p. 1.

Kuhn, T. (1970).The structure of scientific revolutions (2nd ed.). Chicago: University of Chicago Press.

La Paro, K. M., Pianta, R. C. & Stuhlman, M. (2004). The classroom assessment scoring system: Findings from the prekindergarten year. The Elementary School Journal, vol. 104(5), pp. 409-426.

Laboy-Rush, D. (2011). Whitepaper: Integrated STEM education through project-based learning. Retrieved from http://www.learning.com/STEM/whitepaper/

Lacey, T. A. & Wright, B. (2009). Occupational employment projections to 2018. Monthly Labor Review, vol. 132(11), pp. 82-123.

Lai, E. R. & Viering, M. (2012). Assessing 21st century skills: Integrating research findings. In annual meeting of the National Council on Measurement in Education, Vancouver, BC, Canada.

Langdon, D., McKittrick, G., Beede, D., Khan, B. & Doms, M. (2011). STEM: Good jobs now and for the future. Retrieved from U.S. Department of Commerce Economics and Statistics Administration website: http://www.esa.doc.gov/sites/default/files/reports/documents/stemfinalyjuly14_1.pdf

Lantz, H. B. (2009). Science, technology, and mathematics (STEM) education. What form? What function? Retrieved from www.currtechintegrations.com/pdf/STEMEducationArticle.pdf

LaParo, K. M., Pianta, R. C., Stuhlman, M. & Hamre, B. (2008). Classroom assessment scoring system (CLASS). Charlottesville, VA: National Center for Early Development and Learning. University of Virginia.

LaPorte, J. & Sanders, M. (1993). The T/S/M Integration Project: Integrating technology, science, and mathematics in the middle school. The Technology Teacher, vol. 52(6), pp. 17-21.

Lasswell, H. (2003). The policy orientation. In Sandra Braman (Ed.), Communication researchers and policy-making, 85-104. Cambridge, MA: MIT Press.

Lehman, J. R. (1994). Integrating science and mathematics: Perceptions of pre-service and practicing K-12 teachers. School Science and Mathematics, vol. 94, pp. 58-64.

Lehming, R. F., Alt, M. N., Chen, X., Hall, L., Burton, L., Burrelli, J. S., … others. (2010). Science and engineering indicators, 2010 (No. NSB 10-01.). National Science Board. Retrieved from http://eric.ed.gov/?id=ED514060

Leshner, A. I. (2015). Bridging the opinion gap. Science, vol. 347(6221), pp. 459-459.

Levinson, D. F. (2006). The genetics of depression: a review. Biological psychiatry, vol. 60(2), pp. 84-92.

Lewis, Theodore. (2004). A turn to engineering: The continuing struggle of technology education for legitimisation as a school subject. Journal of Technology Education, vol. 16(1). Online publication. Retrieved from http://scholar.lib.vt.edu/ejournals/JTE/v16n1/lewis.html

Lichtenberg, J., Woock, C. & Wright, M. (2008). Ready to Innovate: Are Educators and Executives Aligned on the Creative Readiness of the US Workforce?. Conference Board.

Lichtenstein, G., Loshbaugh, H. G., Claar, B., Bailey, T. L. & Sheppard, S. (2007). Should I stay or should go? Engineering students' persistence is based on little experience or data. Proceedings of the American Society for Engineering Education Annual Conference, Honolulu, HI.

Lin, H. S., Hong, Z. R. & Lawrenz, F. (2012). Promoting and scaffolding argumentation through reflective asynchronous discussions. Computers & Education, vol. 59(2), pp. 378-384.

Lingard, B. & Rizvi, F. (Eds.) (2013). Globalizing education policy. London: Routledge.

Lingard, B. (2013). Conceptions of Education Policy. In Lingard, B. and Rizvi, F. (Eds.), Globalizing education policy (pp. 1-21). London: Routledge.

Litzler, E. & Young, J. (2012). Understanding the risk of attrition in undergraduate engineering: Results from the project to assess climate in engineering. Journal of Engineering Education, vol. 101(2), p. 319.

Liu, E. Z. F. (2011). Avoiding internet addiction when integrating digital games into teaching. Social Behaviour and Personality: an international journal, vol. 39(10), pp. 1325-1335.

Liu, E. Z. F., Chun-Hung, L. I. N., Pei-Hsin, J. I. A. N. & Pey-Yan, L. I. O. U. (2012). The dynamics of motivation and learning strategy in a creativity-supporting learning environment in higher education. TOJET: The Turkish Online Journal of Educational Technology, vol. 11(1), pp. 172-180.

Louis, K. S., Thomas, E., Gordon, M. F. & Febey, K. S. (2008). Does state leadership matter?: An analysis of three states. Educational Administration Quarterly, vol. 44(4), pp. 562-592.

Loveless, T. (2013). The common core initiative: What are the chances of success? Educational Leadership, vol. 70(4), pp. 60-63.

MacEwan, M. (2013). Getting intentional about STEM learning. Afterschool Matters, vol. 17, pp. 58-61.

Magnusson, S., Krajcik, J. & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), Examining pedagogical content knowledge (pp. 95-132). Netherlands: Springer.

Mahani, S. & Molki, A. (2011). Factors influencing female Emirati students' decision to study engineering. Global Journal of Engineering Education, vol. 13(1), pp. 26-31.

Mahil, S. (2016, April). Fostering STEM+ education: Improve design thinking skills. In Global Engineering Education Conference (EDUCON), 2016 IEEE(pp. 125-129). IEEE.

Mahoney, M.J. (1991). Human Change Processes. New York: Basic Books.

Makhmasi, S., Zaki, R., Barada, H. & Al-Hammadi, Y. (2012, April). Students' interest in STEM education. In Global Engineering Education Conference (EDUCON), 2012 IEEE (pp. 1-3). IEEE.

Mann, C. R. (1918). The carnegie foundation for the advancement of teaching: A study of engineering education (Vol. 11).

Mansilla, V. B. (2006). Assessing expert interdisciplinary work at the frontier: an empirical exploration. Research Evaluation, vol. 15(1), pp. 17-29.

Manzo, K. K. (2001). Academic record. Education Week, vol. 20(35), pp. 22-35.

Margheri, L. (2016). Women in Engineering, Science, and Technology in the United Arab Emirates [Women in Engineering]. IEEE Robotics & Automation Magazine, vol. 23(2), pp. 102-104.

Marlowe, B. A. & Page, M. L. (2005). Creating and sustaining the constructivist classroom. Corwin Press.

Marshall, C., Mitchell, D. & Wirt, F. (1989). Culture and education policy in the American states. New York: The Falmer Press.

Marshall, S. P. (2010). Re-imagining specialised STEM academies: Igniting and nurturing decidedly different minds, by design. Roeper Review, vol. 32(1), pp. 48-60.

Martinello, M. L. & Cook, G. E. (2000). Interdisciplinary inquiry in teaching and learning. Merrill, an imprint of Prentice Hall, Order Processing Center, PO Box 11071, Des Moines, IA 50336-1071.

Mason, K., Brewer, J., Redman, J., Bomar, C., Ghenciu, P., LeDocq, M. & Chapel, C. (2012). SySTEMically improving student academic achievement in mathematics and science. Journal for Quality & Participation, vol. 35(2), pp. 20-24.

Matthews, C. M. (2007). Science, engineering, and mathematics education: Status and issues. Congressional Research Service, Library of Congress. Washington, D.C.: Author.

Matthews, M. (2012). Keeping students in engineering: A research-to-practice brief. American Society for Engineering Education. Retrieved from http://www.asee.org/retentionproject/keeping-students-in-engineering-a-research-guide-to-improving-retention.

McCarthy, S. & Rousseau, D. M. (2007). Educating managers from an evidence-based perspective. Academy of Management Learning & Education, vol. 6(1), pp. 84-101.

McClelland, S.I., & Holland, K.J. (2014). You, Me, or Her: Leaders; Perceptions of responsibility for Increasing Gender Diversity in STEM Departments. Psychology of Women Quarterly, 39(2); 1.

McLaughlin, C. (2009, September). Stem: it's elementary, too!. Technology and Children. pp. 18-19.

McLaughlin, M. W. & Talbert, J. E. (2006). Building school-based teacher learning communities: Professional strategies to improve student achievement (Vol. 45). Teachers College Press.

Meng, C. C., Idris, N. & Eu, L. K. (2014). Secondary students' perceptions of assessments in Science, Technology, Engineering, and Mathematics (STEM). EURASIA Journal Of Mathematics, Science & Technology Education, vol. 10(3), pp. 219-227.

Mercer, N. & Howe, C. (2012). Explaining the dialogic processes of teaching and learning: The value and potential of sociocultural theory. Learning, Culture and Social Interaction, vol. 1(1), pp. 12-21.

Merriam, S.B. (2009). Qualitative research: a guide to design and implementation. San Francisco: Jossey-Bass/Wiley.

Merrill, C. (2009). The Future of TE Masters Degrees: STEM. Presentation at the 70th Annual International Technology Education Association Conference, Louisville, Kentucky. (2012, December 8). Integrative STEM education as “best practice”. Retrieved from http://www.teachmeteamwork.com/files/sanders.terc-paper.pdf

Merrill, C. & Daugherty, J. (2009). The future of TE masters degrees: STEM.

Meyerson, D. E. & Tompkins, M. (2007). Tempered radicals as institutional change agents: The case of advancing gender equity at the university of Michigan. Harvard Journal of Law and Gender, vol. 30, pp. 303-322.

Miaoulis, I. (2010). K-12 engineering - the missing core discipline. In D. Grasso & M.B. Burkins (Eds.), Holistic Engineering Education (pp. 37-51). New York: Spring Science + Business Media.

Miles, M. & Huberman, A.M. (1994). Qualitative data analysis. Thousand Oaks, CA: Sage.

Minerick, A.R., Wasburn, M.H. & Young, V.L. (2009). Mothers on the tenure track: What engineering and technology faculty still confront. Engineering Studies, vol. 1(3), pp. 271-235.

Ministry of Cabinet Affairs (MOCA) (2011). Highlights of the UAE Government Strategy 2011-2013. Retrieved from: http://www.moca.gov.ae/?page_id=631

Ministry of Education (MOE). (2012). Education Reform for Knowledge Economy: Second Phase, Narrative Report. Amman, Jordan: Development Coordination Unit (DCU).

Ministry of Higher Education and Scientific Research. (2015, October). Retrieved from http://www.mohesr.gov.ae/En/HigherEducation/Pages/AboutHigherEducation.aspx

Mitchell, D. E., Crowson, R. L & Shipps, D. (2011). Shaping education policy: Power and process. New York: Routledge.

Mizell, H. (2010). Why Professional Development Matters. Learning Forward. 504 South Locust Street, Oxford, OH 45056.

Moghaddam, A. A. & Redzuan, M. R. (2012). Globalisation and economic growth: A case study in a few developing countries (1980-2010). Research in World Economy, vol. 3(1), pp. 54.

Monk, D. & King, J. (1994). Multilevel teacher resource effects on pupil performance in secondary mathematics and science. In R. G. Ehrenberg (Ed.), Choices and consequences (pp. 29-58). Ithaca, NY: ILR Press.

Monroe, K., Ozyurt, S., Wrigley, T. & Alexander, A. (2008). Gender equality in academia: Bad news from the trenches, and some possible solutions. Perspectives on politics, vol. 6(2), pp. 215-233.

Moonesar, I. & Mourtada, R. (2015). Persistence in the Abu Dhabi STEM Pipeline: Preparing Emirati Youth for Careers in the UAE Innovation Economy. Technical Report. Retrieved from https://www.researchgate.net/publication/283279547_Persistence_in_the_Abu_Dhabi

_STEM_Pipeline_Preparing_Emirati_Youth_for_Careers_in_the_UAE_Innovation_Economy

Moore, T., Stohlmann, M., Wang, H., Tank, K., Glancy, A., Roehrig, G. (2014). Implementation and integration of engineering in K-12 STEM education. In S. Purzer, J. Strobel & M. Cardella (Eds.), Engineering in pre-college settings (pp. 5-59). West Lafayette, IN: Purdue University Press.

Morgan, D. (1998). Practical strategies for combining qualitative and quantitative methods: Applications to health research. Qualitative Health Research, vol. 3, pp. 362-376.

Morgan, D. L (2007). Paradigms lost and pragmatism regained. Journal of Mixed Methods Research, vol. 1, pp. 48-76.

Morrison, J. (2006). Attitudes of STEM education: The student, the school, the classroom STEM education monograph series. Teaching Institute for Excellence in STEM. Retrieved from http://www.tiesteach.org/

Morse, J. M. (1991). Approaches to qualitative-quantitative methodological triangulation. Nursing Research, vol. 40, pp. 120-123.

Mueller, R. O. & Hancock, G. R. (2008). Best practices in structural equation modeling. Best Practices in Quantitative Methods, pp. 488-508.

Mugan, D. (2009). STEM education. [PowerPoint presentation] Cheney Middle School, West Fargo, ND.

Mullen, E. J. & Streiner, D. L. (2006). The evidence for and against evidence-based practice. Foundations of evidence-based social work practice, pp. 21-34.

Mullis, I.V., Martin, M., Foy, P. & Arora, A. (2011). Trends in International Mathematics and Science Study (TIMSS) 2011 Results in Mathematics. Retrieved from: http://timssandpirls.bc.edu/timss2011/downloads/T11_IR_Mathematics_FullBook.pdf

Mundy, K. (2007). Global governance, educational change. Comparative Education, vol. 43(3), pp. 339-357.

Murphy, T. P. & Mancini-Samuelson, G. J. (2012). Graduating STEM competent and confident teachers: the creation of a STEM certificate for elementary education majors. Journal of College Science Teaching, vol. 42(2), pp. 18-23.

Murray, C. (2007, May 17). Robots tackle core of STEM education. eSchool News. Retrieved from http://www.eschoolnews.com/2007/04/13/robots-tackle-core-of-stem-education/

Museus, S. D., Palmer, R. T., Davis, R. J. & Maramba, D. C. (2011). Special issue: Racial and ethnic minority students' success in STEM education. ASHE Higher Education Report, vol. 36(6), pp. 1-140.

Mykhalovskiy, E. & Weir, L. (2004). The problem of evidence-based medicine: directions for social science. Social science & medicine, vol. 59(5), pp. 1059-1069.

Nadelson, L. S., Callahan, J., Pyke, P., Hay, A., Dance, M. & Pfiester, J. (2013). Teacher STEM perception and preparation: Inquiry-based STEM professional development for K-12 teachers. The Journal of Educational Research, vol. 106(2), pp. 157-168.

National Academy of Engineering [NAE] (2014). NAE Grand Challenges for Engineering in the 21st Century: Implications for industrial and systems engineering. Retrieved from http://www.qscience.com/doi/pdf/10.5339/qproc.2015.elc2014.24

National Academy of Engineering and National Research Council [NAE & NRC]. (2009). Engineering in K-12 Education: Understanding the Status and Improving the Prospects. Washington, DC: National Academies Press.

National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. (2007). Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future. Washington D.C.: The National Academies Press. Retrieved from http://www.nap.edu/catalog.php?record_id=11463

National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. (2011). Rising above the gathering storm revisited: Rapidly approaching category 5. Condensed version. Washington, DC: The National Academies Press.

National Assessment of Educational Progress in science (NAEP, 2011). Reading 2011 National Assessment Of Educational Progress At Grades 4 And 8. Retrieved from https://nces.ed.gov/nationsreportcard/pdf/main2011/2012457.pdf

National Commission on Excellence in Education. (1983). A nation at risk. Retrieved from http://www2.ed.gov/pubs/NatAtRisk/risk.html

National Council of Teachers of English (NCTE) (1996). Standards for the English Language Arts. Retrieved from http://www.ncte.org/library/NCTEFiles/Resources/Books/Sample/StandardsDoc.pdf

National Council of Teachers of Mathematics (NCTM) (1989). Curriculum and Evaluation Standards for School Mathematics Reston, VA: NCTM.

National Research Council. (NRC) (1996). National Science Education Standards (NSES). Washington, DC: The National Academies Press.

National Research Council. (NRC) (2011). Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics. Committee on Highly Successful Science Programs for K-12 Science Education, Board on Science Education and Board on Testing and Assessment, Division of Behavioural and Social Sciences Education. Washington, DC: The National Academies Press.

National Research Council. (NRC) (2012). A framework for k-12 science education: Practices, crosscutting concepts, and core ideas. Washington, DC: The National Academies Press.

National Research Council. (NRC) (2013). Monitoring Progress Toward Successful K-12 STEM Education: A Nation Advancing?. National Academies Press.

National Research Council. (NRC) (2014). STEM integration in K-12 education: Status, prospects, and an agenda for research. National Academies Press.

National Science Board. (2010). Preparing the next generation of STEM innovators: Identifying and developing our nation's human capital (NSB-10-33). Washington, DC: Government Printing Office.

National Science Foundation (NSF) (2003). Strategic Plan FY 2003-2008. Retrieved from http://www.nsf.gov/pubs/2004/nsf04201/FY2003-2008.pdf

National Science Foundation (NSF) (2016). Science and Engineering Indicators. Retrieved from https://www.nsf.gov/statistics/2016/nsb20161/uploads/1/nsb20161.pdf

National Staff Development Council (NSDC, 2013). NSDC standards: Learning communities.

Nazzal, N. (2015, February 9). People, not oil, UAE's real wealth. Gulf News. Retrieved from: http://gulfnews.com/news/uae/government/people-not-oil-uaes-real-wealth-1.1454065

Newell, G. E., Koukis, S. & Boster, S. (2007). Best practices in developing a writing across the curriculum program in the secondary school. Best practices in writing instruction, pp. 74-98.

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. Teaching and Teacher Education, vol. 21(5), pp. 509-523.

Nikirk, M. (2012). Teaching STEM to millennial students. Tech Directions, vol. 71(7), pp. 13-15.

Norris, S. (2016). Scientific inquiry processes: Doing Science. PowerPoint presentation at the STEM seminar, San Francisco, CA.

Nye, B., Konstantopoulos, S. & Hedges, L. V. (2004). How large are teacher effects?. Educational evaluation and policy analysis, vol. 26(3), pp. 237-257.

O'Connor, K. (2011). A repair kit for grading : 15 fixes for broken grades. Boston: Pearson.

O'Neill, T., Yamagata, L., Yamagata, J. & Togioka, S. (2012). Teaching STEM means teacher learning. Phi Delta Kappan, vol. 94(1), pp. 36-40.

Onwuegbuzie, A. J. (2000). Expanding the Framework of Internal and External Validity in Quantitative Research.

Onwuegbuzie, A. J. & Leech, N. L. (2005). On becoming a pragmatist researcher: The importance of combining quantitative and qualitative research methodologies. International Journal of Social Research Methodology: Theory & Practice, vol. 8, pp. 375-387.

Organisation for Economic Co-operation and Development (OECD) (2013). PISA 2012 Results in Focus: What 15 year olds know and what they can do with what they know. Retrieved from: http://www.oecd.org/pisa/keyfindings/pisa-2012-results-overview.pdf

Organisation for Economic Cooperation and Development. (n.d.). skills.oecd. OECD: Better Policies for Better Lives. Retrieved from http://skills.oecd.org/

Orlikowski, W. J. & Baroudi, J. J. (1991). Studying information technology in organisations: Research approaches and assumptions. Information systems research, 2(1), 1-28.

Ostler, E. (2012). 21st Century STEM education: A tactical model for long range success. International Journal for Applied Science and Technology, vol. 2(1), pp. 28-33.

Page, C. A., Lewis, C. W., Autenrieth, R. L. & Butler-Purry, K. (2013). Enrichment experiences in engineering (E3) for teachers summer research program: An examination of mixed-method evaluation findings on high school teacher implementation of engineering content in high school STEM classrooms. Journal of STEM Education: Innovations & Research, vol. 14(3), pp. 27-33.

Pang, J. & Good, R. (2000). A review of the integration of science and mathematics: Implications for further research. School Science and Mathematics, vol. 100, pp. 135-144.

Parsons, E. & Priola, V. (2013). Agents for Change and Changed Agents: The Micro-politics of Change and Feminism in the Academy. Gender, Work & Organisation, vol. 20(5), pp. 580-598.

Pasha-Zaidi, N. & Afari, E. (2016). Gender in STEM Education: an Exploratory Study of Student Perceptions of Math and Science Instructors in the United Arab Emirates. International Journal of Science and Mathematics Education, vol. 14(7), pp. 1215-1231.

Patton, M. (2002). Qualitative research and evaluation methods. (3rd ed.). Thousand Oaks, CA: Sage.

Pedretti, E. & Nazir, J. (2011). Currents in STSE education: Mapping a complex field, 40 years on. Science Education, vol. 95, pp. 601-626.

Pennington, R. (2014, January 14). Smart Learning Programme transforms education in UAE’s government schools. The National. Retrieved from: http://www.thenational.ae/uae/education/smart-learning-programmetransforms-education-in-uaes-government-schools

Pennington, R. (2015, October). Challenges of the Arab world addressed at the Beirut Institute summit. The National. Retrieved from http://www.thenational.ae

Perignat, E. & Katz-Buonincontro, J. (2017). From STEM to STEAM: Using Brain-Compatible Strategies to Integrate the Arts, by David A. Sousa and Tom Pilecki.(2013). Thousand Oaks, CA: Sage. 280 pp.

Peters-Burton, E., Lynch, S., Behrend, T. & Means, B. (2014). Inclusive STEM high school design: 10 critical components. Theory into Practice, vol. 53(1), pp. 64-71.

Pfeffer, J. & Sutton, R. I. (2007). Suppose we took evidence-based management seriously: Implications for reading and writing management. Academy of Management Learning & Education, vol. 6(1), pp. 153-155.

Pfeiffer, S. I., Overstreet, J. M. & Park, A. (2010). The state of science and mathematics education in state-supported residential academies: A nationwide survey. Roeper Review, vol. 32(1), pp. 25-31.

Pink, D. H. (2011). Drive : The surprising truth about what motivates us. New York: Riverhead Books.

Pinnell, M., Rowly, J., Preiss, S., Franco, S., Blust, R. & Beach, R. (2013). Bridging the gap between engineering design and PK-12 curriculum development through the use the STEM education quality framework. Journal of STEM Education: Innovations and Research, vol. 14(4), p. 28.

Pitt, J. (2009). Blurring the boundaries--STEM education and education for sustainable development. Design and Technology Education, vol. 14(1), pp. 37-48.

Pop, M. M., Dixon, P. & Grove, C. M. (2010). Research experiences for teachers (RET): Motivation, expectations, and changes to teaching practices due to professional program involvement. Journal of Science Teacher Education, vol. 21(2), pp. 127-147.

Porter, A. C., Garet, M. S., Desimone, L. M. & Birman, B. F. (2003). Providing effective professional development: Lessons from the Eisenhower program. Science Educator, vol. 12(1), p. 23.

Porter, A. C., Garet, M. S., Desimone, L., Yoon, K. S. & Birman, B. F. (2000). Does professional development change teaching practice? Results from a three-year study.

Prepare and inspire: K-12 (2010, September). Education in science, technology, engineering, and math (STEM) for America's future. Retrieved from http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcaststemed-report.pdf

President's Council of Advisors on Science and Technology (PCAST). (2010). Prepare and inspire: K-12 education in science, technology, engineering, and math (STEM) for America's future. Washington, DC: Author.

Prevost, A., Nathan, M., Stein, B., Tran, N. & Phelps, A. (2009). Integration of mathematics in pre-college engineering: The search for explicit connections. In Proceeding of the American Society of Engineering Education (ASEE) Annual Conference and Exposition. Austin, TX: ASEE.

Prime Minister's Office (PMO) (2010). Vision 2021: First Rate Education System. Retrieved from: http://www.vision2021.ae/en/national-priority-areas/first-rateeducation-system

Prince, M. J. & Felder, R. M. (2006). Inductive teaching and learning methods: Definitions, comparisons, and research bases. Journal of Engineering Education, vol. 95(2), p. 123.

Pryor, B. W., Pryor C.R. & Kang, R. (2016). Teachers' thoughts on integrating STEM into social studies instruction: Beliefs, attitudes, and behavioral decisions. The Journal of Social Studies Research, vol. 40, pp. 123-136.

Public Law 85-864. (1958). National Defence Education Act (NDEA). United States Statutes at Large, 72,1580 - 1605. Retrieved from http://wwwedu.oulu.fi/tohtorikoulutus/jarjestettava_opetus/Troehler/NDEA_1958.pdf

Puntambekar, S. and Kolodner, J. L. (2005). Toward implementing distributed scaffolding: Helping students learn science from design. Journal of Research in Science Teaching, vol. 42(2), pp. 185-217.

Puntambekar, S. & Hubscher, R. (2005). Tools for scaffolding students in a complex learning environment: What have we gained and what have we missed? Educational Psychologist, vol. 40(1), pp. 1-12.

Putnam, R.T. & Borko, H. (2000). What do new views of knowledge of thinking have to say about research on teacher learning? Educational Researchers, vol. 29, pp.4- 15.

Pwc (2016). Understanding the GCC Education Sector - a country by country guide. Country Profile: UAE. Retrieved from https://www.pwc.com/m1/en/industries/education/publications/education-country-profile-uae.pdf

Quinn, H., Schweingruber, H. & Keller, T. (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. Washington, D.C.: The National Academies Press.

Radhakrishna, R. B. (2007). Tips for developing and testing questionnaires/instruments. Journal of Extension, vol. 45(1). Retrieved from https://www.joe.org/joe/2007february/tt2.php

Ralston, P. A., Hieb, J. L. & Rivoli, G. (2012). Partnerships and experience in building STEM pipelines. Journal of Professional Issues in Engineering Education and Practice, vol. 139(2), pp. 156-162.

Rampey, B. D., Dion, G. S. & Donahue, P. L. (2009). NAEP 2008: Trends in academic progress. NCES 2009-479. Washington, D.C.: US Government Printing Office.

Rampino. (2012). Design research: between scientific method and project praxis. FrancoAngeli, Italy.

Rawlings, H.R. (2011). Framework for systematic change in undergraduate graduate STEM teaching and learning. AAU Undergraduate STEM Education Initiative. Retrieved from https://www.aau.edu/sites/default/files/STEM%20Scholarship/AAU_Framework.pdf. Accessed on December 23, 2017.

Reeve, E. M. (2014). STEM thinking! (cover story). Technology & Engineering Teacher, vol. 74(4), pp. 8-16.

Reid, K. & Feldhaus, C. (2007). Issues for universities working with K-12 institutions implementing prepackaged pre-engineering curricula such as Project Lead the Way. Journal of STEM Education, vol. 8(3&4), pp. 5-14.

Reinsvold, L. A., Reinsvold, R. J., Cleveland, L. M., Adams, W. K. & Keenan, S. M. (2014). Report of the 2013 Colorado STEM teachers' preparation symposium, University of Northern Colorado, May 2014.

Repko, A. F. (2009). Transforming an Experimental Innovation into a Sustainable Academic Program at the University of Texas–Arlington. T. Augsburg & S. Henry The politics of interdisciplinary studies: Essays on transformations in American undergraduate programs. Jefferson, NC: McFarland.

Reynolds, D., Yazdani, N. & Manzur, T. (2013). STEM high school teaching enhancement through collaborative engineering research on extreme winds. Journal of STEM Education:Innovations & Research, vol. 14(1), pp. 12-19.

Riechert, S. E. & Post, B. K. (2010). From skeletons to bridges & other STEM enrichment exercises for high school biology. American Biology Teacher (National Association of Biology Teachers), vol. 72(1), pp. 20-22.

Rittmayer, A. & Beier, M. (2008). Overview: self-efficacy in stem. Manuscript submitted for publication, College of Engineering, Rice University, Houston, TX, Retrieved from http://www.engr.psu.edu/awe/misc/ARPs/ARP_SelfEfficacy_Overview_122208.pdf

Rivkin, S. G., Hanushek, E. A. & Kain, J. F. (2005). Teachers, schools, and academic achievement. Econometrica, vol. 73(2), pp. 417-458.

Rockland, R., Bloom, D. S., Carpinelli, J., Burr-Alexander, L., Hirsch, L. S. & Kimmel, H. (2010). Advancing the "E" in K-12 STEM education. Journal of Technology Studies, 36(1), 53-64.

Roehrig, G. H., Moore, T. J., Wang, H. H. & Park, M. S. (2012). Is adding the E enough? Investigating the impact of K-12 engineering standards on the implementation of STEM integration. School Science and Mathematics, vol. 112(1), pp. 31-44.

Rogoff, B. (2003). The cultural nature of human development. New York: Oxford University Press.

Romance, N. R. & Vitale, M. R. (2012). Science IDEAS: A research-based K-5 interdisciplinary instructional model linking science and literacy. Science Educator, vol. 21(1), p.1.

Root-Bernstein, R. (2011, April 11). The art of scientific and technological innovations [Blog post]. Retrieved from Art of Science Learning website: http://scienceblogs.com/art_of_science_learning/2011/04/11/the-art-of-scientificand-tech-1/

Roth, G., Kanat-Maymon, Y. & Bibi, U. (2011). Prevention of school bullying: The important role of autonomy-supportive teaching and internalization of pro-social values. British Journal of Educational Psychology, vol. 81(4), pp. 654-666.

Rousseau, D. M. (2006). Is there such a thing as “Evidence-Based Management”? Academy of Management Review, vol. 31(2), pp. 256-269.

Rowan, B., Chiang, F. & Miller, R. (1997). Using research on employee’s performance to study the effects of teacher on students’ achievement. Sociology of Education, vol. 70, pp. 256-284.

Rushefsky, M. E. (2002). Public policy in the United States: At the dawn of the twentyfirst century. Armonk, NY: M. E. Sharpe.

Sabatier, P. A. (2007). The need for better theories. In P. A. Sabatier (Ed.), Theories of the policy process, 9-24. Boulder, CO: Westview Press.

Sabol, T. J., Hong, S. S., Pianta, R. C. & Burchinal, M. R. (2013). Can rating pre-K programs predict children's learning?. Science, vol. 341(6148), pp. 845-846.

Sadler, T. D. (2004). Informal reasoning regarding socioscientific issues: A critical review of research. Journal of research in science teaching, vol. 41(5), pp. 513-536.

Sadler, T. D. (2011). Situating socio-scientific issues in classrooms as a means of achieving goals of science education. TD Sadler (Ed). Socio-scientific Issues in the Classroom: Teaching, Learning and Research (pp. 1-10).

Sadler, T. D. & Zeidler, D. L. (2005). Patterns of informal reasoning in the context of socioscientific decision making. Journal of Research in Science Teaching, vol. 42, pp. 112-138.

Sadler, T. D., Barab, S. & Scott, B. (2007). What do students gain by engaging in socioscientific inquiry? Research in Science Education, vol. 37(4), pp. 371-391.

Sahin, A. (2013). STEM clubs and science fair competitions: Effects on post-secondary matriculation. Journal of STEM Education: Innovations & Research, vol. 14(1), pp. 5-11.

Sahin, A., Ayar, M., & Adiguzel, T. (2014). STEM Related After-School Program Activities and Associated Outcomes on Student Learning. Educational Sciences: Theory & Practice, 14(1); 309-322.

Sahin, A. & Top, N. (2015). STEM Students on the Stage (SOS): Promoting student voice and choice in STEM education through an interdisciplinary, standards-focused, project based learning approach. Journal Of STEM Education: Innovations & Research, vol. 16(3), pp. 24-33.

Sahoo, S. (2016). Education Ministry makes seven-year deal with McGraw-Hill Education for schools' maths and science. Retrieved from https://www.thenational.ae/business/education-ministry-makes-seven-year-deal-with-mcgraw-hill-education-for-schools-maths-and-science-1.151273

Salzman, H., Kuehn, D. & Lowell, L. (2013) Guestworkers in the high-skill U.S. labour market: An analysis of supply, employment and wage trends in the IT labour market. Economic Policy Institute. Briefing Paper No. 359) Retrieved from http://www.epi.org/publication/bp359-guestworkers-highskill-labour-marketanalysis/.

Sanders, M. (2009). STEM, STEM education, STEMmania. Technology Teacher, vol. 68(4), pp. 20-26.

Sanders, M. (2012, December 8). Integrative STEM education as “best practice”. Retrieved from http://www.teachmeteamwork.com/files/sanders.terc-paper.pdf

Santos, W. L. P. D. (2009). Scientific literacy: A Freirean perspective as a radical view of humanistic science education. Science Education, vol. 93(2), pp. 361-382.

Sapru, R. K. (2010). Public policy: Art and craft of policy analysis. New Delhi: PHI Learning Pvt. Ltd.

Satchwell, R. & Loepp, F. L. (2002-Spring). Designing and Implementing an Integrated Mathematics, Science, and Technology Curriculum for the Middle School. Retrieved from Journal of Industrial Teacher Education: http://scholar.lib.vt.edu/ejournals/JITE/v39n3/satchwell.html.

Saudi Ministry of Education. (2010). The National Strategy for the Development of Public Education.

Schmidt, C. D., Hardinge, G. B. & Rokutani, L. J. (2012). Expanding the school counselor repertoire through STEM-focused career development. Career Development Quarterly, vol. 60(1), pp. 25-35.

Schmidt, M. & Fulton, L. (2015). Lessons learned from creation of an exemplary STEM unit for K-12 teachers: A case study. In D. Slykhuis & G. Marks (Eds.), Proceedings of Society for Information Technology & Teacher Education International Conference 2015, 2866-2874. Chesapeake, VA: Association for the Advancement in Computing in Education (AACE).

Schunk, D.H. (2012). Learning theories: An educational perspective (6th ed.). Boston, MA: Pearson Education.

Schwab, K., Sala-i-Martin, X. & Lopez-Claros, A. (Eds.) (2013). The Global Competitiveness Report 2013-2014. Geneva: World Economic Forum.

Scott, C. (2012). An investigation of science, technology, engineering and mathematics (STEM) focused high schools in the U.S. Journal of STEM Education: Innovations and Research, vol. 13(5), pp. 30-39.

Seidman, I. (2006). Interviewing as qualitative research: A guide for researchers in education and the social sciences. 3rd Ed. New York: Teachers College Press.

Settlage, J., Southerland, S. A., Smith, L. K. & Ceglie, R. (2009). Constructing a doubt-free teaching self: Self-efficacy, teacher identity, and science instruction within diverse settings. Journal of Research in Science Teaching, vol. 46, pp. 102-125.

Shabani, K., & Ewing, B.F. (2016). Applications of Vygotsky’s sociocultural approach for teachers’ professional development. Journal of Cogent Education, 3(1); 1-89.

Shafritz, J. M., Layne, K. S. & Borick, C. P. (2005). Classics of public policy. New York, NY: Pearson Education.

Sherrod, S. E., Dwyer, J. & Narayan, R. (2009). Developing science and math integrated activities for middle school students. International Journal of Mathematical Education in Science & Technology, vol. 40(2), pp. 247-257.

Shirish, T. (2013). Research Methodology in Education. Lulu Publication, USA.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, vol. 15(2), pp. 4-14.

Sidlauskiene, V. & Butasova, K. (2013). Designing gender equality as institutional transformation at a higher education institution. Gender Studies & Research, vol. 11, pp. 50-69.

Silverman, J. & Clay, E. L. (2009). Online asynchronous collaboration in mathematics teacher education and the development of mathematical knowledge for teaching. The Teacher Educator, vol. 45(1), pp. 54-73.

Singh, M., Han, J. & Woodrow, C. (2012). Shifting pedagogies through distributed leadership: Mentoring chilean early childhood educators in literacy teaching. Australasian Journal of Early Childhood, vol. 37(4), pp. 68-76.

Singh, R. (2016). The impact of intrinsic and extrinsic motivators on employee engagement in information organisations. Journal of Education for Library and Information Science, vol. 57(2), pp. 197-206.

Skinner, B. F. (1984). The shame of American education. American Psychologist, vol. 39(9), pp. 947.

Smith, K. B. & Larimer, C. W. (2009). The public policy theory primer. Boulder, CO: Westview Press.

Soules, A., Nielsen, S., LeDuc, D., Inouye, C., Singley, J., Wildy, E. & Seitz, J. (2014). Embedding multiple literacies into STEM curricula. College Teaching, vol. 62(4), pp. 121-128.

Spalding, E. (2002). Of organelles and octagons: what do preservice secondary teachers learn from interdisciplinary teaching?. Teaching and Teacher Education, vol. 18(6), pp. 699-714.

Spelt, E. J., Biemans, H. J., Tobi, H., Luning, P. A. & Mulder, M. (2009). Teaching and learning in interdisciplinary higher education: A systematic review. Educational Psychology Review, vol. 21(4), p. 365.

Spillane, J. P., Reiser, B. J. & Reimer, T. (2002). Policy implementation and cognition: Reframing and refocusing implementation research. Review of educational research, vol. 72(3), pp. 387-431.

Squires, A. & Mitchell, C. T. (2015, April). UNO EUREKA-STEM: Doing something about the double bind. Unpublished manuscript.

Stearns, L. M., Morgan, J., Capraro, M. M. & Capraro, R. M. (2012). A teacher observation instrument for PBL classroom instruction. Journal of STEM Education: Innovations and Research, vol. 13(3), pp. 7.

Steiner-Khamsi, G. (2010). The politics and economics of comparison. Comparative Education Review, vol. 54(3), pp. 323-342.

Stevenson, H. (2014). Myths and motives behind STEM (science, technology, engineering, and mathematics) education and the STEM-worker shortage narrative. Issues in Teacher Education, vol. 23(1), pp. 133-146.

Stickney, J. A. (2012). Judging teachers: Foucault, governance and agency during education reforms. Educational Philosophy and Theory, vol. 44(6), pp. 649-662.

Stohlmann, M., Moore, T. J. & Roehrig, G. H. (2012). Considerations for teaching integrated STEM education. Journal of Pre-College Engineering Education Research (J-PEER), vol. 2(1), pp. 28-34.

Stohlmann, M., Moore, T. J., McClelland, J. & Roehrig, G. H. (2011). Impressions of a middle grades STEM integration program. Middle School Journal, vol. 43(1), pp. 32-40.

Stone, J.R., III. (2012). Delivering STEM education through career and technical education schools and programs. Paper presented at the National Research Council Workshop on Successful STEM Education in K-12 Schools. Available at http://www7.nationalacademies.org/bose/STEM_Schools_Workshop_Paper_Stone.pdf.

Stone, M. L., Kent, K. M., Roscoe, R. D., Corley, K. M., Allen, L. K. & McNamara, D. S. (2017). The Design Implementation Framework. End-User Considerations in Educational Technology Design, vol. 76.

Streiner, D. (2003). Being inconsistent about consistency: when coefficient alpha does and doesn’t matter. Journal of Personality Assessment, vol. 80(3), pp. 217-222.

Strickland, D. (2012). Planning curriculum to meet the common core state standards. Reading Today, vol. 29(4), pp. 25-26.

Strobel, J. & van Barneveld, A. (2009). When is PBL more effective? A meta-synthesis of meta-analyses comparing PBL to conventional classrooms. Interdisciplinary Journal of Problem-based Learning, vol. 3(1), pp. 44-58.

Sturm, S. (2006). The architecture of inclusion: Advancing workplace equity in higher education. Harvard Journal of Law & Gender, vol. 29, pp. 247-334.

Sunyoung, H., Yalvac B., Capraro, M.M. & Capraro, R.M. (2015). In-service teachers' implementation and understanding of STEM project based learning. Eurasia Journal of Mathematics, Science, and Technology Education, vol. 11(1), pp. 63-76.

Symonds, W. C., Schwartz, R. & Ferguson, R. F. (2011). Pathways to prosperity: Meeting the challenge of preparing young Americans for the 21st century.

Tabari, R. (2014). Education Reform in the UAE: An Investigation of Teachers' Views of Change and Factors Impeding Reforms in Ras Al Khaimah Schools. Ras Al Khaima, UAE.

Tanenbaum, C. (2016). STEM 2026: A vision for innovation in STEM education. Retrieved from https://innovation.ed.gov/files/2016/09/AIR-STEM2026_Report_2016.pdf

Tashakkori, A. & Teddlie, C. (1998). Mixed methodology: Combining qualitative and quantitative approaches. Thousand Oaks, CA: SAGE.

Tavakol, M. & Dennick, R. (2011). Making sense of Cronbach's alpha. International Journal of Medical Education, vol. 2, pp. 53-65.

Taylor, H. A. & Hutton, A. (2013). Think3d!: Training spatial thinking fundamental to STEM education. Cognition and Instruction, vol. 31(4), pp. 434-455.

Tchangalova, N. (2009). “Jumping onto the Bandwagon: New Librarians Navigating the Science/Technology Librarianship.” Electronic Journal of Academic and Special Librarianship 10, no. 3 (Winter 2009), http://southernlibrarianship.icaap.org/content/v10n03/tchangalova_n01.htm

Teddlie, C. & Tashakkori, A. (2003). Major issues and controveries inthe use of mixed methods in the social and behvioral sciences. Handbook of mixed methods in social & behavioural research, pp. 3-50.

Teddlie, C. & Tashakkori, A. (2009). Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social and behavioral sciences. Los Angeles, CA: Sage Publications.

Teo, T. W. (2012). Building potemkin schools: Science curriculum reform in a STEM school. Journal of Curriculum Studies, vol. 44(5), pp. 659-678.

Teo, T. W. & Kaijie, J. K. (2014). Challenges in STEM teaching: Implication for preservice and inservice teacher education program. Theory into Practice, vol. 53, pp. 18-24.

The Connecticut Department of Labour (2012). Math & Science Knowledge and Skills: Catalysts for Future Economic Growth Within Connecticut. Retrieved from https://www1.ctdol.state.ct.us/lmi/pubs/math_science.pdf

The Executive Council (TEC). (2015). Dubai Plan 2021. Retrieved from: http://www.dubaiplan2021.ae/dubai--2021/

The National Academies Press (2010). Rising Above The Gathering Storm. Washington, D.C. Retrieved from www.nap.edu

The STEM Achievement Gap Strategic Planning Workgroup Report (2011). Retrieved from http://www.mnp20.org/working_groups/documents/December152011WorkingGroupReport-STEMAchievementGapFinal3Report.pdf

Thomas, N., Bystydzienski, J. & Desai, A. (2015). Changing institutional culture through peer mentoring of women STEM faculty. Innovative Higher Education, vol. 40(2), pp. 143-157.

Thompson, B. (2004). Exploratory and confirmatory factor analysis: Understanding concepts and applications. Washington, DC: American Psychological Association.

Topçu, M. S., Yılmaz-Tüzün, Ö. & Sadler, T. D. (2011). Turkish preservice science teachers' informal reasoning regarding socioscientific issues and the factors influencing their informal reasoning. Journal of Science Teacher Education, vol. 22(4), pp. 313-332.

Torp, L. & Sage, S. (2002). Problems as possibilities : Problem-based learning for K-16 education. Alexandria, Va.: Association for Supervision and Curriculum Development.

Tran, N.A., Nathan, M.J. (2010). Pre-college engineering studies: An investigation of the relationship between pre-college engineering studies and student achievement in science and mathematics. Journal of Engineering Education, vol. 99(2), pp. 143-157.

Trank, C. (2014). "Reading" evidence-based management; The possibilities of interpretation. Academy of Management Learning & Education, vol. 13(3). pp. 381-395.

Treffinger, D. J. & Isaksen, S. G. (2005). Creative problem solving: The history, development, and implications for gifted education and talent development. Gifted Child Quarterly, vol. 49(4), pp. 342-353.

Trend, R. (2009). Commentary: fostering students' argumentation skills in Geoscience Education. Journal of Geoscience Education, vol. 57(4), pp. 224-232.

Turner, K. B. (2013). Northeast Tennessee Educators' Perception of STEM Education Implementation (Doctoral dissertation, East Tennessee State University).

Turner, S. L. & Lapan, R. T. (2005). Evaluation of an intervention to increase nontraditional career interests and career-related self-efficacy among middle-school adolescents. Journal of Vocational Behaviour, vol. 66(3), pp. 516-531.

Tyack, D. B. & Cuban, L. (1995). Tinkering toward Utopia: A century of public school reform. Cambridge, MA: Harvard University Press.

U.S. Bureau of Labour Statistics (2017). Spot on Statistics. Retrieved from https://www.bls.gov/spotlight/2017/science-technology-engineering-and-mathematics-STEM-occupations-past-present-and-future/home.htm

U.S. Congress Joint Economic Committee. (2012). STEM education: Preparing for the jobs of the future (p. 17). A Report by the Joint Economic Committee Chairman's Staff Senator Bob Casey, Chairman. Retrieved from http://www.jec.senate.gov/public/index.cfm?a=Files.Serve&File_id=6aaa7e1f-9586-47be-82e7-326f47658320

U.S. Congress Joint Economic Committee. (2012). STEM education: Preparing for the jobs of the future. Washington, D.C.: U.S. Congress Joint Economic Committee.

U.S. Department of Commerce b. (2012). The competitiveness and innovative capacity of the United States. Retrieved from http://www.commerce.gov/sites/default/files/documents/2012/january/competes_010511_0.pdf

U.S. Department of Education (2016). Science, Technology, Engineering and Math: Education for Global Leadership U.S. Department of Education. Ed.gov. Retrieved from http://www.ed.gov/stemhttp://www.ed.gov/stem

UAE Cabinet (2014). UAE Vision 2021: United in ambition and determination.

UAE Government. (2012). Vison2021. 1st ed. Abu Dhabi, UAE: UAE Government.

Ujifusa, A. (2013, May 15). Standards supporters fighting back. Education Week, vol. 32(31).

Valtorta, C. & Berland, L. (2015). Math, science, and engineering integration in a high school engineering course: A qualitative study. Journal of Pre-College Engineering Education Research, vol. 5(1), pp. 15-29.

Van Manen, M. (1990). Beyond assumptions: Shifting the limits of action research. Theory into practice, vol. 29(3), pp. 152-157.

Vasquez, J. A. (2014). STEM beyond the acronym. Educational Leadership, vol. 72(4), pp. 10-15.

Vasquez, J. A., Sneider, C. I. & Comer, M. W. (2013). STEM lesson essentials, grades 3-8: Integrating science, technology, engineering, and mathematics. Heinemann.

Verger, A., Altinyelken, H. & Novelli, M. (Eds.) (2013). Global Education Policy and International Development New Agendas, Issues and Policies. Bloomsbury Publishing.

Vess, D. (2000). Explorations in interdisciplinary teaching and learning.

Vygotsky, L. (1978). Interaction between learning and development. Readings on the development of children, vol. 23(3), pp. 34-41.

Vygotsky, L. S. (1986). Thought and language (rev. ed.).

Vygtosky, L. S. (1962) Thought and language. Cambridge, MA: MIT Press.

Wang, H. H., Moore, T. J., Roehrig, G. H. & Park, M. S. (2011). STEM integration: Teacher perceptions and practice. Journal of Pre-College Engineering Education Research (J-PEER), vol. 1(2), pp. 2.

Wasserman, N. H. & Rossi, D. (2015). Mathematics and Science Teachers' Use of and Confidence in Empirical Reasoning: Implications for STEM Teacher Preparation. School Science & Mathematics, vol. 115(1), pp. 22-34.

Watt, H. M., Richardson, P. W. & Pietsch, J. (2007). Choosing to teach in the “STEM” disciplines: Characteristics and motivations of science, ICT, and mathematics teachers. Mathematics: Essential research, essential practice, vol. 2, pp. 795-804.

Weber, A. (2011). Arabic speakers’ use of English language course management systems: a case study. Learning and Teaching in Higher Education: Gulf Perspectives, vol. 8(1).

Weld, J. & Funk, L. (2005). “I’m not the science type”: Effect of an inquiry biology content course on preservice K-12 teachers’ intentions about teaching science. Journal of Science Teacher Education, vol. 16(3), pp. 189-204.

West, W. (2009). Research report: Situating the researcher in qualitative psychotherapy research around spirituality. Counselling Psychology Quarterly, 22.187.

White House. (2009). Educate to innovate campaign. Washington, DC: The White House. Retrieved from http: https://www.whitehouse.gov/the-press- office/president-obamalaunches-educate-innovate-campaign-excellence- science-technology-en

Whitehurst, G. J. (2002, March). Scientifically based research on teacher quality: Research on teacher preparation and professional development. In White House Conference on Preparing Tomorrow's Teacher.

Whittaker, J. A. & Montgomery, B. L. (2014). Cultivating institutional transformation and sustainable STEM diversity in higher education through integrative faculty development. Innovative Higher Education, vol. 39(4), pp. 263-275.

Wicklein, R. C. & Schell, J. W. (1995). Case studies of multidisciplinary approaches to integrating mathematics, science and technology education. Journal of Technology Education, vol. 6(2), pp. 59-76.

Wieman, C., Perkins, K. & Gilbert, S. (2010). Transforming science education at large research universities: A case study in progress. Change: The Magazine of Higher Learning, vol. 42(2), pp. 7-14.

Williams, J. (2010). Technology education to engineering: A good move? The Journal of Technology Studies, vol. 16(2), pp. 10-19.

Williams, J. P. (2011). STEM education: Proceed with caution. Design and Technology Education, 16(1), pp. 26-35.

Williford, A. P., Maier, M. F., Downer, J. T., Pianta, R. C. & Howes, C. (2013). Understanding how children’s engagement and teachers' interactions combine to predict school readiness. Journal of Applied Developmental Psychology, vol. 34(6), pp. 299-309.

Wilson, S. (Ed., 2009). Teacher quality (Educational policy white paper). Washington DC: National Academy of Education.

Wirt, F. M. & Kirst, M. W. (1989). The politics of education: Schools in conflict (2nd ed.). Berkeley, CA: McCutchan.

Wirt, F., Mitchell, D,. & Marshall, C. (1988). Culture and Education Policy: Analyzing values in state policy systems. Educational Evaluation and Policy Analysis, vol. 10(4), pp. 271-284.

Worker, S. & Mahacek, R. (2013). 4-H out-of-school-time STEM education. Children's Technology & Engineering, vol. 18(2), pp. 16-20.

World Bank. (2013). World Development Indicators 2013. Washington, DC: World Bank. doi: 10.1596/978-0-8213-9824-1.

World Bank. (2014). World Development Indicators 2014. Washington, DC: World Bank. doi: 10.1596/978-1-4648-0163-1

Wright, S. P., Horn, S. P. & Sanders, W. L. (1997). Teacher and classroom context effects on student achievement: Implications for teacher evaluation. Journal of Personnel Evaluation in Education, vol. 11(1), pp. 57-67.

Yanow, D. (1996). How does a policy mean?: Interpreting policy and organisational action. Washington, D.C.: Georgetown University Press.

Yin, R. (2011). Applications of case study research (3rd ed). Thousand Oaks: SAGE Publications.

Yin, R.K. (2014). Case Study Research: Design and Methods (5th ed.). Thousand Oaks, CA: Sage Publications, Inc.

Yoon, K. S., Duncan, T., Lee, S. W. Y., Scarloss, B. & Shapley, K. L. (2007). Reviewing the Evidence on How Teacher Professional Development Affects Student Achievement. Issues & Answers. REL 2007-No. 033. Regional Educational Laboratory Southwest (NJ1).

Zaatari, S. (2017). Education vital for switch to knowledge-based economy. Gulf News, 10 January. http://gulfnews.com/news/uae/education/education-vital-for-switch-to-knowledgebased-economy-1.

Zan, B. (2010). Introduction to collected papers from the seed (STEM in early education and development) conference. Beyond this Issue. Retrieved from http://ecrp.uiuc.edu/beyond/seed/intro.html

Zeidler, D. L. & Keefer, M. (2003). The role of moral reasoning and the status of socioscientific issues in science education. In The role of moral reasoning on socioscientific issues and discourse in science education (pp. 7-38). Springer Netherlands.

Zeidler, D. L. & Nichols, B. H. (2009). Socioscientific issues: Theory and practice. Journal of Elementary Science Education, vol. 21(2), pp. 49-58.

Zeidler, D. L., Sadler, T. D., Applebaum, S. & Callahan, B. E. (2009). Advancing reflective judgment through socioscientific issues. Journal of Research in Science Teaching, vol. 46(1), pp. 74-101.

Zeidler, D. L., Sadler, T. D., Simmons, M. & Howe, E. (2005). Beyond STS: A research based framework for socioscientific issues education. Science Education, vol. 89(3), pp. 357-377.

Zeidler, D. L.,Walker, K. A., Ackett,W. A. & Simmons, M. L. (2002). Tangled up in views: Beliefs in the nature of science and responses to socioscientific dilemmas. Science Education, vol. 86(3), pp. 343-367.

Zhang, L. J. (2008). Constructivist pedagogy in strategic reading instruction: Exploring pathways to learner development in the English as a second language (ESL) classroom. Instructional Science, vol. 36(2), pp. 89-116.

Zhe, J., Doverspike, D., Zhao, J., Lam, P. & Menzemer, C. (2010). High school bridge program: A multidisciplinary STEM research program. Journal of STEM Education: Innovations & Research, vol. 11(1), pp. 61-68.

Zollman, A. (2012). Learning for STEM literacy: STEM literacy for learning. School Science and Mathematics, vol. 112(1), pp. 12-19.

Zollman, A., Tahernezhadi, M. & Billman, P. (2012). Science, technology, engineering and mathematics education in the united states: Areas of current successes and future needs. International Journal of Science in Society, vol. 3(2), pp.103-111.

APPENDICES

APPENDIX 1: DOCUMENT ANALYSIS PROTOCOL

Date:
Document Title:
Document Type (learning outcome statement or assessment tool):
Source:
Document Number/Citation:
Summary of Document:
Why it is Important?
Which Research Question Does It Help Answer?
Key Exemplars/Quotes:
Does Document Discovery Need Follow Up?

APPENDIX 2: INTERVIEW SURVEY WITH TEACHERS

Dear instructor,
We request you to provide your views and perception about best practices associated with the success of STEM integration. This information is sought for research purpose only. Your identity and opinions will not be revealed to anyone.

1- What do you perceive as integrated STEM education? a) How would you define integrated STEM? b) What are the key components of integrated STEM?

2- In your opinion, what are the three biggest challenges in teaching or learning STEM?

3- What are the main advantages of teaching or learning in a STEM context?

4- What does it take to create integrated STEM education? a) What resources will it take to implement integrated STEM education? b) What changes in staffing do you see being needed to implement integrated STEM education? c) Any thoughts on teacher certification considerations? d) What about facilities, equipment, software, etc. e) Are there teacher preparation/professional development needs to be addressed in order to implement integrated STEM education? If so, what are they?

5- How does one implement integrated STEM education? a) Are changes in the structures of schools necessary for integrated STEM education to take place? If so, what? b) Whom do you see teaching integrated STEM education? c) Where does it fit into the curricular structure of schools?

6- How would you assess integrated STEM education? What would be the ideal forms of assessment? a) What assessment strategies would best fit integrated STEM curriculum? Why? b) How can integrated STEM be assessed to match current standards? c) How will an integrated STEM curriculum fit into the current standardised testing model found in education? d) How would ideal assessment strategies relate to national standards for the STEM disciplines?

7- Any additional comments on this topic:

APPENDIX 2: SAMPLE INTERVIEW SURVEY WITH TEACHERS (13)

Dear instructor,
We request you to provide your views and perception about best practices associated with the success of STEM integration. This information is sought for research purpose only. Your identity and opinions will not be revealed to anyone.

1- What do you perceive as integrated STEM education? a) How would you define integrated STEM? b) What are the key components of integrated STEM?

Integrated STEM education is when you take multiple discipline contents and you use the knowledge that you gain from those content areas and apply them toward problem solving.

2- In your opinion, what are the three biggest challenges in teaching or learning STEM?

Public education is very good at devaluing hands-on skills, but being able to take an electron microscope and being able to apply that in different areas, that should not be devalued

Lack of proper equipment such as labs for STEM

Challenges with teachers' professional development

Ineffective leadership- I think we need practical visionaries...Practical visionaries...What I mean by that are people who can lead and demonstrate.

3- What are the main advantages of teaching or learning in a STEM context?

Helps the learners to harness knowledge from different subjects and apply it to the real world

It involves a wider variety of individuals/partners

4- What does it take to create integrated STEM education? a) What resources will it take to implement integrated STEM education? b) What changes in staffing do you see being needed to implement integrated STEM education? c) Any thoughts on teacher certification considerations? d) What about facilities, equipment, software, etc. e) Are there teacher preparation/professional development needs to be addressed in order to implement integrated STEM education? If so, what are they?

It takes partnerships and collaboration and you need people to advise you…the partnership has to go outside the school doors. You have to reach out into the community. Your school board definitely has to be a part of that creative team as well.

It requires involving some of the community colleges to bring that expertise into your school.

Along with that business and industry partnership, they can also bring in people who have expertise that are not always available to a school and likewise they become your partner if you need equipment of any kind.

Professional development that needs to take place…Safety is one. Ethics is two and you have to get the professional development specific for the teacher who is in STEM.

5- How does one implement integrated STEM education? a) Are changes in the structures of schools necessary for integrated STEM education to take place? If so, what? b) Whom do you see teaching integrated STEM education? c) Where does it fit into the curricular structure of schools?

Along with that business and industry partnership, they can also bring in people who have expertise that are not always available to a school and likewise they become your partner if you need equipment of any kind.

It [integrated STEM] takes partnerships and collaboration and you need people to advise you. The partnership has to go outside the school doors.

6- How would you assess integrated STEM education? What would be the ideal forms of assessment? a) What assessment strategies would best fit integrated STEM curriculum? Why? b) How can integrated STEM be assessed to match current standards? c) How will an integrated STEM curriculum fit into the current standardised testing model found in education? d) How would ideal assessment strategies relate to national standards for the STEM disciplines?

We have not thought of all the possible assessment that we really can use.

Assessment needs to also take the questioning and put it at different levels, different thought levels through their students, and they need to know which ones address the higher learning, so that they are able to assess students in that

7- Any additional comments on this topic:

APPENDIX 3: INTERVIEW SURVEY WITH SCHOOL LEADERS

STEM Education is teaching and learning that:
• Aligns to the Engineering Design Process/Engineering Connections to engage students in a way of critical thinking, reasoning, collaborative teamwork, investigative and creative skills that are real-world and relevant to today's society
• Anchor to content in the areas of science, technology, engineering, and mathematics (STEM)
• Complements courses in the Arts, Career and Technical Education, English Language Arts, Healthful Living, Music, Social Studies, and World Languages and to Out-of-School programs

We need **co-ordinated efforts** to increase education **participation** in with **industry**, with support from the Scientist …… has commenced a strategic school – industry STEM partnership to assist in this area.

We need a greater focus on developing engaging and integrating curriculum as well significantly expanding our STEM-qualified teaching workforce. Now it is time to act for the UAE to become a strong STEM economy.

Leadership Domain

LD1-Is there a vision at your organisation for STEM education? Is your vision for STEM field informed by the latest research and based on exemplary practices? Kindly elaborate on the same.

LD2-What do you want to accomplish through embedding STEM in your organisation?

LD3-In what way does STEM contribute to lead the development of the overall ethos of the organisation?

LD4-How do you involve stakeholders at all levels in planning for STEM implementation, give me examples?

LD5- In the tertiary education sector, participation in STEM-related disciplines in the UAE is low in absolute terms and in comparison with other comparable nation, why?

LD6- In your opinion, how can the consistence of STEM reform efforts with other school/district reforms enhance public attitudes toward STEM reform?

Curriculum Domain

CD1-Does the school have systematic planning for STEM integration, practice and students' experiences in order to inform innovative curriculum design?

CD2-Does the school have access to a wide variety of resources that support cross curricular integration in a STEM context?

CD3- Does the school receive extra funds for purchasing equipment and supplies for STEM?

CD4 -Are there any National/District curriculum frameworks for STEM/ level of integration at your organisation?

CD5- Do you think having a proposed STEM framework can support the country National agenda in advancing STEM fields or disciplines from professional associations and industry group's perspective?

Pedagogical Knowledge and Engagement Domain - Middle leaders

The main areas that will be covered are:
Have a shared vision and clear pathway for developing the STEM integration.
Teacher opinions, teacher perceived importance, Instructional influences, teacher preparedness, frequency of use of effective pedagogy, student activities, parental support, principal support, and professional development experiences. Impact on outcomes

PN1-Do you think STEM teachers in the school are well supplied with materials for investigative instruction inherent in STEM.

PN2- Do you think teachers feel supported by colleagues to try out new ideas in teaching STEM teachers in this school?

PN3- Do teachers have time during the regular school week to work with peers on STEM curriculum and instruction?

PN4- Do you believe the STEM program in this organisation is strongly supported by local organisations, institutions, and/or business?

PN5- Is there a wide range of high quality ICT integration that has a strong impact on students' and teachers overall digital competencies?

PN6- Quality of available instructional materials.

Community Domain

COD1- One way of supporting STEM can be through sustained public and private investment at an appropriate level to keep it comparable with the best performing nations, how this can apply to the UAE context.

COD2- Acceptance by the community of the outcomes from STEM will only arise when the community has confidence in the UAE's STEM enterprise, how can we ensure this?

COD3- To what extent do politicians and researchers look ahead to the grand challenges of society and identify key, long-term research problems?

APPENDIX 4: CLASSROOM OBSERVATION CHECKLIST

<table>
<tr><th>Check list</th><th>Key indicators</th><th>Level of implementation</th></tr>
<tr><td></td><td>Project-based learning with integrated content across STEM subjects is evident in the classroom
• Collaborative opportunities
• Effective interactions between students
• Effective feedback for adjusting learning
• Effective interactions between teachers and students
• Rubrics and success criteria are clear</td><td></td></tr>
<tr><td></td><td>Inquiry-based learning is emphasised, along with the teaching of critical thinking and the scientific method.
• Questioning techniques
• Encouraging Curiosity
• Positive affirmation
• Safe learning environment for making mistakes
• Opportunities for think pair share
• Planning for reasoning skills
• Assessment for learning is embedded at various levels</td><td></td></tr>
<tr><td></td><td>Curricula and the corresponding syllabi reflect the transient and evolving character of the factual knowledge of STEM and provide a strong focus on the practice of STEM.
• Curriculum modification
• Curriculum adaptation
• Intervention plans
• Mid-term planning
• Scope and sequences
• Enrichment resources
• Long term planning
• Continuity and progression</td><td></td></tr>
<tr><td></td><td>The Classroom Culture domain fosters teacher's ability to create and facilitate a learning environment.
• Physical learning environment
• Resources
• Positive relationships
• Culture of creativity
• Effective feedback
• Learning environment
• Success celebration</td><td></td></tr>
<tr><td></td><td>Curricula is delivered to students in ways that encourage curiosity and reflection</td><td></td></tr>
</table>

	• Opportunities for reflection • Wait time • Differentiated instructions • Planning for language • Feedback • Thinking for oneself • the sequencing of instructional activities is planned for • Teacher gives attention to the pace of the lesson	

APPENDIX 5: QUESTIONNAIRE SURVEY WITH TEACHERS

Dear instructor,
We request you to provide your views about best practices associated with the success of STEM/STEAM integration. This information is sought for research purpose only. Your identity and opinions will not be revealed to anyone.

Section A: Demographics

Please provide the following information. Please circle one option that is applicable to you.

D1- Sector:
(a) Private (b) Public

D2- Campus name:
(a) Sharjah (b) Dubai (c) Abu Dhabi (d) Al Ain
(e) Fujirah (f) Ras Al Khaimah (g) Ajman

D3- Degree major:
(a) Maths (b) Engineering (c) Education
(d) Computer Science (e) Science (f) other

D4- Instructional level:
(a) Grade 9 (b) Grade 10 (c) Grade 11 (d) Grade 12

D5- Gender:
(a) Male (b) Female

D6- How many years have you been teaching in the STEM/STEAM field?
(A) 1 year (b) 2 years (c) more than 2 years.

Section B: Closed-ended questions

Part I

For each statement please circle "O" the option which most closely corresponds to your opinion with that statement.

		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1	STEM/STEAM helps students improve their understanding of problem solving across disciplines.					
2	STEM/STEAM helps students visualize the problems holistically rather than discretely.					
3	STEM/STEAM helps students to concentrate on deep understanding of the concepts involved.					
4	STEM/STEAM encourages students to think for themselves.					
5	STEM/STEAM encourages the development of my knowledge in cross-disciplinary teaching.					
6	STEM/STEAM creates opportunities for tailored learning preferences and capabilities.					
7	STEM/STEAM allows for providing helpful feedback on students' work.					
8	STEM/STEAM can be better improved if instructors have time to plan together.					
9	Due to STEM/STEAM, my interest in Engineering, Science, Math and Technology has increased.					

		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
10	I believe STEM/STEAM-based professional development could improve my instructional capabilities.					
11	STEM/STEAM increases my engagement and interaction with materials.					
12	STEM/STEAM is useful to strengthen student's project- based learning.					
13	STEM/STEAM is useful to strengthen students' problem- based learning					
14	I find teaching through STEM/STEAM is easy for me.					
15	STEM/STEAM provides students with investigative skills.					
16	STEM/STEAM is an enjoyable and stimulating approach for building content knowledge and competencies.					
17	I use some Apps to facilitate problem solving in STEM/STEAM disciplines with ease and efficiency.					
18	I am not as confident in teaching STEM/STEAM curriculum as I am with teaching each principle in discrete					
19	STEM/STEAM teaches students how to solve real life problems.					
20	Equipment, facilities, and resources are available in the classroom or at the					

		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
	college site to meet STEM/STEAM education goals, objectives, or standards.					
21	Professional development opportunities around STEM/STEAM are regularly provided to teachers in my organisation					
22	Technology is used throughout my STEM/STEAM program as a tool to facilitate research					
23	STEM/STEAM curriculum in my organisation is a multi –disciplinary (Concepts and skills are learned separately in each discipline but within a common theme)					
24	STEM/STEAM curriculum in my organisation is interdisciplinary (Closely linked concepts and skills are learned from two or more disciplines with the aim of deepening knowledge and skills).					
25	STEM/STEAM curriculum in my organisation is transdisciplinary (Knowledge and skills learned from two or more disciplines are applied to real-world problems and projects, thus helping to shape the learning experience).					
26	Business and industry partners are involved with STEM/STEAM education in my organisation.					

		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
27	A STEM/STEAM class or course in my organisation has equal emphasis regarding content (instruction) in the four disciplines/areas.					
28	STEM/STEAM assessment policy in my organisation has a clear structure for summative assessment only.					
29	STEM/STEAM assessment policy in my organisation has a clear structure for formative assessments only.					
30	STEM/STEAM assessment policy in my organisation has a clear structure for both summative and formative assessments.					
31	We received appropriate PD on best assessment strategies in the STEM/STEAM field.					
32	STEM/STEAM teachers collaborate often to reflect on student work. Leadership PD					
33	STEM/STEAM teachers meet with the STEM/STEAM coordinator to discuss strategies for using the results to inform instruction, and to co-create various measures of student success.					
34	My organisation promotes a culture of innovation and entrepreneurship in STEM/STEAM field amongst students.					

		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
35	As a teacher, I believe that I can connect concepts to those of engineering, science, and technology					
36	As a teacher, I believe that I can teach my content within an integrated STEM/STEAM framework					
37	As a teacher, I believe that I can develop new knowledge and skills necessary to teach subjects from within an integrated STEM/STEAM framework					
38	As a teacher, I believe that I can adapt to new teaching situations such as those necessary to teach subjects from within an integrated STEM/STEAM framework					
39	As a teacher, I believe that I can learn new technologies that will enable me to teach from within an integrated STEM/STEAM framework					
40	As a teacher, I believe that I can get students to experience excitement, interest, and motivation to learn about science, technology, engineering and mathematics connection to the real world					
41	As a teacher, I believe that I can develop different kinds of assessments to measure students' integrated knowledge of					

		Strongly agree	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
	STEM/STEAM at the end of an instructional unit					
42	As a teacher, I believe that I can play facilitator role and guide the students to learn and use their knowledge to learn mathematics within STEM/STEAM /STEAM framework					
43	As a teacher, I believe that I can access and use resources necessary to teach mathematics within an integrated STEM/STEAM/STEAM/STEAM framework					
44	As a teacher, I believe that I can obtain the materials necessary to teach mathematics through STEM/STEAM in an integrated way					

Thank you for your time!

APPENDIX 6: SELECTED DOCUMENTS FOR THE DOCUMENT ANALYSIS

NO	Context	Documents' Name	Purpose	Description
1	"Indiana, United States of America" (2012)	"Indiana's STEM initiative plan"	"A plan introducing the vision and mission of STEM in the Indiana Department of Education"	"This initiative plan introduces the Indiana's education department vision and a non-traditional model of education that enhances career preparation"
2	"United States of America" (2011)	"Successful K-12 STEM education schools"	"A project identifying effective approaches in STEM schools"	"This report was developed in response to a request from the National Science Foundation to recognise the highly successful k-12 schools and programs in STEM"
3	"California, United States of America" (2014)	"Innovate: A blueprint for STEM in California Public Schools"	"A report that was developed under the direction of professional learning support division as a recommendatory"	"This report has been developed to improve support for STEM teaching and learning in California, it also drafted a new vision and direction to provide access to high quality STEM practices."
4	"Massachusetts, United States of America" (2013)	"A foundation for the future Massachusetts' Plan for Excellence in STEM Education science, technology, engineering and math Version 2.0:	"An STEM plan report which is intended to catalyse a common movement across the Commonwealth that takes place at the local level in order to prepare citizens to be STEM	"The report outlines the plan which is based on community feedback that the STEM Council received from all levels of education, government, non-profits, and industry during the summer of 2013. The goals of the plan still have the same focus as our plan from 2010. New elements of the plan include trend data from 2009 through the present, concrete strategies that

		Expanding the Pipeline for All”	literate and to prepare the STEM Talent Pipeline.”	can be implemented at the local level, increased agency alignment, improved metrics, and greater inclusion of all students.”
5	“30 European Countries: (Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Greece, Hungary, Ireland, Israel, Italy, Latvia, Lithuania, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom)” (2015)	“Efforts to increase students’ interest in pursuing science, technology, engineering and mathematics studies and careers National measures taken by 30 countries – 2015 report”	“A report about national efforts to increase students’ interest in pursuing Science, Technology, Engineering, and Mathematics (STEM) studies and careers.”	“The report is the result of an analysis of country responses to a survey launched in the summer of 2015, addressing recent, current or planned priorities, policies and initiatives aimed at improving the relevance and quality of STEM education to encourage more students to study and choose a career in the STEM field. This year sees the inclusion of the largest number of countries to have yet taken part in the survey. The report is written within the framework of the project Scientix – the community for Science education in Europe. Scientix promotes and supports a Europe-wide collaboration among STEM (Science, Technology, Engineering and Mathematics) teachers, education researchers, policymakers and other STEM education professionals”
6	“Australia” (2015)	“National STEM school education strategy A comprehensive plan for science, technology,	“A report highlighted the trends that all education systems are grappling with – the performance of Australian	“The paper outlines the strategy to build on a range of reforms and activities already underway. It aims to better coordinate and target this effort and sharpen the focus on the key areas where collaborative action will deliver improvements to STEM education.”

		engineering and mathematics education in Australia”	students against international benchmarks has stalled or declined as has participation in senior secondary science and advanced maths”	
7	“Australia” (2013)	“Science, Technology, Engineering, and Mathematics in the National Interest: A Strategic Approach”	“A report outlining the prospectus of STEM education in Australia and its future impacts on Australian education”	“This paper outlines the strategy which is directed to the Australian Government. This is because it is the approach of the Australian Government and its expenditure profile that will have the most significant impact on STEM in Australia. It is important, however, that the States and Territories are consulted about relevant matters as policies and programs are developed. The pay-off will be greater if some proportion of State and Territory investments are aligned with that of the federal government”
8	“Australia” (2014)	“Science, Technology, Engineering and Mathematics: Australia’s future”	“A report outlining the prospectus of STEM education in Australia and its future impacts on Australian education”	“The report emphasises in boosting Australia’s focus on science, technology, engineering and maths at the heart of a country’s competitiveness and why it is important that Australia should not neglect science as they look at the general educational and training schemes.”
9	“Australia” (2014)	“Science, Mathematics, Engineering and	“A report outlining the prospectus of STEM education	“The report has been prepared for the Securing Australia’s Future / Australian Council of Learned Academies (SAF/ACOLA) STEM: Country

		Technology (STEM) in Australia: Practice, policy and programs”	in Australia and its future impacts on Australian education”	Comparisons Project. The report examines community attitudes to STEM, school student participation and performance in the enabling sciences and mathematics, vocational education and training (VET) and university student participation in STEM-disciplines, and STEM labour market shortages. The report provides a snapshot of Commonwealth, state and territory policy interventions to support science, technology, engineering and mathematics (STEM) through initiatives focused on schools, teaching quality, universities, the existing workforce, and science and innovation. The report does not examine issues regarding student engagement, identity or pedagogy, as these are addressed in Tytler et al, *Opening up pathways: Engagement in STEM across the Primary-Secondary school transition* (2008), nor does the report examine familial attitudes towards education generally (for example, the global theme of ‘helicopter’ parents), nor science and mathematics specifically”
10	“United Kingdom” (2011)	“Supporting STEM in schools and colleges in England The role of research A report for Universities UK”	“A report presenting the case studies for understanding the problem of STEM, teaching and learning – pedagogy in STEM, teaching and learning –	“The report was commissioned by Universities UK and GuildHE on behalf of the Teacher Education Advisory Group (TEAG). The report demonstrates the importance of education research to the sustainability of the STEM fi eld through its contribution to the development of the supply of young people with knowledge and skills in this area.”

			curriculum and resources, teaching and learning – assessment, and out-of-class support in STEM.”	
11.	“Japan” (2014)	“Consultant Report STEM Country Comparisons: Japan”	“A comprehensive report on national STEM policy in Japan”	“The report provides the overview of national STEM policy in Japan and overview of the role of science and technology in Japan’s modern and historical context and discusses key legislation. The report then provides detailed analysis of data gathered on Japanese students’ STEM performance as indicated by international comparisons such as PISA and TIMSS, attitudes toward STEM, participation in STEM at the primary, secondary and tertiary levels, career paths for STEM graduates, and the representation of women in STEM education, research and careers. The report then examines the strategies, policies and programs created and implemented by MEXT (the Japanese Ministry of Education, Sports, Science and Technology) along with other agencies”
12.	“25 economies including Saudi Arabia” (2016)	“Yidan Prize Forecast Education to 2030”	“A comprehensive report on how key inputs and outcomes of five education indicators across	“The report examined and forecasted shifting demographics (public expenditure on education and the affordability of tertiary education), the future of work and the skills needed to succeed (youth unemployment and STEM graduates), and the use of technology (Internet access in schools).”

			a mix of 25 economies will change over the next 14 years”	
13.	“Europe, Middle East and Africa (EMEA) countries” (2016)	“Science, technology, engineering and mathematics education in EMEA advancing the agenda through multi-stakeholder partnerships”	“A comprehensive report on STEM education in Europe Middle East and Africa (EMEA), highlighting specific country and regional practices, and make further recommendations”	“Through discussions with key experts, the report identified four major areas of work which can help address the situation of STEM education in Europe Middle East and Africa (EMEA) and improve interest in STEM education and careers: working with schools and teachers, engaging girls in STEM, widening the impact of science fairs, and building and sustaining effective partnerships.”
14.	“Turkey” (2017)	“Investigating the STEM Education Reform Through 4p Framework”	“A conference paper which examined the science teachers’ perceptions of STEM Education reform in Turkey.”	“The paper examined Bybee (1997; 2010) presented a model that uses the terms purposes, policies, programs, and practices to represent different education domains—in short, the 4Ps in order to locate issues, initiatives, and approaches to education reform in STEM education.”
15.	“Turkey” (2016)	“STEM Applications in Turkish Science High Schools”	“A research sponsored by Ministry of National Education, Turkey discussing on STEM projects and the vision for increasing the STEM education	“The report was initiated by examining Ankara Science High School project and the protocols at the establishment phase and the legislation in different ways. The numbers of high school graduates placed to STEM education in the university were reviewed. In addition, documents were conducted with Ankara Science High School graduates, students, and teachers. The report highlighted that in Turkey, public and private science high schools

			in Turkey and other developed countries”	contribute to the actualisation of 2023 targets by submitting qualified students to universities. For a better quality, the following suggestions should be considered. Curriculum needs to be changed to accelerate the transition from industrial society to the information society, so individuals should be trained for future technologies and professions. Labouratories in STEM High Schools should be updated. Physical conditions of high schools should be improved to the best level. Cooperation between alumni, students, parents, and schools should be strengthened.”
16.	“United Arab Emirates” (2014)	“UAE ECONOMIC Vision: Women in Science, Technology and Engineering”	“An Economist Intelligence Unit report, sponsored by the Advanced Technology Investment Company, it looks at the United Arab Emirates’ strategy for becoming a knowledge-based economy, with particular attention paid to the role women will play in science, technology and	“The research is based on a combination of extensive desk research, in-depth documents with independent experts and a survey of 394 UAE-based female students conducted in October and November 2013. Of these students, 85% are Emirati nationals and 70% are studying science, technology, engineering and mathematics (STEM)-related courses. The majority are in engineering (50%) at undergraduate level. Most respondents (82%) are between the ages of 18 and 24, but almost 13% have work experience in a science, technology and engineering (STE) environment. Here are the main conclusions of the report: The UAE has made admirable progress in empowering women; STEM education is the long-term solution to Emirati unemployment; STEM education is the long-term solution to

			engineering (STE) in the future."	Emirati unemployment; Female UAE-based STEM students view education as more than a means to make money; Perceptions of females studying and working in STE are evolving quickly; Women have made gains in STE work, but challenges still exist; Government efforts to empower women in STEM education will benefit the economy in the long-term"
17.	"United Arab Emirates" (2016)	"Building an Inclusive Society: Supporting Youth Employment and Development in the Innovation Economy"	"A Policy Council paper which discussed the gatherings of government partners, educators, and industry leaders regarding an exploratory discussion around the issues involved in achieving the goal of increasing participation among Emirati youth in UAE economic development, particularly in the innovation and knowledge economy and how STEM can play role in this pursuit."	"The report mainly discussed the following issues: 1)Define the desired forms of participation of youth in the new innovation economy 2) Define what youth inclusion might mean for the UAE as it embarks on achieving its 2021 vision 3) Understand the challenges facing youth inclusion in the new innovation economy 4) Discuss possible policy and other solution to youth inclusion in the UAE"

18.	"United Arab Emirates" (2015)	"Persistence in the Abu Dhabi STEM Pipeline: Preparing Emirati Youth for Careers in the UAE Innovation Economy"	"A study, conducted by the MBRSG and the Emirates Foundation, investigated the "leaks" in the STEM pipeline in the Emirate of Abu Dhabi and found that students in both schools and universities showed a great deal of enthusiasm for STEM subjects and careers. Many viewed STEM preparation as an appropriate way to support the UAE's national agenda."	"This report investigated the leaks in the STEM pipeline among Emiratis in Abu Dhabi. The government of Abu Dhabi's ambitious plans for the future necessitate a skilled and committed STEM workforce and so, understanding why talented Emirati students are not filling the ranks of engineering, science, and technology jobs is of utmost importance. The findings of hte paper indicated that while enthusiasm for science and for the direction that the country is moving toward is high, participation in STEM remains low. This could be explained by the high social cost that is associated with studying STEM and entering STEM careers. STEM careers are still viewed as being time consuming, difficult and demanding. The time spent on these activities is seen as reducing the quality and amount of time that one can spend on social activities such as spending time with friends and family. While the cost of participating in STEM is viewed as high, the reward is also viewed as high. The survey conducted as a part of the study, and among university students, found that, by and large, STEM students believed that jobs in the STEM labour market are of high quality (83%), and are highly available (85%). 88% were optimistic about finding jobs in that market. When asked if they felt prepared to enter the STEM job market, 89% reported that they did indeed feel prepared. Correlation analysis showed that

				attitude toward the quality and availability of STEM jobs was significantly correlated with students' intentions to pursue STEM careers. Among high school students, encouragement from parents was highly correlated with the desire to enter into STEM fields. This was also true for "science identities". The more that a student viewed themselves as a 'science person' or capable in the sciences, the more likely they were to want to continue on in STEM concentrations in university. Of course, interest in math and science was also a significantly correlated factor, suggesting that interest in math and science is closely related to students' enrolment in those fields."

APPENDIX 7: LABELLING OF QUESTIONNAIRE

Item No in Questionnaire	Description	Categories	Codes
7	STEM allows for providing helpful feedback on students' work.	Assessment	AS1
12	STEM is useful to strengthen student's project- based learning.	Assessment	AS2
13	STEM is useful to strengthen students' problem- based learning	Assessment	AS3
15	STEM provides students with investigative skills.	Assessment	AS4
28	STEM assessment policy in my organisation has a clear structure for summative assessment only.	Assessment	AS5
29	STEM assessment policy in my organisation has a clear structure for formative assessments only.	Assessment	AS6
30	STEM assessment policy in my organisation has a clear structure for both summative and formative assessments.	Assessment	AS7
41	As a teacher, I believe that I can develop different kinds of assessments to measure students' integrated knowledge of STEM at the end of an instructional unit	Assessment	AS8
19	STEM/STEAM teaches students how to solve real life problems.	Connection	C1
26	Business and industry partners are involved with STEM education in my organisation	Connection	C2
34	My organisation promotes a culture of innovation and entrepreneurship in STEM field amongst students.	Connection	C3
35	As a teacher, I believe that I can connect concepts to those of engineering, science, and technology	Connection	C4
36	As a teacher, I believe that I can teach my content within an integrated STEM framework	Connection	C5
1	STEM helps students improve their understanding of problem-solving across disciplines.	Curriculum and Delivery	CD1
2	STEM helps students visualize the problems holistically rather than discretely.	Curriculum and Delivery	CD2

3	STEM helps students to concentrate on deep understanding of the concepts involved.	Curriculum and Delivery	CD3
4	STEM encourages students to think for themselves.	Curriculum and Delivery	CD4
6	STEM creates opportunities for tailored learning preferences and capabilities.	Curriculum and Delivery	CD5
23	STEM curriculum in my organisation is a multi -disciplinary(Concepts and skills are learned separately in each discipline but within a common theme)	Curriculum and Delivery	CD6
24	STEM curriculum in my organisation is interdisciplinary(Closely linked concepts and skills are learned from two or more disciplines with the aim of deepening knowledge and skills)	Curriculum and Delivery	CD7
25	STEM curriculum in my organisation is transdisciplinary (Knowledge and skills learned from two or more disciplines are applied to real-world problems and projects, thus helping to shape the learning experience.	Curriculum and Delivery	CD8
27	A STEM class or course in my organisation has equal emphasis regarding content (instruction) in the four disciplines/areas.	Curriculum and Delivery	CD9
8	STEM can be better improved if instructors have time to plan together.	Leadership	L1
21	Professional development opportunities around STEM are regularly provided to teachers in my organisation	Leadership	L2
31	We received appropriate PD on best assessment strategies in the STEM field.	Leadership	L3
32	STEM teachers collaborate often to reflect on student work.	Leadership	L4
33	STEM teachers meet with the STEM coordinator to discuss strategies for using the results to inform instruction, and to co-create various measures of student success.	Leadership	L5
5	STEM encourages the development of my knowledge in cross-disciplinary teaching.	Pedagogical Content Knowledge	PCK1

9	Due to STEM, my interest in Engineering, Science, Maths and Technology has increased.	Pedagogical Content Knowledge	PCK2
10	I believe STEM-based professional development could improve my instructional capabilities.	Pedagogical Content Knowledge	PCK3
11	STEM increases my engagement and interaction with materials.	Pedagogical Content Knowledge	PCK4
14	I find teaching through STEM is easy for me.	Pedagogical Content Knowledge	PCK5
16	STEM is an enjoyable and stimulating approach for building content knowledge and competencies.	Pedagogical Content Knowledge	PCK6
18	I am not as confident in teaching STEM/STEAM curriculum as I am with teaching each principle in discrete	Pedagogical Content Knowledge	PCK7
37	As a teacher, I believe that I can develop new knowledge and skills necessary to teach subjects from within an integrated STEM framework	Pedagogical Content Knowledge	PCK8
38	As a teacher, I believe that I can adapt to new teaching situations such as those necessary to teach subjects from within an integrated STEM framework	Pedagogical Content Knowledge	PCK9
39	As a teacher, I believe that I can learn new technologies that will enable me to teach from within an integrated STEM framework	Pedagogical Content Knowledge	PCK10
40	As a teacher, I believe that I can get students to experience excitement, interest, and motivation to learn about science, technology, engineering and mathematics connection to the real world	Pedagogical Content Knowledge	PCK11
42	As a teacher, I believe that I can play facilitator role and guide the students to learn and use their knowledge to learn mathematics within STEM framework	Pedagogical Content Knowledge	PCK12
17	I use some Apps to facilitate problem solving in STEM disciplines with ease and efficiency.	Technology and Resources	TR1

20	Equipment, facilities, and resources are available in the classroom or at the college site to meet STEM education goals, objectives, or standards.	Technology and Resources	TR2
22	Technology is used throughout my STEM program as a tool to facilitate research	Technology and Resources	TR3
43	As a teacher, I believe that I can access and use resources necessary to teach mathematics within an integrated STEM framework	Technology and Resources	TR4
44	As a teacher, I believe that I can obtain the materials necessary to teach mathematics through STEM in an integrated way	Technology and Resources	TR5

APPENDIX 8: TABLE 28

Table 28- Demographic Characteristics of the Participants

		Count	**Percent**
Sector	Public	93	45.8%
	Private	108	53.2%
	Sub-Total	201	100.0%
Campus	Dubai	100	49.3%
	Al Ain	32	15.8%
	Sharjah	32	15.8%
	Abu Dhabi	21	10.3%
	Ras Al Khaimah	12	5.9%
	Ajman	5	2.5%
	Sub-Total	203	100.0%
Degree Major (ranked with highest)	Education	48	23.6%
	Science	47	23.2%
	Maths	36	17.7%

	Computer Science	34	16.7%
	Engineering	21	10.3%
	Others	16	7.9%
	Sub-Total	203	100.0%
Instructional Level (ranked with highest)	High School	121	59.6%
	Middle School	50	24.6%
	Primary School	16	7.9%
	Missing	9	4.4%
	Kindergarten	7	3.4%
	Sub-Total	203	100.0%
Gender	Male	104	51.2%
	Female	91	44.8%
	Missing	8	3.9%
	Sub-Total	203	100.0%
Years of Teaching	1 Year	31	15.3%
	2 Years	40	19.7%
	More than 2 Years	128	63.1%
	Missing	4	2.0%
	Sub-Total	203	100.0%

APPENDIX 9: TABLE 29

Table 29: Results of Classroom Observations

Check list	Key indicators	Level of implementation
✓	Project-based learning with integrated content across STEM subjects is evident in the classroom • Collaborative opportunities • Effective interactions between students • Effective feedback for adjusting learning • Effective interactions between teachers and students • Rubrics and success criteria are clear	High
✓	Inquiry-based learning is emphasised, along with the teaching of critical thinking and the scientific c method. • Questioning techniques • Encouraging Curiosity • Positive affirmation • Safe learning environment for making mistakes • Opportunities for think pair share • Planning for reasoning skills • Assessment for learning is embedded at various levels	High
✓	Curricula and the corresponding syllabi. • Curriculum modification • Curriculum adaptation • Intervention plans • Mid-term planning • Scope and sequences • Enrichment resources • Long term planning • Continuity and progression	Moderate
✓	The Classroom Culture domain fosters teacher's ability to create and facilitate a classroom environment. • Physical learning environment • Resources • Positive relationships • Culture of creativity • Effective feedback • Learning environment • Success celebration	High

✓	Curricula is delivered to students in ways that encourage curiosity and reflection • Opportunities for reflection • Wait time • Differentiated instructions • Planning for language • Feedback • Thinking for oneself • the sequencing of instructional activities is planned for • Teacher gives attention to the pace of the lesson	High

APPENDIX 10: CONTINUED LITERATURE REVIEW: THEORETICAL FRAMEWORK

2.1.4 Evidence Based Management

The theory of evidence-based decision-making was developed in the 1990s as a spin-off to the already developed theory of evidence-based medicine (Briner et al. 2009). Advocates of evidence-based decision-making recognise that practitioners must bring a consideration of context, stakeholders, and even ethics to the decision-making process (Trank 2014). Evidence-based decision-making promises more attainment of organisational goals, valid learning, and continuous improvement (Rousseau 2006). For this reason, it is essential that organisational managers begin to incorporate this practice into their management and leadership style.

Evidence-based decision making includes identifying systematic research and applying the research outcomes to everyday decision-making practices (Erez & Grant 2014). This approach encourages responsible people to make decisions based on the available scientific evidence (Erez & Grant 2014). Improving the utilisation of evidence-based decision making includes identifying and publishing the steps that can be taken for its practical application. This approach will provide managers with the framework for why evidence-based decision making practices are best suited for today's organisations (Cohen 2007).

Evidence-based decision making places a greater emphasis on inquiry, analysis, and data collection (Pfeffer & Sutton, 2007). Implementing evidence-based decision making starts by changing the culture and mind-set of the managers in the organisation. Managers must first learn how to identify and gather evidence-based information and apply it to a particular setting (Rousseau, 2006). The implementation of evidence-based decision making includes gathering scientific evidence, practitioner expertise, and organisation information to use the information to make an informed decision (Bennett, Kepes & McDaniel, 2014). The process of implementing evidence-based decision making includes the manager starting with a particular problem or issue, gathering and examining data and evidence to check the validity of the problem or issue, identifying external evidence from published research about the problem or issue, considering the views of individuals that were affected by the decision, and making a decision that considers the integration of the four sources of information (Briner et al., 2009). For managers to make the transformation to implementing evidence-based decision making, they must first incorporate a different process for interpreting organisational facts and begin applying scientific research to making decisions.

Arriving at the point of applying evidence-based solutions starts with informing managers about the process for translating scientific evidence into practice (Rousseau 2006). Scientific evidence refers to the gathering of external evidence or research that is relevant to the decision. Gathering scientific evidence starts with a review of systematic research for the purpose of guiding the decision (Bansal et al., 2012; Howard, Liang & Rasa, 2011). Evidence-based decision making is inclusive of making decisions based on information or data gathered from internal organisational sources or external scientific research and critically evaluating the data before utilising it for making the decision (Briner & Walshe, 2014; Fischer et al., 2014; Bennett et al., 2014).

In critical evaluation of the data is essential to determine which information is relevant to the decision at hand (Briner & Walshe, 2014). The positive aspects of the application of evidence-based decision making outweigh the time and effort that it may take managers to increase their awareness of the scientific facts. Evidence-based decision making leads to valid learning among employees and continuous improvement within the organisation (Rousseau, 2006).

Additionally, evidence-based decision making yields high-quality management decisions that are better implemented and it improves organisational goals (Rousseau, 2006). This information adds to the importance and significance of the inclusion of evidence-based decision making by today's managers (Rousseau, 2006).

Meta-analysis studies in education highlighted the importance of using the scale of the effect size measures to show the impact of educational practices on students' overall development (Hattie & Yates, 2013; Graen, 2009; McCarthy & Rousseau, 2007; Dollaghan, 2004; Mullen & Streiner, 2006). Hattie and Yates (2013) points out to the 0.4 hinge average and suggested that methods with an effect size above this average should be considered as a prioritised intervention in education. The nature of STEM education in encouraging collaborative and creative work as well as developing students' autonomous learning are identified as the top in the list of effective learning. Therefore, making decisions that incorporate the best research with decision maker expertise preferences will guide practices toward more desirable results (e.g., Mykhalovskiy & Weir, 2004; Mullen & Strainer, 2006). Notably, this argument can be extrapolated by the findings of a research done by Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt, and Wenderoth (2014). Freeman et al. (2014) contend that effect size highlights that examination performance by students and the conception of inventories augmented by 0.7 SDs through active learning; besides, the odds ratio regarding failing was approximated at 1.95 cognizant of lecturing. The findings depict that scores in average examinations improve by 6% during active studying, students in traditional learning settings have 1.5 times chances of failure compared to those in active learning. In this regard, the researchers concluded that active studying, which is the core of STEM education bolsters scores and it is effective when applied through all class sizes; however, greatest impacts are evinced in small classes (Freeman et al., 2014).

2.1.5 Sociocultural/Social Development Theory

Vygtosky (1962) posits a theory of Sociocultural/Social Development arguing that "construction of knowledge is the result of social interaction, interpretation, and understanding" (p.4). Vygtosky's theory pointed to experiential learning as the root of how humans learn (Anderson 2002). According to Vygtosky, the foundation of constructing knowledge should be sought in the conception of social interaction, which is co-constructed between a less and a more knowledgeable person and not in the mind. Similarly, knowledge construction is a facet that is mediated through sociocultural means and affected by the psychological and physical artefacts and tools (Shabani & Ewing, 2016). Learning through planned experiences with opportunities to analyse information and apply it in a real-world setting, known as constructivism, allows students to explore the many facets of the scientific method and problem-solving process. In addition, constructivist teaching practices have been proven to facilitate the higher-order thinking process and provide avenues for students to explore content with more meaning and depth in comparison to traditional teaching practices (Weld & Funk 2005). For effective learning to take place, students must be able to access social elements of learning if they are to develop a personal interpretation of learning. This interaction implies a need to focus on the learner rather than the subject matter (Adams 2006). Emphasising the role of others in the individual construction of knowledge proves the social process of learning. Given the complexities of the transnational educational approach, constructivism can be useful in informing curriculum development and teaching strategies in a multicultural, globalised environment where interests of alliance partners must shape educational practices. Vygtosky's emphasis on the social context of learning may be applied to internationalised higher education because of the insights into the role of culture and society (Jones & Brader-Araje 2002).

Vygotsky (1962) emphasized the development of self through educational practice that incorporated effective social connection and meaningful communication within the context of that connection (Alterio & McDrury 2003). In general, social-cultural constructivists like Vygotsky are most concerned with the communication practice and the influence of social factors when building of knowledge. In his theory of the "Zone of Proximal Development", he observed that when children were learning tasks on their own they did not do as well when tested as they did when they were learning by engaging with others to learn the task. He added that the development of language and verbalization of ideas was key in the process of learning and development.

The basic premise behind Vygotsky's social development theory is that "it indicates the importance of reasoning and language development in the zone of proximal development, specifically interactions with adults and participation in language-rich environments" (Schunk 2012, p.242). Teacher-child interactions and interactions with peers are the foundational ways children learn (Bodrova, Germeroth & Leong 2012; Bodrova & Leong 2005; Comparini, Douglas & Perez 2014; Hazen & Black 1989; Köymen, Rosenbaum & Tomasello 2014; Williford et al. 2013). Emotionally supportive classrooms with positive climate, teachers who are sensitive to children's needs, and have regard for student perspectives increase language skills in preschool students. Instructional supports such as concept development, language modelling, and quality of feedback also increases language and reasoning development in preschool age students (LaParo et al. 2008.; Justice et al. 2008; LaParo, Pianta & Stuhlman 2004; Sabol et al. 2013; Williford et al. 2013).

Sociocultural learning, attributed to the philosophies of Lev Vygotsky, plays a key role in teaching both teamwork and stretching students beyond their comfort zone into what Vygotsky calls the zone of proximal development (Schunk 2012). “Vygotsky considered the social environment critical for learning and thought that social interactions transformed learning experiences” (Schunk 2012, p. 242). Schunk (2012) explained that Vygotsky’s philosophy held that students independently solving problems could enhance their understanding through collaboration with more capable peers. In this learning theory, “learners bring their own understandings to social interactions and construct meanings by integrating those understandings with their experiences in the construct” (Schunk 2012, p. 244). Much as Socrates and Plato utilised social interactions to deepen understanding, today’s science classrooms utilise collaborative interactions in a social setting to help students reason together. This methodology, credited to the work of Vygotsky, allows students and teachers to interact and collaboratively expand their knowledge base.

Vygotsky is also credited with the pedagogical practice of scaffolding (Puntambekar & Hubscher 2005). Originally this approach provided both instructional support and limited external factors to enhance learning in the specified context (Puntambekar & Hubscher 2005; Schunk 2012). Today, “the scaffolding construct is being applied more broadly, to include the support provided in technology tools, peer interactions, and discussions aimed at the whole class” (Puntambekar & Hubscher 2005, p. 1). These new meanings for the term scaffolding do not always correlate with the original meaning of scaffolding and individualised instruction, which allow each student to maximise their learning and is difficult with today’s larger class sizes (Puntambekar & Hubscher 2005). Despite these restrictions for STEM courses, “techniques such as scaffolding and peer collaboration can help students be successful with challenging tasks and move beyond their current state of knowledge” (Honey et al. 2014, p. 4).

Sociocultural theory also addresses the fact that science is increasingly a dialogue with people of diverse backgrounds and cultural identities. “Students learn science when they are able to adopt scientific language, values, and social norms for the purpose of participating in scientific practices, such as inquiry and application of scientific concepts” (Anderson 2007, p. 18). However, understanding sociocultural diversity in science classrooms is difficult. “Science educators must struggle to see hidden sociocultural conflicts and to make use of the cultural resources that children bring to science learning” (Anderson 2007, p. 19). Vygotsky’s sociocultural theories may have been more concerned with the internal social interaction of students and peers, but cultural differences and understandings of science, what is truth, and cultural incompatibilities must be considered in the multicultural classroom of the 21st century (Schunk 2012). “Though fundamental to all learning experiences, social and cultural experiences such as those which require students to work with each other and actively engage in discussion, joint decision making, and collaborative problem solving may be particularly important in integrated learning” (Honey et al. 2014, p. 4).

Barbara Rogoff’s work on human development is based on Vygotskian (1978) perspectives that development is understood through social interactions and social contexts that are mediated by cultural knowledge, practices, artefacts, and tools. Rogoff (2003) theorises that understanding human development requires examination of the cultural nature of everyday experiences. This includes studying “people’s use and transformation of cultural tools and technologies and their involvement in cultural traditions and the structures and institutions of family life and community practices” (Rogoff 2003, p. 10). According to Rogoff (2003), to understand the transformation of cultural tools, she suggests that it is imperative to "examine how [people] think about cultural processes and their relation to individual development" (p. 10). Rogoff (2003) outlined what she called "orienting concepts" for understanding cultural processes and how this influences the transformation of cultural tools and contributes to human development. She believes that, "humans develop through their changing participation in the sociocultural activities of their communities, which also change" (Rogoff 2003, p. 11). For instance, cultural tools can be a multitude of things that are greatly influenced by interactions and practices between individuals in the environment as well as the way culture and environment influences the people and usage of the tools (Rogoff 2003). This parallels with Rogoff (2003) in the way she described how humans acquire knowledge through observation and listening to others as they work together on shared tasks.

In other words, people play a significant role to the "creation of cultural processes and cultural processes contributes to the creation of people" (Rogoff 2003, p.4). Cultural tools thus are passed down and transformed by subsequent generations and through collaboration with members of the community (Rogoff 2003).

Adopting the sociocultural approach in the classroom requires educators to gain an understanding of the social, cultural, and historical contexts that influence children's lives (Jordan et al. 2009; Rogoff 2003). This includes incorporating children's intellectual assets into their learning experiences at school (Singh 2016).

According to Mercer and Howe (2012), "Children's intellectual achievements and failures are not just dependent upon their own efforts or discoveries, but the product of culturally-situated forms of social interaction. Knowledge is not just an individual possession but also the creation and shared property of members of communities, who use 'cultural tools' (including spoken and written language), relationships and institutions (such as schools) for that purpose" (p. 12).

From this sociocultural perspective, the way in which children think, learn, and develop individually and collectively can be understood by considering their language and its use as well as their communal and historical nature of human life (Mercer & Howe 2012). However, to make significant changes in the classroom aligned with the sociocultural approach, educators need to modify their practices and reposition the school's curricula in relation to children, families, and their communities (Rogoff 2003). For instance, this requires the school's curricula to connect to children's language, experiences and the skills that they have acquired in their social context outside the school. Notably, McClure, Guernsey, Clements, Bales, Nichols, Kendall-Taylor, and Levine (2017) affirms that children can and should participate in STEM learning in their early years; in fact, young kids are capable of studying STEM practices and conceptions than when they are grown. In perspective, an increasing number of researches indicate a relationship between early STEM experiences and success in respective subjects in later years. In this regard, the language of children regarding the various toys should be keenly studied to align the children towards STEM education. The communities in which children live and family members with whom they interact, play a fundamental role in shaping who they are as individuals and the skills and knowledge they bring to the classroom. Thus, the school's curricula need to relate to the children, families, and communities they live in. Also, it is imperative that educators integrate pedagogical strategies that include "dialogue, scaffolding and co-construction in relationships that resemble intellectual partnerships" (Singh et al. 2012, p. 68). Integrating these pedagogical strategies in the classroom is imperative for the sociocultural approach because it creates learning opportunities for children. Through dialogue, scaffolding, and co-construction, children and teachers work together to find meanings, rather than children solely obtaining facts. These pedagogical strategies give children the opportunity to make meaning of the world through discourse and collaboration with peers and teachers. This is in line with the sociocultural approach because Vygotsky “adapted his educational methods to the specific historical and cultural setting in which his students lived, [and as a result] they were able to combine their spontaneous concepts (those based on social practice) with those introduced by teachers in instructional settings” (Vygotsky 1986, p. 131). When the sociocultural approach is embedded in the institution, children are given the opportunity to integrate and apply their knowledge in the classroom and teachers facilitate their learning with various pedagogical strategies to increase their comprehension. However, such a transition requires institutional support and professional learning to create an environment that is in line with the sociocultural approach (Edwards, 2007; Singh, 2016).

2.1.6 Post Modernity and Global Economy

In “Paulo Freire’s Revolutionary Pedagogy” Arnett explains that postmodernity is an age “in which contention over virtue and power disparity are commonplace” (Freire, 2000, p.5). Arnett suggests that postmodernity suspends public consensus regarding any authority as the purveyor of knowledge. Therefore, science as the gauge of knowledge from the preceding era of modernity is no longer feasible to the diverse sensitivities of a postmodern society. Rather, the multiplicity of voices that are often at odds with each other lead to an emergence of individualism as a hallmark of the United States society’s current understanding of the world.

The competing narratives that define the postmodern era suggest that there is no consensus on a universal understanding of a world-view. In postmodernity, “the pluralisation of voices makes sense only if they can be heard in harmony—that is, if they represent consensus or can be brought into concerted cooperation” (Anderson, Cissna and Arnett 1994, p.61). In this case, the idea of STEM can only be heard if there is diversity among the participants including gender and students with disabilities. In so doing, the rights of all individuals could be advocated for and included in the policy frameworks, which foster their learning, interaction, and development. In the United States, the diverse and often divergent narratives of students and professors in the undergraduate classroom reflects the confusion among professors and students surrounding authority, as well as perceived rules of communication. Therefore, it is essential to teaching and learning to establish consensus about classroom communication between faculty and students; the STEM context demands a consensual agreement between the entire education shareholders.

Bok (2009) considers the historical moment in understanding today's university student, stating that "without some knowledge of the past one cannot fully appreciate which aspects of the undergraduate program are amenable to change and which seem to stubbornly resist reform" (p.11). In fact, what began before the American Civil War as institutions that resembled "religious bodies and finishing school more closely than institutions of advanced education . . . [where] student behaviour was closely regulated both inside and outside the classroom" have become universities that "boast huge enrolments . . . [and] legions of faculty members and other instructors that fill their campuses today" (Bok 2009, p.12). This shift is significant to the communicative relationship between professor and student as tuition-driven universities are increasingly attentive to their enrolments in the United States, especially given the recent drop in student enrolment. Universities' competition for students, places students in the role of consumer. Many believe that this communicative relationship creates a conflict of interest that impedes teaching and learning.

The semantics of globalisation is highly elusive and complex. While it can be perceived as an external force directly imposed on national education systems and policies, it is also conceived as being voluntarily accepted, or negotiated within a nation's policy context

(Lingard & Rizvi 2013; Steiner-Khamsi 2010). However, most scholars agree that it is a global force that has had and continues to have a strong influence on national and transnational relationships (Dale 1999). Verger et al. (2013) characterise it as consisting of three main features, “hyperliberalism in the economic domain, governance without government in the political domain, and commodification and consumerism in the cultural one” (Verger et al. 2013, p. 5). Within the context of comparative education, Steiner-Khamsi (2010) defines the term as the “travel of educational reforms from one cultural context to another” (p.3).

In the 1980s with the fall of Keynsian economics, the rise of neoliberal economics driven by global powers and the introduction of critical theories saw government policies including those in education shift from ‘rationalist’ and prescriptive to more market-driven policies influenced by global forces and processes of globalisation. This phase also brought about a restructuring in how states function from bureaucratic towards “‘new public management’ or ‘corporate managerialism,’…” whereby “…changes in the structure and modalities of the state almost invariably imply new production rules for education policy in relation to both its content and its processes” (Lingard 2013, p.10-11).

Despite changes in the role of the state in driving public policy, the state still holds traditional authority that both justifies the implementation of certain policies and governs through the use of policies. However, the drivers behind new policies and ideas are no longer restricted to the nation state alone; they are increasingly driven by powerful international and supranational organisations promoting global discourses (Mundy, 2007; Steiner-Khamsi, 2004).

This context has opened up the doors for new actors to participate in the policy process, many of whom come from the private sector. “The new state formation, new managerialism, and new public/private sector relations have been described as ushering in a transition from government to governance” (Lingard 2013, p. 17). Jessop (2002) defines this process as the “hollowing out of the state,” where not only is the policy process more inclusive of other local, transnational, and other non-state actors and networks, it is also more driven by global and economic values of competitiveness and human capital production while promoting new public/private sector relations in STEM education.

Local particularities of policies tend to be one of the tensions that run through policy making and policy enactment in order to derive the commonalities and general patterns across localities (Ball, 2016). This emphasis is central to this study to attend to the general features in contemporary international education and the process of translation those common practices into national settings. Postmodernity is characterised by the way a person responses to the conditions of the society. Most forms of the postmodernity theory are fiercely associated with the globalisation movement and the representation of society demands in political and educational power structure. Postmodernism is a cultural paradigm that signifies the special cultural economic paradigm in order to nurture particular conditions of receiving knowledge and the special relationship amongst its elements. According to Moghaddam and Redzuan (2012) postmodernism and globalisation are inspired by post-structuralism within the scientific realms’ mainstream. Those views however aim at moving ahead in a collective and harmonistic manner to develop countries and strengthen the dominance of the world capitalism. Amid disagreements about the way to teach our students the value of global education to ascertain success of today’s young people, professionals and educators persevere to agree upon the vital importance of enabling those students to thrive in the global workplace and leverage the appropriate skills and talents for navigating in a competitive landscape in an age of international connectedness.

Policy makers, educators and industries are working interconnetedly influenced by the evolving global economy and the skills people need to participate in it. The emergence of STEM education decreases the gap between K-12 and the social and economic changes based on number of characteristics that have implications for career development. A broad set of hard and soft skills are equally important and carefully embedded in the context of STEM approaches. In addition, the ability to learn continuously throughout life need flexibility, creative thinking, conflict resolution and the capacity for innovation. To some extent, STEM curricular designers are harnessing the power to centre on the general skills for one's career development within the wider global and local context (Ahmed, 2016).

At present, the communication in the classroom between professor and students is varied. Some professors make complete use of technology in their classrooms, while others maintain a dialogic style in a very rudimentary tradition. Jeff Stickney asserts that, "in higher education today there is no reigning theoretical orthodoxy that exerts its primacy over or hegemony over all other theoretical frameworks" (Stickney, 2012, p.328). Technology, the different styles of learning between professor and student (each incorporating rhetoric differently), as well as an increasingly diverse population of learners in a postmodern society elucidates the differences that exist and why they may pose challenges to learning in the classroom. Understanding the differences brought on by technology in the 21st century help to situate the ways in which students obtain their information (Stickney, 2012).

APPENDIX 11: CONTINUED DEFINITION OF CONCEPTS AND TERMS

According to Herschbach (2011), most people were taught, and are being taught today, with subjects in "silo," or with little to no integration of disciplines, each subject is given allotted time during the school day, and that is the only time students generally utilise skills from that area. This can be referred to as "S-T-E-M," with the hyphens indicating each discipline as separate from each other (Dugger and Fellow 2011). Dugger and Fellow (2011) pointed out several techniques that require some integration. One way is to teach all four STEM subjects, but emphasise one or two subject more than others. For example, if science and mathematics were emphasised more than technology and engineering, this would be referred to as 'SteM' (Dugger and Fellow 2011). Dugger and Fellow (2011) noted this is the most common method currently used in U. S. schools. Another technique is to integrate three of the disciplines into one of the subjects being taught, such as integrating math, science and technology into an engineering course. Finally, according to Dugger and Fellow (2011), the most complete model of delivery would be to "infuse all four disciplines into each other and teach them as integrated subject matter" (p. 5). This is sometimes referred to as "immersion."

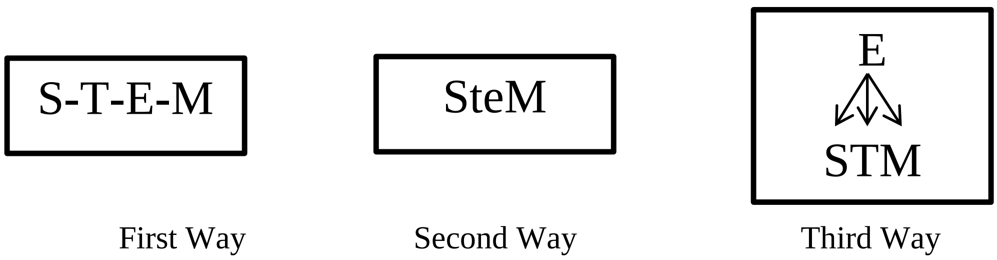

Figure 19: "The different ways of Interdisciplinary STEM (Dugger & Fellow 2011)".

Dugger and Fellow (2011) stated the evolution of STEM and implementation and momentum in the United States was due to: the emphasis of the National Science Foundation (NSF); federal funding; some states including "T and E" in offerings; evolution and implementation of content standards in all areas for K-12; ITEEA name change. Dugger and Fellow (2011) indicated a "promising future" in the STEM movement. Several authors indicated the federal, and in some cases, state governments committed significant resources to support STEM education in the K-12 setting. Yet, schools lagged in implementation of comprehensive STEM curriculum. Also, there was disparity how STEM was implemented in various school districts across the United States. STEM articles recently bemoaned the fact of the missing “T and E” in many STEM adoptions noting a distressing number curricular solution in schools being limited to science and math and to a lesser amount engineering (Cavanagh 2008; Katehi 2009; Katehi et al 2009; Murray 2007).

The Rowan University Study by DeJarnette (2012), *America's Children: Providing Early Exposure to STEM Initiatives*, demonstrated that STEM implementation in the critical K-12 school years prepares students for collaboration and problem solving which aligns to the 21st century workplace. DeJarnette (2012) looked at literature related to current initiatives and research regarding early exposure for students to STEM initiatives in the kindergarten grades and concluded that the interactive Problem-Based Learning activities found within an integrated STEM curriculum are innovative and exciting for students. She believes integrated STEM will create motivation for students to take advanced mathematics and science courses as well as consider STEM careers.

Hansen and Gonzalez (2014) surveyed practitioners and STEM advocates to construct a comprehensive definition for STEM. Results of their survey suggest that STEM education has four foundational principles. They state “STEM learning should integrate technology, reach across disciplines both within and beyond STEM fields, relate to authentic, or real-world, problems, and be based on project-focused tasks” (Hansen & Gonzalez 2014, p. 141). Through STEM related activities, intellectual goals should be embedded that emphasise reasoning, hypothesising, predicting, investigating, understanding and development of ideas (Katz 2010). Thus, integrating STEM into early childhood education involves not only providing children with meaningful experiences and content that promotes learning in science, mathematical thinking and engineering, learning experiences must also be infused with reflection, talk, representation, and documentation (Zan 2010). An appropriate scientific inquiry curriculum for young children that focus on these processes would encourage and motivate children to ask questions, observe, measure, sort and classify, predict, infer, communicate and document (Katz 2010; Norris 2016).

With an expectation for increased academic performance as a result of the National Common Core Curriculum, teachers must invest in new ways to present instruction to students. Rittmayer and Beier (2008) indicated that the College of Engineering at Texas A & M University exposed undergraduate students to an integrated STEM curriculum with math and science as its basis, and the study found that typical low-achieving students improved more dramatically in the areas of math and science over their high achieving peers. The STEM Achievement Gap Strategic Planning Workgroup Report (2011) supports the integration of STEM in K-12 learning experiences to assist in the understanding of the foundation skills of reading and mathematics and to prepare students for success in college and career. Charlie McLaughlin (2009), Chair of the Department of Educational Studies at Rhode Island College, states in *Technology and Children* magazine that STEM classrooms move students from memorizing discreet facts to experiencing inquiry with a focus on independent learning.

A review of the Common Core standards developed by many states across the United States of America (USA) was also a point of research in the literature review. The Common Core Curriculum standards (CCSS) increase the rigor and raise the educational expectations to align with college and career readiness. Standards that sweep across the United States ensure that all students, regardless of where they live or go to school, are exposed to and taught a unified set of skills and information. The Common Core curriculum initiative has created a common expectation of what students know, understand and are able to perform (Strickland 2012).

While the implementation of the Common Core curriculum has intended positive outcomes for students and the educational system in the United States as a whole, there are other residual effects to its enactment. Evans, Executive Director of the National Science Teachers Association (NSTA) has stated that Common Core will change the way teachers must instruct and finding appropriate professional development to support the changes will be a challenge (Ujifusa 2013). This paradigm shift in instructional practice will require greater content knowledge expertise and advancement in pedagogy. Gewertz (2013) wrote in *Standards Worrying Teachers*, Dickinson, Assistant Director of Educational issues for the American Federation of Teachers, indicated that teachers need more time to collaborate to unpack standards, analyse lessons and understand what the new instructional practice looks like.

The Common Core Curriculum is not a defined curriculum blueprint but instead a framework of expectations to prepare students to be college and career ready. More rigorous content expectations coupled with higher levels of knowledge application will prepare students to meet the demands of the new 21st century world. Higher levels of accountability for both students and teachers will result in greater learning outcomes and higher results (National Research Council 2014; Belland et al. 2017; Gehrke & Kezar 2017).

APPENDIX 12: HISTORICAL OVERVIEW OF STEM EDUCATION

Historical Overview of STEM Education

In many ways, STEM education has a long history in the United States dating back to almost the founding of the nation (Gehrke & Kezar 2017). The establishment of West Point Military Academy in 1802 had several purposes including the expectations that the institution's graduates would become the designers of the country's infrastructure like roads, bridges, and railroads (Jolly 2009). The nation's stake in STEM education continued with the Morrill Act of 1862. The purpose of the Morrill Act was to improve agriculture and work skills through the creation of land grant universities, but it had the additional consequence of developing science and engineering programs in all states (Butz & Science and Technology Institute Rand Corporation 2004).

The next big change in education policy related to STEM education happened in 1957 with the "launch of Sputnik by the Russians". With the "Cold War" raging, the National Defence Education Act of 1958 "mandated specific educational courses and strengthening of instruction related to mathematics, science, and foreign language interesting, but not surprising!" (Public Law 85-864 1958). Education continued to be impacted through governmental action with the "Elementary and Secondary Education Act of 1965 (Public Law 89-10)" being passed by the Johnson administration. With data showing that students in upper grades did substantially less well in mathematics in 1970 than in 1963, the 1970's again presented a change in educational philosophy with the "back-to-basics" movement that was different from the "new math" movement of the 1960's (Kolata 1977).

In 1983, the "National Commission on Excellence in Education" released the report, "A Nation at Risk". This report outlined a national crisis in American Schools related to mathematics and science. The report stated: "Our nation is at risk. Our once unchallenged pre-eminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world...If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might have viewed it as an act of war...We have, in effect, been committing an act of unthinking, unilateral educational disarmament" (National Commission on Excellence in Education 1983, p. 5).

This report again changed the educational landscape. It called for higher graduation requirements in core subjects including math and science. It recommended that K-12 and higher education adopt more “rigorous and measureable standards” and that expectations for student performance and conduct be raised (Graham 2013). The standards movement stemmed from this report, and subsequently the National Council of Teachers of Mathematics developed the *Curriculum and Evaluation Standards for School Mathematics* (NCTM 1989) and the National Research Council established Benchmarks for Science Literacy, *National Science Education Standards* (National Research Council, 1996).

Near the end of the last century, the U. S. Department of Education published a report that stated, “The rapid pace of change in both the increasingly interdependent global economy and in the American workplace demands widespread mathematics- and science-related knowledge and abilities” (Glenn, 2000, p. 7). This report further stressed “the need for children to achieve competency in mathematics and science” (Glenn, 2000, p.8).

The term “STEM” entered the common vernacular when “Dr. Judith Ramaley, assistant director of the Education and Human Resources Directorate”, first used it while at the National Science Foundation in 2001 (Chute, 2009). Previously, the acronym was “SMET” which did not have the positive connotations of the STEM acronym and it subtly implied that science and mathematics were better than technology and engineering (Chute 2009). Since then, the term “STEM” has spread far beyond the NSF (Chute, 2009).

One theme presented in these varied reports is that STEM education can lead an individual to employment that is valuable and important to the nation’s ability to be innovative. Another conception is that “people need to have a degree of technological literacy to be productive citizens whether they work in STEM fields or not” (National Academy of Engineering [NAE], 2014). This report by the National Academy of Engineering illustrates why STEM education is seen as critical to the prosperity of the United States in the future. According to NSF, NRC, and the NAE, the goal and standards of STEM education ensure that students acquire the learning required to understand how to manage natural resources, make meaningful decisions, and function in the world as responsible citizens (NSF 2016; NRC, 2011). “Drawing on research findings from fields such as neuroscience, cognitive science, social psychology, and human development” (p.54), the United States government affirms that literacy in the STEM disciplines is the driving force of technological advancement for the infrastructure needed to secure economic success in a competitive and innovative world (Watt, Richardson, & Pietsch, 2007). To meet the expectations of STEM education and prepare students to function successfully in the workforce, the United States Common Core policy is taking instruction in this direction (CCSS, 2012).

The integrated STEM education initiative attempts to incorporate all STEM disciplines into one course or to incorporate extensive collaboration and interdisciplinary efforts between two or more STEM courses. Kelley (2012) argues that “the history of technology education, engineering education” and the current STEM education movement are very similar. Kelley (2012) outlines a three-pronged structure that provides a history of how the current STEM subject integration approach to education has occurred. His three prongs include design–based education, project-based education, and subject integration.

Kelley (2012) argues that design-based education is one of the structures that lead to the current integrated STEM movement. Design-based education is based on the work of Heinrich Pestalozzi from the early 1800’s who believed children should be educated in a wide range of real-life situations using a hands on approach (Kelley, 2012). Later in the 1800’s, Fredrick Froebel, who was the father of modern day kindergarten (Kelley, 2012), built on Pestalozzi’s work. Adelman (2000) argues that Pestalozzi greatly influenced and inspired Froebel’s initial thoughts and practices. Froebel created a line of children’s toys that were boxed sets of blocks designed to teach children about symmetry and beauty (Coleman 2008).

Frank Lloyd Wright played with Froebel blocks and recalled them as formative. Wright believed that the Froebel blocks were critical to helping develop his design abilities (Brosterman, 1997; Coleman, 2008). Design based education was further championed by Frederic Bonser and Lois Coffey Mossman in the early 1900's when both of them emphasised the "need for students to design their own projects" (Kelley, 2012, p.6).

The second prong in the history of the integrated STEM education movement was project-based education. Its roots can be discovered at the Van Rensselaer Polytechnic Institute where practical applications of science and mathematics led to the "founding of a department of Mathematical Arts in 1835 for the purpose of giving instruction in Engineering and Technology" (Mann 1918, p. 12). Another "American school of engineering" that combined the theory and practice of engineering was the Worcester Technical Institute (now Worcester Polytechnic Institute) in Worcester, MA. It introduced the use of vocational skills to complete projects as part of the curriculum (Kelley 2012). Project-based learning continued to grow during the 20th century with the work of Kilpatrick and Dewey. Their approaches to learning argue for meaningful task-like, case-based instruction and project-based learning (Dewey 1938; Kilpatrick 1918). Project-based learning has continued to remain a focus in education with authors Dym et al. (2005) studying the "complexity of engineering design and how it is best taught" (p.12). These authors deem "project-based learning as the most favourable approach for teaching design in engineering education and further indicate that the best context for project-based learning is first year engineering education because it provides the opportunity for students to transfer learning from one experience to another" (Dym et al. 2005, p.21). In Czech Republic, for example, teacher training is an activity that has been decentralised with universities having augmented degree of autonomy. In this regard, universities have established novel methods to instigate initial teacher learning to strengthen the conception of inquiry-based technique (Kearney, 2016). This aspect if founded on Hejny method, which is associated to mathematics at the primary level. The Hejny method is aimed at allowing the kids to discover math by themselves and enjoy the procedures (Kearney, 2016).

The third leg of the STEM integration platform is subject integration pioneered by Lois Coffey Mossman, who wrote that “integration of school subjects could be accomplished through practical classroom activities” (Kelley, 2012, p.4). In order to study the category of STEM education, the framework for STEM education outlined by Kelley (2012) will be used. Kelley argues that three different educational movements; design-based education, project-based education, and subject integration; have combined in the form of today’s STEM education. This framework was chosen because it fits the problematic nature of STEM education found by Pitt. Project-based learning aligns with the concept of transfer of knowledge. Design-based education addresses pre-vocational learning and training. Finally, subject integration crosses the boundaries between STEM subjects. Subject integration again came to the forefront in the Math/Science/Technology (MST) movement of the 1990’s (LaPorte & Sanders, 1993). These authors state that “the MST approach would improve the status of technology education by its incorporation into the core subjects” (LaPorte & Sanders, 1993, p.64). Subject integration/project-based learning/design-based education is the backbone pedagogical methods for integrated STEM, and professional development would provide the necessary training. Specific evidence related to these links can be found in the “subject integration/project-based learning/design-based education” and professional development categories that are developed in the structural implementation categories section (Kelley, 2012). An example of a country that is integrating STEM education is Israel; as implicated by Kearney (2016), the country has numerous initiatives intended to augment employment of STEM teachers. For instance, the program to retrain engineers as teachers in the secondary schools for STEM disciplines. The programme is jointly implemented and intended for individuals with diplomas in electrical engineering, mechanical engineering, and electronics engineering (Kearney, 2016). In so doing, the ministry of education is making vast steps towards integrating STEM education among the teaching fraternity, which in turn boost the implementation of STEM initiatives in the classroom.

These three prongs, design based education, project-based education and subject integrated education, can all be seen in the current initiative of integrative STEM education as proposed by Sanders (2012). His view of integrated STEM education refers to a designed based learning approach that integrates the concepts of mathematics and science education intentionally with the concepts and practices of technology and engineering education. He believes that STEM education can be further improved by integrating it even further with other subjects like language arts, art, and social studies (Sanders, 2012).

Kelley's three-pronged structure for the history of STEM education shows that the underlying concepts of STEM education have existed throughout the history of the American educational system. It may not be in exactly the same form as the current integrated STEM initiative; however, parts of the current movement have surfaced in the past in response to challenges that are not that unlike the challenges of today.

APPENDIX 13: FURTHER FEATURES OF PROFESSIONAL DEVELOPMENT

Defining interdisciplinary teaching is not a simple task because the lines between disciplines have become more sharply defined during the last decade. Teachers in K-12 schools taught all of the basic subjects, teachers in middle and high school taught only a single subject or discipline. Regarding a definitive definition of an interdisciplinary approach to teaching, the construct has been defined as a way of approaching curriculum by "applying methods and language from more than one academic discipline to examine a theme, an issue, a question, a problem, or an experience" (Drake & Burns 2004, p.8). An interdisciplinary approach is about finding ways to link multiple content areas. Another definition of interdisciplinary teaching is learning that promotes understanding of knowledge and modes of thinking from more than one discipline to create a new understanding and or a more comprehensive answer. While the three pillars of integrative approaches- multidisciplinary, transdisciplinary, and interdisciplinary connect to each other, the difference between them is the degree of separation that exists between subject areas and their different goals (Jacobs et al. 2005). Moreover, according to Mahoney (1991) “an interdisciplinary approach to teaching and learning is not new; the method is based on a constructive approach” (p. 97). The literature review examined how interdisciplinary approaches can bring interconnectedness to the awareness of concept connections that exist among scientific disciplines. It also discusses the characteristics of interdisciplinary approaches and the benefits that interdisciplinary approaches bring to teachers and students.

The interconnectedness of science disciplines. Increased information that teachers and students should know, understand, and use makes meaningful connections and applications to new concepts. Real-world issues have created new demands and requirements for reform approaches in teaching and learning, especially in STM education (Moonesar & Mourtada 2015). Traditionally, as stated earlier, content disciplines are taught and assessed in separate entities. Evidence shows that with the new demands of science, engineering, and mathematics in the 21st century STEM Standards (Moonesar & Mourtada 2015), new approaches to science education have begun to focus on the interconnectedness of concepts in STEM disciplines. Interconnectedness in STEM disciplines refers to applying a practice to content knowledge that helps to connect science, technology, engineering, and mathematics concepts to the *“Big Ideas”* in each of the disciplines. Through professional development in an interdisciplinary approach, teachers can have opportunities to conceptualise and experience the interconnectedness of the STEM disciplines. Teachers’ knowledge and understanding of the interconnectedness of STEM disciplines will, in turn, be reflected in classroom practices (Moonesar & Mourtada 2015).

Interconnectedness is not new. In fact, interdisciplinary teaching has been one of the most current curriculum reform efforts of the past decade (Spalding 2002). For example, the convergence of the Life Sciences, Physical Sciences, and Engineering has been in place in K-12 for a long time and makes up the same scientific endeavour (AAAS 2012; Newell, Koukis & Boster 2007) for successive generations. This is to achieve an understanding of the human species and the environment through observing, experimenting, inferring, and validating. As previously mentioned, only in recent years has the urgent need for the United States to retain her place globally and to ensure that students are prepared to thrive in the modern workforce that reform movements such as the NRC, the NSTA, and AAAS have revisited and offered new standards and ways of teaching content disciplines. The new set of norms and expectations have emphasised the full use of the principles of scientific inquiry to instruction that research shows has the potential to enhance teaching and learning. Even so, studies indicate that students still need more knowledge and skills to be successful adults and to be more competitive with their foreign counterparts (Bybee 2010). Implementing teaching strategies, such as an interdisciplinary approach to instruction that research shows has the potential to enhance teaching and learning, and which has characteristics that meet the standards of Moonesar and Mourtada (2015) and the goal of STEM education, undoubtedly may improve student achievement in science. For this reason, an interdisciplinary approach is a preferred method for the proposed design of STEM professional development.

APPENDIX 14: BUiD letter

الجامعة البريطانية في دبي

The British University *in* Dubai

www.buid.ac.ae

12 April 2017

To Whom It May Concern

This is to certify that Ms Elaine Jamil Al Quraan with ID number 2014121109 is a registered student on the Doctor of Education programme in The British University in Dubai since September 2014.

Ms Al Quraan is currently working on her research titled "Exploration of STEM Reforms for Developing an Effective Large Scale, Research-based Policy in the UAE". She is required to gather data through surveys, interviews and lesson observations at IAT schools across the United Arab Emirates. Your permission to conduct her research in your organisation is hereby requested. Further support provided to her in this regard will be highly appreciated.

This letter is issued on Ms Al Quraan's request.

Yours sincerely,

Amer Alaya
Head of Student Administration

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