Investigating Teachers' perceptions and implementation of STEM Education in The United Arab Emirates

البحث في فهم وتطبيق المعلمين للتعليم في مجال العلوم والتكنولوجيا والهندسة والرياضيات في دولة الإمارات العربية المتحدة

by

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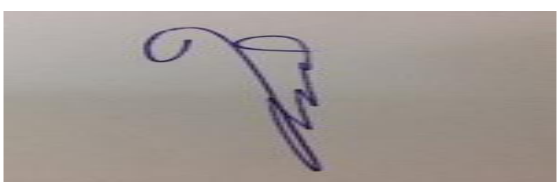

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Abstract

With the current international focus on enhancing and improving STEM education, the United Arab Emirates is one of the developing counties that is paying attention to STEM education. This study was conducted to investigate STEM-related subjects' teachers' perceptions and implementations in American-system schools in the UAE. No research has been conducted in the UAE context on this topic. A mixed-methods approach was used to collect data; a questionnaire was developed to examine the perceptions and practices of STEM education for (144) in-service teachers of science, mathematics, and technology, then it was supported by interviews with some of the teachers. Data analysis was presented. Results indicated that STEM education is well-perceived by majority of teachers in UAE, STEM is implemented through project-based learning as a part of curricula or as an activity per month or per term, engineering concepts are presented while engineering practices are underrepresented, successful collaboration and well-informed understanding of disciplines' core concepts are needed. In general; it was found that secondary and middle school teachers in the UAE showed positive perceptions and better implementing of overall STEM education than elementary school teachers.

Keywords: STEM education, integration, NGSS, collaboration, project-based learning, problem-solving.

الملخص

ينصب التركيز الدولي حاليا على تطوير وتحسين التعليم في مجال العلوم والتكنولوجيا والهندسة والرياضيات، وتُعد دولة الإمارات العربية المتحدة إحدى الدول المتقدمة التي تُولي اهتمامًا بالتعليم في مجال العلوم والتكنولوجيا والهندسة والرياضيات، وقد أجريت هذه الدراسة بهدف الوقوف على تصورات معلمي المواد وثيقة الصلة بهذا المجال، وتطبيقات تعليم العلوم والتكنولوجيا والهندسة والرياضيات في مدارس النظام الأمريكي داخل دولة الإمارات. علمًا بأنه لم يسبق إجراء أي أبحاث حول هذا الموضوع في السياق الإماراتي، فيما تُوخي نهج قائم على طرق مختلطة في جمع البيانات، وأُجري استبيان لدراسة تصورات وممارسات تعليم العلوم والتكنولوجيا والهندسة والرياضيات لدى (144) معلم علوم وتكنولوجيا وهندسة ورياضيات في الخدمة، ومن ثم دُعّم بمقابلات مع بعض المعلمين، وتم إجراء تحليل للبيانات.

وقد أشارت النتائج إلى قبول لدى المعلمين في دولة الإمارات لتعليم العلوم والتكنولوجيا والهندسة والرياضيات. يُطبق تعليم العلوم والتكنولوجيا والهندسة والرياضيات من خلال التعلم القائم على المشاريع كجزء من المنهج الدراسي أو كنشاط كل شهر أو كل فصل دراسي، وفيه تُقدم المفاهيم الهندسية فيما لا تزال الممارسات الهندسية غير ممثلة بالقدر الكافي. وفي هذا الصدد، ينبغي التنويه بالحاجة إلى التعاون الناجح والفهم الجيد للمفاهيم الأساسية للتخصصات. وتجدر الإشارة أيضًا إلى وجود تصورات أكثر إيجابية وتطبيق لدى معلمي المدارس الثانوية والمتوسطة فيما يخص تعليم العلوم والتكنولوجيا والهندسة والرياضيات مقارنة بمعلمي المدارس الابتدائية.

كلمات مفتاحية: تعليم العلوم والتكنولوجيا والهندسة والرياضيات، التكامل، معايير العلوم للجيل القادم، التعاون، التعلم القائم على المشاريع، حل المشكلات.

Dedication

The last several months were full of challenges; hence, this work could not be completed without the support of my family and friends.

This achievement is dedicated to my husband, my lovely daughter and sons, for their patience and support.

Acknowledgment

I would like to express my acknowledgment and thanks to my dissertation supervisor professor **Sufian Forawi** for his continuous support, and constructive feedback. I learned a lot from him.

Thanks for all persons who gave me support.

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CHAPTER ONE

INTRODUCTION

In this rapidly growing world with its numerous economic competitions, different global financial problems, an accelerated technological evolution and hidden future challenges, there is a need to come up with initiatives mandate a new reform in the education sector as a part of this globe In particular, teaching science, mathematics, engineering and technology in a shape that enhances skillful pedagogical content and connects to real-life problems. Nurturing a new generation which is reinforced with high thinking skills that can benefit its societies and bring up its countries' economies is extensively needed (Radloff & Guzey, 2016; Roehring et al, 2012).

STEM is an approach that integrates the disciplines of science, math, engineering and technology into a cross-disciplined curriculum that depends on inquiry strategies and problem-solving skills for authentic problems (Park, et al, 2016; Glancy & Moore, 2013; Mitts, 2016; Asghar, et. al, 2012; Brown, et. al. 2011). Scholars recommend giving students the chance to explore, test, solve problems in a real context and think critically (Kennedy & Odell 2014; Asghar, et. al. 2012), accordingly making students act as scientists, explorers, and engineers; these points are at the core of STEM education. STEM education can be operated either as an integrative, interdisciplinary approach where all disciplines are treated as one whole dynamic mass and are given in the same class session, since the disciplines' specific contents are not separated (Hansen & Gonzalez 2014; Ejiwale 2012; Brown, et. al. 2011), or STEM can be operated as a multidisciplinary approach where the specific content of each discipline is a silo by its nature, and disciplines are taught in separate classes; subsequently, a major discipline or disciplines will be at the center of the problem or project and other disciplines are added (Asunda

& Mativo 2016; McDonald 2016; Ritz & Fan 2015; Asghar, et. al. 2012; Roehring, et. al 2012; Sanders 2009). To foster students' understanding of STEM concepts in real-world application, it is recommended to blur boundaries between disciplines and give the chance for a cross-disciplinary curriculum to take place (Asghar, et. al. 2012). Asunda and Mativo (2016) suggest integrating math and science concepts into engineering and technology applications. Kelley and Knowles (2016) state that successful STEM requires integrating of engineering and technology in the curricula of science and math to form a rigorous curriculum that fosters engineering design and scientific inquiry.

An Interdisciplinary STEM approach can be integrated into numerous strategies such as problem-based learning, which depends mainly on solving problems in the real life context, project-based learning which depends on engineering design, and inquiry learning strategies that foster higher order thinking skills by a student-centered learning and hands-on approaches. Despite the implementation of these strategies, literature wash back shows that collaboration, hands-on, using technology and design, and real life problem-solving skills are the core objectives of STEM education strategies. If these strategies are successfully accomplished, we can bring up a new generation reinforced with a high level of knowledge and 21st century skills. Consequently, this generation is capable of overcoming future challenges. Two of the recent educational reforms that call for enhancing STEM education are the Next Generations Science Standards (NGSS) and the Common Core State Standards for Mathematics (CCSSM); these reforms were inspired by the National Research Committee (NRC 2012) documents that advocated the need for purposeful STEM education. These integration committees provide stakeholders with (a) an identified picture about the existing STEM approaches; (b) impact of STEM on students' motivation, understanding and achievements, and (c) priorities in conducting research about STEM education. The NGSS (2013) framework drew outlines for STEM education that depends on three elements: the disciplines' core ideas, cross-cutting concepts, and engineering practice: these elements form a skeleton for bringing STEM education to life.

1.1 Background of the research

Calling for STEM education has taken place over the past two decades; it has been the focus of policymakers in many countries (Winn, Mi Choi & Hand 2016). Recently, extensive attention has been given to STEM education because of the global industrial, economical, technological and educational competitiveness. The new generation is required to be able to prevail over future challenges and to handle this competitiveness competently. STEM education has the powerful potential to boost students with higher order thinking skills, critical thinking skills, creativity, and self-learning skills; moreover STEM education can go beyond the separate disciplines to integrate these disciplines to solve authentic problems and challenge students to create a design for a certain project. Winn, Mi Choi and Hand (2016) state that STEM education is a broad field because every single discipline has many sub-sections related to it, and that makes STEM education interesting and challenging at the same time. The cross-discipline curricula have better impact on students' understandings of math and science concepts, in addition to better achievements (Hasnsen & Gonzalez 2014). Kasza and Slater (2017) believe that STEM education can foster problem-solving through inquiry strategies and engineering design.

Ritz and Fan (2015) post in their study that STEM education responds to the economic challenges in the world, particularly in the developed countries, because it focuses on developing a skilled workforce required in this century. In the United States, adopting STEM education has become a paramount goal in order to keep the United States in a competitive position as one of the best economies (President's Council of Advisors on Science and Technology 2012; Guzey, Harwell & Moore 2014; Forman, et. al 2015). Furthermore, in South Korea the Ministry of Education has made big efforts to foster successful STEM education (Park, et. al. 2016). The United Arab Emirates (UAE) is a developing country with a rapidly increasing economy as well as increasing attention to high quality education, which in turn benefits its students and economy simultaneously. STEM education has been known in the UAE only since 2010 after many schools started adopting the Next Generation Science Standards (NGSS) as their science curriculum, so STEM education is considered to be new in the UAE, and in the Arabic region in general, as Ahmed (2016) said; however, there is not enough research about STEM education and how it has been perceived and implemented in Arab region schools, and particularly, UAE schools.

The Ministry of Education (MOE) in the UAE introduced the educational strategic plan 2010-2020 that focuses on

- Performing a creative curriculum that enhances active learning.
- Developing critical thinking and communication skills.
- Creating learning environments that are conducive as well as challenging.
- Allowing a teaching environment full of innovation.

The UAE national agenda in education has emphasized focusing on learning technologies and research skills in schools; it recommends that teaching strategies should promote critical thinking as well. The conducted activities should be skillful and elicit higher thinking skills and problem-solving skills in a real life context. STEM education can intensify the fulfillment of the UAE educational strategic plan and national agenda targets if it is implemented successfully and affectively. Accordingly, this current research is studying STEM-related subjects' teachers' perceptions and implementation in the schools that implement it in the UAE.

1.2 Research problem

As mentioned in the research background, STEM education is one of the most crucial reforms in education, and has priority in the national agendas of many countries around the world, especially the industrially and economically developed countries (Guzey, Harwell & Moore 2014; NRC 2012). Roehrig et. al. (2012) state that there is no unique definition for STEM education and no widespread agreementon the way to implement it, so this gives teachers a wide margin in implementing STEM from different perspectives. But at the same time, it is agreed that there are main aspects which define STEM education and certain elements that should be available in any adopted STEM approach (Osman, Hiong & Vebrianto 2013).

STEM education has two main approaches that can be used. One approach is the integrative approach in which all subjects are integrated in one single course. The other approach is the multidisciplinary approach in which knowledge is integrated from separate STEM disciplines (McDonald 2016; Ritz & Fan 2015; Guzey, Harwell & Moore 2014). Some educators believe that the multidisciplinary approach is best (Cevik 2017); others think that the integrative approach is preferable (Ritz & Fan 2015). These approaches can both be conducted using strategies of problem-based learning, project-based learning or inquiry-based learning (Mitts

2016; Mandeville & Stoner 2015; Bruce-Davis, et. al. 2014; Asghar, et. al. 2012; Psycharis 2016), and at the same time, these strategies should be wrapped with collaboration, authentic problem-solving skills, design and technology, and higher order thinking skills (Ashton 2017; Lesseig, et. al. 2016; Asunda & Mativo 2016; Kennedy & Odell 2014;Shernoff, et. al. 2017; Osman, Hiong & Vebriano 2013; Brown, et. a. 2011; Mandeville & Stoner 2015).

Assefa and Rorissa (2013) say that in order to enhance STEM curricular activities, it is essential to first recognize the complicated relationships web that surrounds the STEM education field. It is known that teachers play the main role in steering the learning process, and they are responsible for ensuring that students master the needed skills in STEM education (Flogie & Abersek 2015). Similarly, Bell (2016) states that the way in which teachers perceive and implement STEM in their classes will surely affect STEM delivery.

In the UAE, the MOE and other educational authorities such as the Knowledge and Human Development Authority (KHDA) in Dubai and Abu Dhabi Education Council (ADEC) are giving priority to fostering students' critical thinking, problem-solving skills and use of technology; these elements are clearly stated in the MOE strategic plan and the UAE national agenda, as mentioned above in the research background. KHDA and ADEC are considered to be key decision makers regarding the educational stream in the UAE; every year these authorities publish annual reports about schools in their emirates, highlighting weakness and strength points in every school. A review of many annual inspection reports carried out by these authorities shows that these elements are always being checked, and recommendations given to many schools to enhance these skills (KHDA 2017; Irtiqa' 2017). In addition, it is clearly noticed that schools which have cross-curricular links show better results in fostering critical thinking, problem-solving skills and use of technology, so STEM education is truly needed to develop knowledge that is linked to skills.

In fact, there is still an obscurity about STEM perception, implementation and criteria of STEM success in United States and many countries adopting STEM education (Bruce-Davis, et. al. 2014). In the same way, Park, et. al. (2016) mention that in South Korea, STEM education has been implemented for many years, but still they know very little about how STEM is actually implemented in South Korean schools; accordingly, Park and his team researched how teachers perceive and practice STEM education in Korean schools. The case in the UAE is as the case in other countries who adopt STEM education in their schools; there is still uncertainty about STEM perception and implementation. There is no agreed way to implement STEM, each school implements STEM in its own way, thus it is expected to find many techniques in implementing STEM in UAE American schools but it is not guaranteed that they are all successful and can achieve MOE targets, moreover, research studies into STEM education in UAE are few and there are no studies to investigate teachers' perceptions and implementations of STEM in the UAE.

1.3 Study's purpose and questions

As little is recognized about STEM education in the UAE, extra research is urgently needed to clarify teachers' perceptions of STEM education, its implementation approaches and strategies, and its main aspects that are adopted. The purpose of this study is to investigate STEM-related subjects' teachers' perceptions and implementation in American-system schools in the UAE. A survey was conducted among science, math and technology (ICT) teachers in American schools across the UAE in order to examine STEM perceptions and implementing practices in these schools, and then identifying STEM practices in these schools by interviewing those whose practices align with what is found by educators to be best STEM practices. This study examines the knowledge that the participants have about STEM, and the way they implement STEM; its curriculum, its frequency, existence of the three major ideas, which are: teaching the core concepts of science, using cross-cutting ideas, and utilizing engineering and scientific practices (NRC 2012; Krajcik & Delen 2017). Hernandez et al. (2014) consider design and using technology as core concepts in STEM education, Altan and Ercan (2016) and Strimel and Grubbs (2016) state in their research that collaboration is a key term in STEM education. In addition, Kennedy and Odell (2014) say that promoting the inquiry-based learning that promotes students' self-directed learning is essential for successful STEM education, as well as Mitts (2016) who believes that problem-solving skills that foster critical thinking are at the top of successful STEM elements. Moreover, linking problems to real life context is the core of STEM education (Guzey, Harwell & Moore 2014). Krajcil and Delen (2017) say that engineering and science practices alongside problem-solving and collaboration can give a meaningful STEM education. Accordingly, this research examines the existence and practice of integration model, rich-concept science curriculum, engineering and design, collaboration, cross-cutting concepts like problem solving and inquiry-based strategies, and the link between classroom and real life context, as these elements are expected to enhance successful STEM education and are considered as STEM education objectives.

This study is conducted to answer these questions:

1 - What are teachers' perceptions of STEM education in the UAE?

2- What are teachers' practices of STEM education in the UAE?

3 - What influence (if any), do demographic variables have on STEM-related subjects teachers' perceptions of the American schools in the UAE?

1.4 Structure of the dissertation

The first chapter is presented in this section, and it shows the importance of STEM education globally and nationally; it explains the topic's significance and background, then it posts the problem of the research, and finally it introduces the purpose and questions of this research. Chapter Two reviews the literature and explains the theoretical framework of STEM education. Chapter Three is a detailed section about the methodology of the research; the mixed-methods approach is used in this study to answer research questions. Philosophical underpinning, the sample, the instruments and the procedures are elaborated in this chapter. Chapter Four analyzes the results, and finally, the fifth chapter discusses the findings and outlines the conclusion, recommendations and limitations.

CHAPTER TWO

LITERATURE REVIEW

This chapter offers an overview of STEM education: its importance, its definition, the theoretical framework of this study, which includes integration theories according to Dewey (1938) and Drake (1991), and the framework of the NRC 2012 and NGSS 2013, along with a literature review, comprise the main topics in this chapter.

2.1 Overview of STEM education

Attention to STEM education has increased this century as global challenges have increased. The coming generations are required to be critical thinkers, creative, armed with knowledge and practical skills (Rissanen 2014), hence, they are required to deal with energy issues, economic crises, and environment challenges and sustainability (Shernoff, et al. 2017); these concerns mandate integration between different sciences and technologies to be resolved.

STEM education points out integrated programs which focus on every discipline's skills and knowledge (Altan & Ercan 2016). STEM is considered as a reform in teaching science, math, technology and engineering; this reform switches from memorizing information and isolated facts into thinking holistically about real-life problems using different skills that utilize knowledge, think critically and solve problems (Asghar, et al. 2012). Moye, Dugger and Starkweather (2014) said that STEM education is much more than learning its disciplines; it is a practical application of disciplines, theories, designs and laws in a way that shows the utilizing of knowledge; in addition it aims to give students opportunities to act as scientists, mathematicians and engineers and to think across separate disciplines, as it reflects how the real world works. Adopting the new reform by teaching STEM is capable to foster problem-solving skills and critical thinking as well as enhancing social and communication skills (Sahin, Ayar & Adiguzel 2014). Jones (2017) believes that STEM helps students to develop the sixteen habits of minds which were developed by Costa and Kallick; some of these habits include persisting, flexible and independent thinking, accuracy, and managing. Erdogan and Ciftci (2017) believe that STEM can develop 21st century skills, students' interdisciplinary perspective, creativity, and engineering skills. Corlu, Capraro and Capraro (2014) said that STEM education can create integration between subjects while at the same time maintaining the unique characteristics of each subject. These reviews show the holistic meaning of the new reform. McDonald (2016) advised in his study to get the benefits of the new reform by teaching STEM from early schooling years, Schmidt and Fluton (2016) also believe that teaching STEM should start early; Holter (2017) believes that teaching STEM from earlier years in school can develop communications and vocabulary use, improve technological skills, and help to master visualization and motor skills in a better way than beginning to teach STEM in higher schooling years. Mitts (2016) published a study titled "Why STEM?" in which he wondered about STEM's importance and its role in reforming science education; he concluded that science proposes the theory which answers the question "why", technology explains the process which answers the question "how", engineering determines the design which answers the question "what", and math, which gives the concept, reveals relationships between disciplines.

There is still no agreed definition of STEM education (Bruce-Davis, et al. 2014), yet researchers try to give a definition, which is being improved over the years: Brown, et al. (2011) posited that

STEM is an acronym describing a cross-disciplinary of science, math, engineering and technology; Johnson (2013) defined STEM as a teaching instruction that integrates science and mathematics into scientific practices and engineering design; Kennedy and Odell (2014) defined STEM as integration between subjects in which the barriers between them are eliminated; whereas Corlu, Capraro and Capraro (2014) defined STEM as a collaborative construction of knowledge and skills of more than one area of STEM subjects. Fitzallen (2015) defined STEM as a holistic approach that aims to offer connected and meaningful education by connecting disciplines; Johnson, Peters-Burton and Moore (2016) considered STEM as disciplines' contents as well as practices are integrated together in a way that includes science and math knowledge in engineering design and essential technologies. Ashton (2017) believes that STEM is a symbiotic relationship among the four disciplines, Kasza and Slater (2017) believe that STEM uses math, science and technology to do engineering; Shernoff, et al. (2017) quoted the STEM definition of the State's Department of Education (DoE) which explained STEM as enhancing student-centered learning by using the knowledge and skills of math, science, technology and engineering and then promoting critical thinking, creativity, collaboration and 21st century skills to solve real-life problems.

2.2 Theoretical Framework

The theories of integration which were developed by John Dewey (1938) and Susan Drake (1991) in addition to the Next Generations Science Standards (NGSS 2013) framework which was developed upon the framework of K-12 science education of the National Research Council (NRC2012), which all constitute the theoretical framework of this study as shown in figure (1).

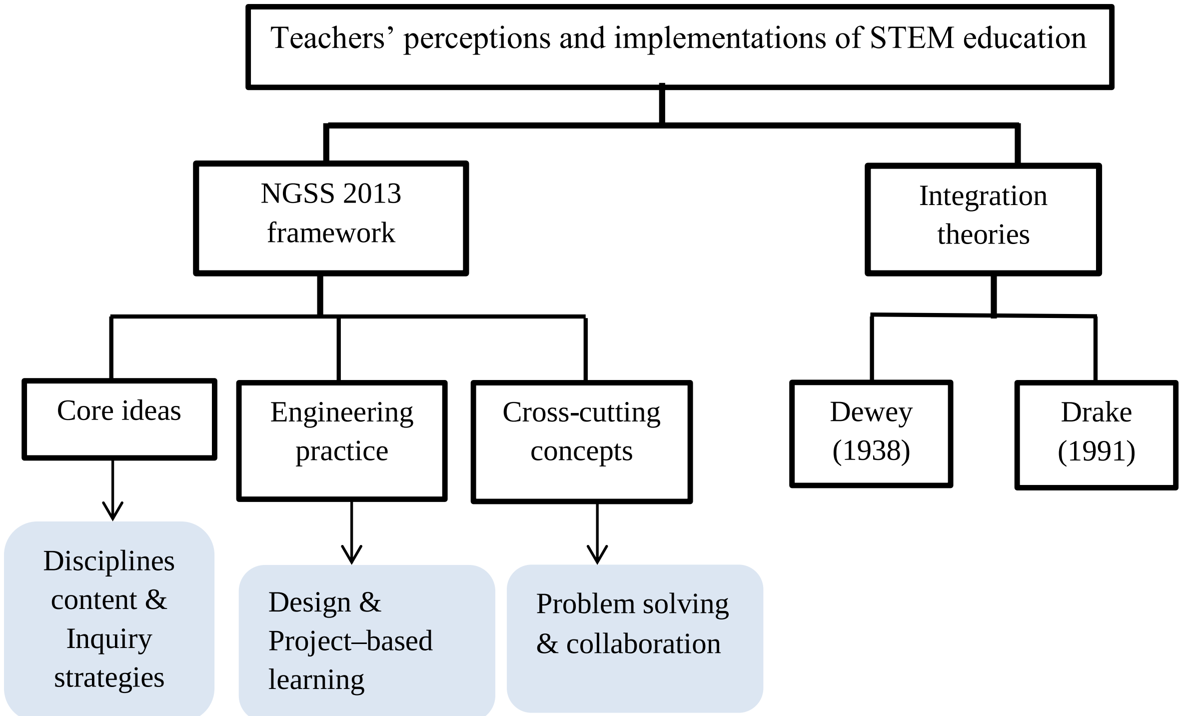

Figure (1) shows the Theoretical Framework of this study

2.2.1 Dewey's integration paradigm

John Dewey (1859-1952) is one of the pioneering American educationists of the 20th century, he was considered as the father of the progressive education reform as he campaigned for reforms in curricula and teaching aspects; his philosophy called for integrity of "theory and practice" (Westbrook 1991), his philosophy in education depends on obvious ideas and effective practice within the social aim; schools should create intelligent efforts to develop these reforms because all individuals in society have the right to share in human invention (Dewey 1934). He mentioned that there is no need for new ideals to reform the educational system according to big social changes because such ideals already exist, but new methods are needed (Dewey 1936). He believed that the purpose of education is to equip students with social experiences through interaction with society and environment around them; and so, students can understand relationships and differentiate interconnections between different experiences. In teaching methods, Dewey believed in learning through doing activities from real life surrounding the student; this powerful thought of Dewey's was interpreted later to form the principles of project-based learning and problem-based learning (Westbrook 1991). Dewey believed in integration; he avoided teaching isolated subjects because this was against their unity in the real world, as he said. He added that school activities should simulate experiences outside school to fulfill social engagement and to help students to think with the inherent values of their experiences; these activities must be done collaboratively and students must act as community members because he believed that experiences that engage students in their community can support their learning currently and in the future. In addition, he called for "interdisciplinary curriculum and connecting multiple subjects" (Westbrook 1991). In one of his lectures in 1899, Dewey led an argument against the traditional teaching method which taught subjects isolated from each other instead of interdisciplinary; he said that the traditional method in teaching discouraged students from understanding the entirety of their pursuits. Glancy and Moore published in 2013 an article describing Dewey's integration theory; they said that Dewey believed ineffective learning could be enhanced by maximizing connections between different disciplines, and there should be coordination between learning objectives and classroom activities.

2.2.2 Drake's integration paradigm

Susan Drake is an educator who guided evolutionary continuum in integrated curricula in the 1980s and 1990s. She posited that the academic performance of the students in integrated education is better than students' performance in traditional disciplines programs (Drake & Burns 2004). She defined integration in three different approaches: multidisciplinary, interdisciplinary, and trans-disciplinary. A multidisciplinary approach involves subjects in a certain theme activity, in this approach a certain theme is investigated from multi disciplines' perspective as shown in figure (2), whereby skills and knowledge are fused into school curricula. After more exploration of the theme being studied, Drake found that subjects' contents overlapped and there were connections between subjects, which she called the interdisciplinary approach. In this approach a curriculum is organized around certain learning across identifiable disciplines to express concepts and skills, as shown in figure (3); then she started breaking activity down to its components, she found with her team that there are no real boundaries between subject areas and this was the trans-disciplinary approach of integration. In this approach the curriculum is organized based on students' concerns, skills are applied in real-life contexts as shown in figure (4). Drake believed strongly in this approach. Drake and Savage (2016) stated that the trans-disciplinary curriculum was an improvement on the integrated curriculum, and that it was raised in reaction to the problems society face in the 21st century. Drake stated that the difference between the integration approaches was the separation degree between discipline areas. In addition, Drake and Reid (2010) developed the "Know/Do/Be" bridge which describes the implementing framework of the integrated curriculum. This bridge gives an idea about what information students should know what they should do, and how they should act to carry out integrated tasks.

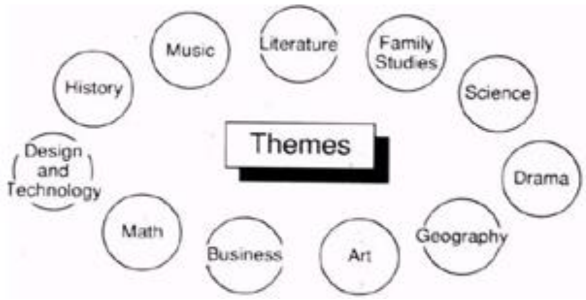

Figure (2) shows the multidisciplinary approach according to Drake (1991)

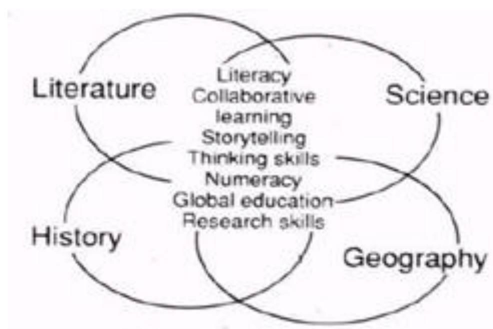

Figure (3) shows the interdisciplinary approach according to Drake (1991)

Figure (4) shows the trans-disciplinary approach according to Drake (1991)

2.2.3 Next Generations Science Standards (NGSS) framework

In 2012 the National Research Council finished writing K-12 science education. A framework which focused on engineering enterprises side by side with scientific ones, the NGSS framework was published in 2013 based on the NRC's (2012) vision that defines scientific and engineering practices, disciplinary core ideas and cross-cutting concepts to formulate the next generation of science classrooms. NGSS was adopted by most of the states in the U.S. and in many countries in Middle East and North Africa (MENA) (Simpson, Sunder & Gabler 2017). The NGSS published framework aimed to engage students in community discourse and arm students with knowledge and skills needed for their careers (Bartholomew 2015). NGSS instructions have three dimensions which formulate the STEM education elements: the core ideas, engineering and scientific practices, and the interdisciplinary concepts. According to NGSS (2013) these dimensions should be integrated in curricula and standards, instructional strategies, and assessment.

Disciplines' core ideas focus on content knowledge (pedagogical content), inquiry and reflective practices in an authentic context (Peters-Burton & Moore 2016). Some disciplinary core ideas are essential to understand, explain and investigate a phenomenon or authentic problem. The idea is considered to be a core idea if it is a key concept in a discipline, has broad necessity across many disciplines, plays as a key tool in solving problems, and can be learnable (Bartholomew 2015). Duncan and Cavera (2015) added that core ideas should be meaningful and allow continuous learning, which helps students to explain and find reason for the phenomenon or problem concerned. Disciplinary core ideas are assured to avoid coverage of a huge number of shallow topics printed in textbooks. Ducan and Cavera (2017) argued that students should understand the core aspects which help them to answer two questions, how and why, instead of teaching big chunks about a concept. Krajcik and Delen (2017) added that certain standards and benchmarks are needed to enhance focused STEM literacy and pedagogical content.

Cross-cutting concepts have an interdisciplinary nature that has application across disciplines, and bridge relations among disciplines in a way that makes sense of a problem or phenomenon (Krajcik and Delen 2017). Moreover, these concepts work as lenses to study phenomena from many perspectives (Duncan & Cavera 2015), they are considered as thinking tools, students should be able to use them comfortably depending on the nature of the investigated problem or phenomenon (Duncan & Cavera 2015; Bartholomew 2015; NRC 2012).

NGSS (2013) focused on engineering practices and design because engineering practices reflect the activities of engineers, such as designing and building models (NGSS 2013), furthermore; those practices explain that knowledge should be known and skills should be practiced (Moye, Dugger & Starkweather 2014). Engineering studies connect and integrate to facilitate the solving of problems (Shernoff, et al. 2017). NRC (2012) added that engineering education including design can contextualize students' experience and exploration of how and why a particular problem occurs. Marulcu and Barnett (2016) believe that engineering practices enhance better science and math understanding, increasing the use of technology, and create connection with societal needs as they deal with authentic contexts. Honey, Pearson and Schweingruber (2014) and Kelley and Knowles (2016) mentioned that best engineering practices are those which make engineering thinking to be the habit of the mind: conducting engineering investigation to identify needed criteria in design, integration of mathematical thinking, solving problems related to the design to optimize designing solutions, formulating evidence of the chosen solution. Krajcik and

Delen (2017) believe both engineering and scientific practices are shared and could not be separated. Lesseig, et al. (2016) shared the same opinion, as shown in figure (5); they posted the design cycle as a company between science and engineering practices; first, posing questions; second, problem defining; then searching and creating a design; after that, building a model; then testing the model and evaluating it; and finally adjusting and redesigning.

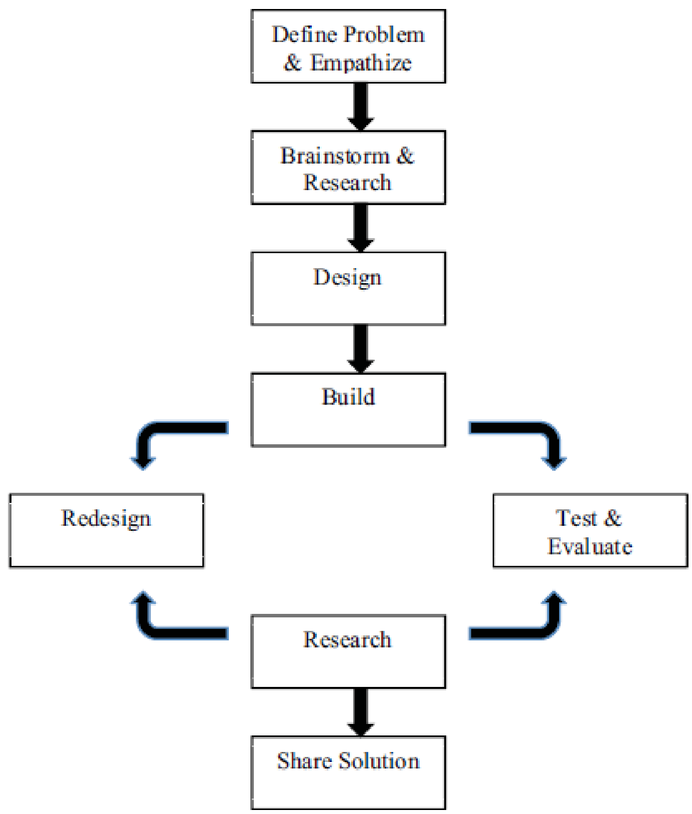

Figure (5) shows engineering design process (adapted from Lesseig, et al. 2016)

2.3 Literature review

2.3.1 STEM education disciplines

Although STEM is ubiquitously known as connecting between its four disciplines, there are wide arguments between educators about the disciplines which should be included in STEM; some of them stress STEM is only its four disciplines, some of them suggest connection among science and engineering (Strimel & Grubbs 2016), others suggest other subjects of connection. Fitzallen's (2015) study talked about different subject connections that could be conducted; he found seven styles of expected connections, but the question here is about the current situations of STEM in schools. McDonald (2016) argued that STEM education in many schools is focusing on science and math only, and in most cases STEM is taught from the disciplines' perspective and not from an interdisciplinary perspective. Kasza and Slater (2017); Asunda and Mativo (2016); Hernandez, et al. (2014) shared the same opinion in their researches; they reported that STEM education in many schools focuses on math and science to be taught separately while technology and engineering are ignored. In addition, Ritz and Fan (2015) agreed that the function of technology and engineering in STEM education is still ambiguous. On the other hand; other educators mentioned that non-STEM disciplines could be added (Shernoff, et. al. 2017; Fitzallen 2015). Yildirim (2016) posited in his study that STEM education is applicable with any school subject although most educators focus on the four main disciplines of STEM; Kelley and Knowles (2016) shared the same opinion.

Regarding engineering, NGSS (2013) defined engineering as an iterative approach in building designs for systems and processes. Guzey, Harwell and Moore (2014) considered engineering as an essential component in integrative STEM; it works like a vehicle in teaching disciplines' concepts. Teaching engineering concepts and design was focused on by the NGSS to provide evidence when solving a problem (NGSS 2013). Engineering is a motivator to learn integration, because it deals with real-world problems that are a mix of science and math concepts (Shernoff, et al. 2017). Teaching engineering concepts and design develops engineering thinking in students' minds (NRC 2012). Asghar, et. al (2012) stated that engineering can foster critical thinking and problem solving which are crucially needed in STEM education. In teaching engineering content, design and cost should be taken into consideration (Duncan & Cavera 2015). Roehrig, et al. (2012) considered engineering as the vehicle that provides the real-life context for STEM education: it is an ideal context to foster problem-solving skills, and it develops students' communications skills.

Technology: McDonald (2016) defined technology needed in STEM education as the ability to use instruments, tools and digital technologies. It provides better understanding of the other STEM subjects (Kennedy & Odell 2014). NGSS (2013) defined technology as an application of science. Bartholomew (2015) believed in engaging technology in all projects in the U.S. to create a background for coming developments.

Mathematics: Math has a major role in daily life, students must be able to deal with mathematical problems and equations; accordingly, teachers are required to develop mathematics concepts in students' minds far away from memorizing and transmissive content and switch into active and collaborative learning (McDonald 2016). Kelley and Knowles (2016) consider math as a foundation for STEM education. English (2016) suggested that mathematical literacy should be assured and not all math concepts could be taught through STEM.

Science: NGSS (2013) defined science as natural sciences of biology, chemistry, earth, space, physics and environment. These sciences could be studied through observation or experimentation (Forawi 2016).

2.3.2 STEM teaching instructions

Successful STEM depends on rigorous curriculum and instructions in science and math, an integration approach, teaching engineering design cycle and problem solving, enhancing inquiry strategies in all disciplines, promoting collaboration, connecting students with their community, promoting multi-perspective viewpoints to develop interdisciplinary ideas, offering investigative learning experiences by using available technologies, including practices of science and engineering, and using project-based learning and problem-based learning (Kennedy & Odell 2014; Storksdieck 2016). The 21st century generations are required to be critical thinkers, creative members, collaborative, cooperative and communicative members in their groups; these skills facilitate the STEM teachers' job, and help teachers to carry out problem solving, engineering design projects and inquiry strategies (Asunda & Mativo 2016; Kelly & Slater 2017).

Berland (2013) suggested principles to help in getting effective instructional design: challenging students with STEM related problems and designs, clarifying the learning goals, and engaging students in a discussion about the design process they approach. Discussion, collaboration, negotiation and communication skills are major components of any task (Morrison, McDuffie & French 2015). Hansen and Gonzalez (2014) adopted four elements to be best STEM practices including technology integration, authentic problems, and project-based tasks that develop students' thinking. Schmidt and Fluton (2016) recommended that the principles of getting high quality STEM are: students' engagement in solving practical problems, using project-based learning, using technology, enhancing meaningful learning, and implementing team-based learning. It is clear that project-based learning, problem-based learning, and inquiry-based learning are agreed to be essential in STEM teaching.

2.3.2.1 Integrative interdisciplinary STEM

One of the affective factors in STEM teaching is the way in which the disciplines are being connected, the nature of integration; disciplines, and connection complexity and size (Shernoff et al. 2017). Integrative STEM can foster STEM literacy, workforce readiness and ability to develop connections between subjects. In addition it increases the century's competencies (Honey, Pearson & Schweingruber 2014). Integrative STEM has international support from different educators and education policy agencies as they believe it enhances STEM education by a stronger connection among subjects (English 2016; Guzey, Harwell & Moore 2014; Ejiwale 2012). These agencies and policies were inspired by traditions of Dewey and Drake as they believed in connecting education to real life (Corlu, Capraro & Capraro 2014). Disciplines are treated as one whole dynamic mass and are given in the same class session since the disciplines' specific contents are not separated (Atlan & Ercan 2016; Hansen & Gonzalez 2014; Ejiwale 2012; Brown, et al. 2011). According to Kelley & Knowles (2016), engaging students in rigorous syllabus with connected instructions in science inquiry, math inquiry and engineering design to solve a real-life problem is considered integrative STEM. Kasza & Slater (2017) suggested using science, math, and technology to engineer solutions. Asunda and Mativo (2016) suggested integrating math and science concepts into technology and engineering to develop a thematic experience. Honey, Pearson and Schweingruber (2014) suggested three implications in implementing integrative STEM: integration must be explicitly done to get knowledge and skills within and across the disciplines through problem-based learning and project-based learning, and in addition, individual disciplines' contents should be supported so students can elicit relevant ideas in an integrated context. NGSS (2013) believed that analytical reasoning of science and integration of mathematics principles could foster engineering teaching. Kelly and Knowles (2016) illustrated the integrative STEM as a system of four pulleys to carry a load, each of these pulleys has its role, as shown in figure (6). The four pulleys to lift the load are: scientific inquiry, mathematical thinking, technology, and engineering design. The four pulleys are connected with the rope of practice; the four pulleys should move in harmony to carry the load which represents STEM learning.

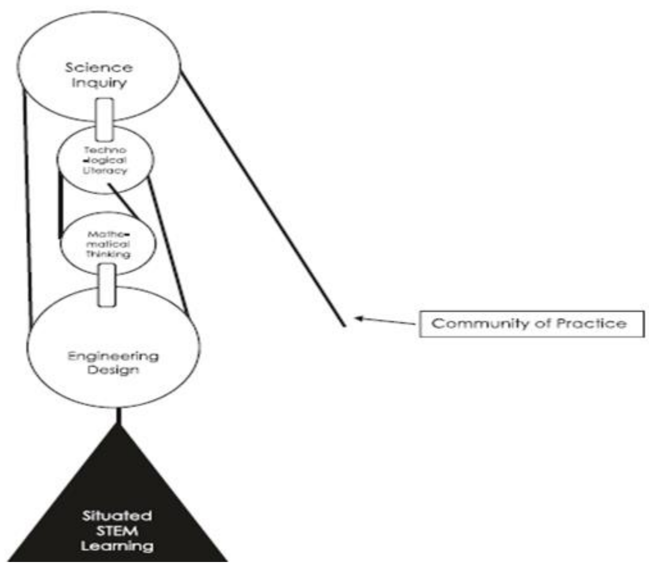

Figure (6) shows the integrative STEM adopted from Kelly & Knowles (2016)

2.3.2.2 Project-based learning (PBL)

Han, et al. (2015), and Capraro and Slough (2013) defined STEM project-based learning (PBL) as an interdisciplinary approach that starts with ill-defined task and ends with well-defined solution or design. Gonzales (2015) shared that PBL is a type of inquiry process developed in authentic and complex questions to create product. Kokotaski, Menzies and Wiggins (2016) argued that using PBL is challenging for students due to problems that may arise when creating a design, such difficulties create cognitive challenges that enhance high-order thinking skills, in addition; if students are effectively guided by their teachers, they can be intrinsically motivated, and self-reliant. Gonzales (2015) believed that PBL helps students to utilize collaboration, communication, creativity, and critical thinking. Hall and Miro (2016) believed that STEM (PBL) can offer deeper self-regulated understanding for students through trial and error. Capraro, Capraro and Morgan (2013) believed that STEM project-based learning is the best representative of engineering practice; it follows the engineering design process which was shown in figure (5), it is driven by a project or design problem, students research to collect information from different disciplines, they create initial ideas about the issue, they apply science, math and technology concepts to analyze available data, they create a design and build a prototype; testing the prototype performance is an essential step to give a chance to refine and identify the best solution, and finally to communicate and share it with others. Altan and Ercan (2016) mentioned the main aspects of successful engineering design as it should be authentic, can be conducted using available tools and materials, should give a chance for many design solutions, the design can be improved and reproduced, and should be conducted in collaborative work. In PBL teachers should offer specific learning context, existence of social interaction, and knowledge sharing (Kokotaski, Menzies & Wiggins 2016).

2.3.2.3 Inquiry-based learning

Inquiry instructions are recommended to understand disciplines' core ideas, as inquiry-based learning (IBL) is the pedagogical approach of STEM education (Psycharis 2016). It is needed in teaching the disciplines' content: students can think, pose questions, hypothesize and carry out investigations like scientists (Kelley & Knowles 2016). Ramnarin (2016) believed that IBL develops experimental skills and guides students to understand the nature of science. If the disciplines' core ideas are focused through inquiry instructions, students will be self-learners and high order thinkers; and then STEM classes are conducted based on focused, conceptual disciplines' literacy (Johnson, Peters-Burton & Moore 2016). Deshmukh, Forawi and Jaiswal (2012) believed that inquiry of multifaceted activity such as observation, gathering evidence, posing investigative questions, testing and making explanations are crucially needed while teaching disciplines' content. McDonald (2016) said that in science, IBL scaffolds students to pose investigative questions, conducting investigations and finding evidences; in mathematics, inquiry strategies develop mathematical thinking and guide students to analyze, hypothesize and justify their answers. DiBiase and McDonald (2015) concluded that students should be able to find evidence by making observations, using tools and technologies to collect data, developing explanations, making predictions and communicating results with others. Forawi (2016) rated inquiry investigations as one of the highest needed benchmarks to enhance critical thinking.

2.3.2.4 Problem-based learning

Problem solving is the core of STEM education; students are engaged in authentic and meaningful problems to foster critical thinking while teacher is a facilitator (Kasza & Slater 2017). Tawfik and Lilly (2015) considered problem-based learning as most renowned instructional strategy that focuses on ill-defined and complex problems. NGSS (2013) stressed that a problem-solving philosophy aims to encourage students' higher order thinking in a way that enhances creativity, critical thinking, effective communication and inquiry while they engage in self-learning approaches (Morrison, McDuffie & French 2015; Chan 2016).Teachers encourage students to work in collaborative groups to do independent research and to use their skills, such as creativity, analytical and critical thinking in searching, and then to make connections among subjects to come up with an outcome. This process can foster critical thinking, encourage collaborative work, and promote scientific inquiry (Asghar, et al. 2012). Tawfic and Trueman (2015) added that problem solving requires authentic context, collaboration, and students' self-learning approaches. Mandeville and Stoner (2015) agreed that problem-solving facilitates the attainment of learning goals. Honey, Pearson and Schweingruber (2014) state that problem- based learning requires student centeredness, self-directed learning, group work, and authentic problems. Chan (2016) concluded that any curriculum includes problem-based learning should be carefully designed; hence it could stimulate questions and encourages students independence. Ronis (2008) mentioned that problem solving starts with messy and open-ended real-life problems, students do research using different technologies and resources to collect information about the problem from different disciplines, they formulate hypotheses and suggest solutions and then present what they have found.

CHAPTER THREE

METHODOLOGY

This chapter presents the mixed-methods research approach and its philosophical underpinning which is displayed through a rationale that explains the ontology and epistemology of this research. In addition, this chapter shows the context, participants and the instruments of the mixed approach which has been adopted. Moreover, it includes the piloting study that was carried out to check reliability and validity. Finally, it clarifies the ethical considerations in this research.

3.1 Study design

This research study follows a mixed-methods approach; specifically, it is an explanatory sequential mixed-method approach. The first part of the research is quantitative, as a questionnaire is completed by science, math and ICT teachers; this questionnaire aims to collect teachers' perceptions and implementation practices of STEM in their schools. The second part is qualitative as interviews are done with teachers to give depth to what is found in the questionnaire to reinforce the results of this study. In the explanatory sequential mixed-methods approach, the quantitative research is conducted firstly and results are analyzed, then a qualitative research is conducted to offer further explanation for the results. In addition, this approach includes unequal participant numbers for each of the study phases (Creswell 2014). This approach aims to give depth and breadth to its results quantitatively and qualitatively (Johnson 2014). The aim of this study is to present information about STEM-related subjects' teachers' perceptions and implementations in UAE. Since there is insufficient data about STEM education, especially STEM understanding and practices in UAE schools, it is essential to conduct a mixed-methods research to investigate STEM education and to collect sufficient and detailed information about teachers understanding and practicing of STEM, both quantitatively and qualitatively.

The quantitative part of this study follows the positivist worldview; it focuses on facts and testing hypotheses and theories through a deductive process (Johnson 2014). It aims to predict and explain empirically what is being studied since its ontology looks to the world objectively. This epistemological and ontological paradigm aligns with this study in its quantitative part; an empirical study including a survey with closed-ended questions is done with math, science and ICT teachers to examine their perceptions and practicing of STEM and test it by the scholarly agreed theories about best STEM practices (Creswell 2014). Afterwards, statistical analysis is used to get generalizations and to extract the factual situation of STEM implementation in the UAE.

The qualitative part of this study follows the constructivist worldview; interviews are conducted with a sample of teachers, and then their interactions and answers to the open-ended questions are recorded to get all points of view for every participant (Creswell 2014). This part is subjective and aims to record participants' reactions and beliefs and then analyze them and come up with a specific view in an inductive process. This epistemological and ontological paradigm aligns with this study in its qualitative part; the interviews aim to give a wide-angle look to STEM perceptions and practices in the UAE context.

3.2 Study methods

The main focus of this research study is to answer its questions; the first and second questions about STEM-related subjects teachers' perceptions and practices in the UAE are the core of this study, and the best way to answer them is to investigate the situation quantitatively and qualitatively and then to check the influence of the demographics on teachers' perceptions and practices, as shown in figure (7). The current study includes:

- A quantitative part which includes teachers' perceptions and implementation of STEM questionnaire with closed-ended questions. It was done with (N1= 144) participants to investigate how science, math, and technology (ICT) teachers understand STEM and implement it in their classrooms.

- The qualitative part includes open-ended structured interview questions about teachers' perceptions and implementation of STEM; it was done with (N2 = 3) participants to collect more details about the participants' views and helps in explaining the quantitative survey. The qualitative part was conducted sequentially after the quantitative part.

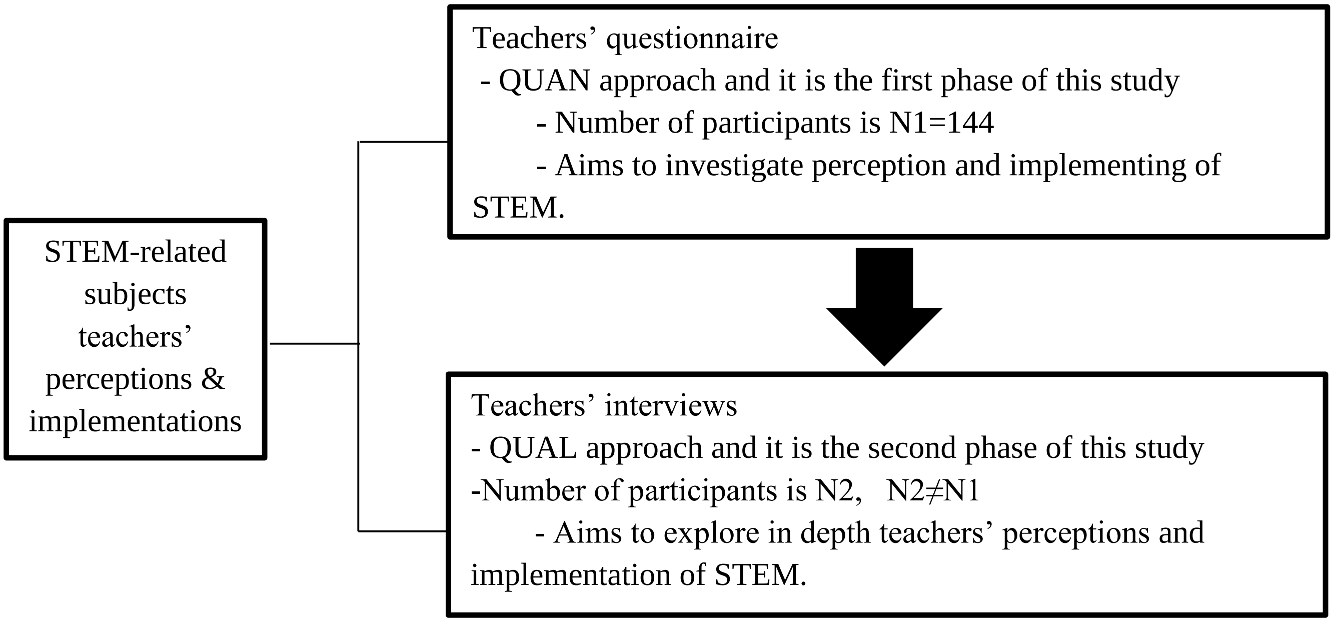

Figure (7): Design of the research method and data collection

3.2.1 Research context

This research was conducted in the UAE context, in particular in the American-system schools there. The reason for choosing these schools was because of the extensive attention that the United States gives to STEM education to support its economy (President's council of advisors on science and technology 2010). This attention was reflected on science, mathematics and computer science curricula; for example, the Next Generation Science Standards (NGSS) focus on STEM activities in its lessons, and then all American-system schools around the world which are adopting NGSS are affected by this attention so that they are teaching STEM to a degree. Educational authorities in the UAE impose regulations on schools, that they should enact a creative curriculum that enhances active learning, develops critical thinking and communication skills, creates learning environments that are conducive as well as challenging, and allows a teaching environment full of innovation (MOE 2010). It is argued that STEM education can enhance these skills if implemented successfully. Hence, this research attempts to identify STEM education features in the UAE and to find out to what extent STEM implementing in the UAE aligns with what educators and scholars agree to be best practices in STEM teaching.

Emails were sent to seventeen American-system UAE schools inviting them to fill out the questionnaire; four schools from Dubai, three schools in Sharjah, two schools in Ras Al Khaimah, two schools in Ajman, and two schools in Abu Dhabi agreed to participate. The researcher followed up participants, collecting completed questionnaires over one month until it was done. After statistical analysis of the questionnaires, data were interpreted and classified then interviews questions were developed. Some participants were purposefully selected to be interviewed to get detailed and deep answers about STEM perceptions and practices. Emails were sent to arrange appointments with the interviews sample, and conducting interviews took ten days in all. Data was analyzed and interpreted; results were discussed to draw conclusions.

3.2.2 Research instruments

This study is an explanatory sequential mixed-methods study; it started with a quantitative part which was followed by the qualitative part to give further clarification (Creswell 2014). It consists of a questionnaire that gathered science, math and ICT teachers' perceptions and implementation of STEM. Then, this questionnaire was followed by interviews which aimed to give detailed and deep data about what was found in the questionnaire. The questionnaire consists of two tables on the Likert scale and multiple choice questions. The first table examines teachers' perceptions; the questions were adopted from Park, et al. (2016) and Hernandez, et al. (2014).

The second table assesses STEM implementation; it investigates the existence of STEM education in the school and the way in which it is implemented: its approaches, its strategies, its subjects, its elements and the existence of scholarly recommended practices of successful STEM. The multiple choice questions ask about the frequency of implementing, type of STEM curriculum and the main subject in STEM teaching.

To develop questions about STEM practices, many research studies were reviewed. In addition to Park, et al. (2016), studies by English (2017); Capraro, Capraro and Morgan (2013); Mitts (2016); Chiocchio, et. al. (2015); Shernoff, et al. (2017); Altan and Ercan (2016); Kennedy and Odell (2014); and Fitzallen (2015) were reviewed to develop questions about STEM implementation in the teachers' questionnaire. Scholarly recommended elements of successful STEM include the existence of design (Lesseig, et al. 2016; McDonald 2016; Hernandez, et al. 2014), collaboration between teachers themselves as well as between students (Kasza & Slater 2017; Altan & Ercan 2016; Morrison, French & McDuffie 2015; Bouwana-Gearhart, Perry & Presley 2014), enhancing problem-solving skills which foster critical thinking (Kasza & Slater 2017; Mitts 2016; Tawfik & Trueman 2015; Kennedy & Odell 2014), problems from real-life contexts (Guzey, Harwell & Moore 2014), and using different strategies of inquiry-based learning to give a chance for student-directed learning, which means minds on and hands on (Mitts 2016; Osman, Hiong &Vebrianto 2013).

To develop the structured interview's questions, in addition to Park, et al's (2016) research, the studies of Krajcik and Delen (2017); Bouwana-Gearhart, Perry and Presley (2014); Bruce-Davis, et al. (2014); and Brown, et al. (2011) were used.

3.2.2.1 Research questionnaire

The questionnaire was designed to assess science, math and ICT teachers' perceptions and practices of STEM education in their American-system schools. This questionnaire was designed to answer the first and the second questions of this study; "What are teachers' perceptions of STEM education in the UAE? What are teachers' practices of STEM education in the UAE? " Implicitly the results of the questionnaire answer the third question; "What influence do demographic variables have on STEM-related subjects teachers' perceptions?" The questionnaire starts with an introduction showing the purpose of the questionnaire and what it investigates and then a demographics part which asks about experience, years in teaching, the grades level taught, and the major of teaching (see Appendix 1). The first set of questions starts with a multiple choice section consisting of four questions: frequency of the use of STEM /month, the curriculum in which STEM is taught, the subject in which STEM is taught, and the type of connection between subjects. Two tables on the Likert scale were then posted: the first table includes statements (1-7) and examines teachers' beliefs and thoughts about the necessity of teaching STEM in UAE schools, STEM's potential impact on critical thinking, decision-making, and problem-solving, STEM's nature and its relation with the real world, its definition and its approaches to its integration.

The second table includes statements (8-42) and examines the implementation of integration, engineering design, collaboration, problem-solving, and pedagogical content consequently. Each of these elements was examined by seven statements in the table. At the end of the questionnaire, two questions were posted, which asked the participants to accept being interviewed or having one of their STEM classes observed. A request to answer all questions was posted with every part in the questionnaire.

The multiple choice question and the first table on Likert's scale were adopted and modified from Park, et al. (2016) and Hernandez, et al. (2014). The second table on Likert's scale was developed depending on the framework of NGSS and integration theories of Dewey and Drake, as was presented in the literature review chapter of this study. STEM education relies on three major components: core disciplinary concepts of science, the crosscutting ideas, and engineering practices (Krajcik & Delen 2017; NRC 2012). These components inspired the development of this questionnaire as each component was broken down into elements and features to facilitate criteria development, so a second table on Likert's scale was developed to assess STEM practices in schools. The table consists of many sections; each section is investigating one element or one feature of STEM implementing. Core disciplinary concepts of science are presented in the pedagogical content section, engineering practice is presented in the engineering design section, and the crosscutting concepts are presented in integration, problem-solving and collaboration sections, as shown in figure (8).

Each section's criteria was developed with reference to scholarly recommended procedures: integration criteria was adapted from Fitzallen (2015); Altan and Ercan (2015); Kennedy and Odell (2014), and with reference to the literature review of Shernoff et al.(2017); from Osman, Hiong and Vebrianto (2013) it investigates the integration approach, which is either a multidisciplinary or interdisciplinary integrative approach, and the subjects included in the integration are either the four disciplines of STEM or other school subjects, and crosscutting concepts and skills. Engineering design criteria was adopted from English (2017) and Capraro,

Capraro and Morgan (2013); it assesses the engineering design process and the existence of project-based learning. Collaboration statements were adopted from Chiocchio, et al.(2012). Problem-solving was modified from Mitts (2016) and Asghar, et al. (2012); it assesses problem-solving strategy, problem-solving skills and the problems' authenticity. The last section in the Likert scale table is the pedagogical content which was adopted from Forawi (2000) and Capraro, Capraro and Morgan (2013).

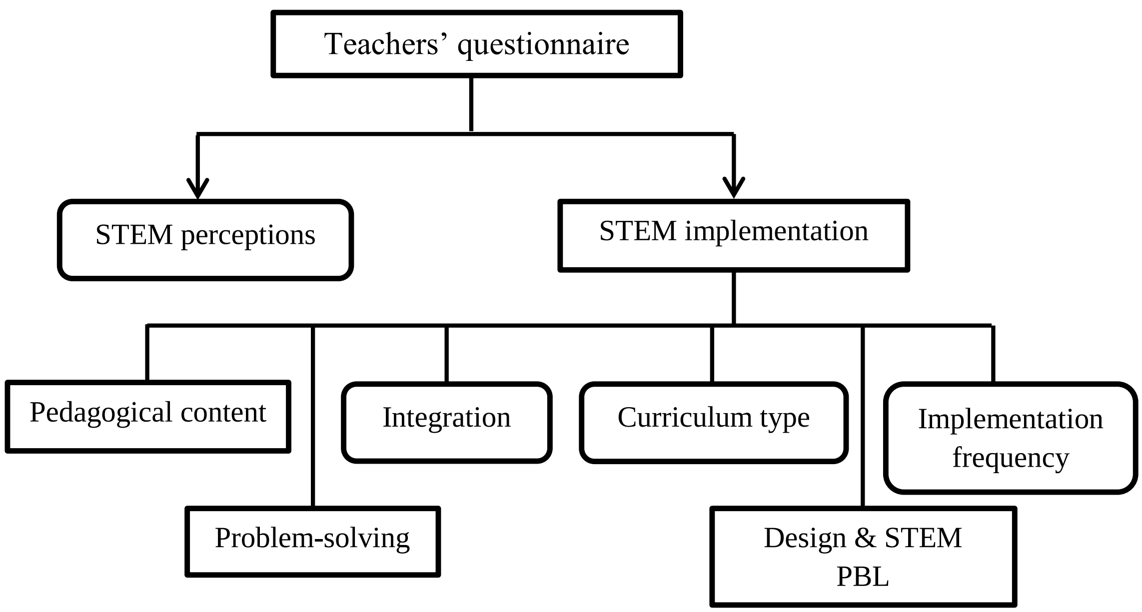

Figure (8) shows the questionnaire's skeleton

3.2.2.2 Research interviews

This is the second phase of this study: after the survey was conducted, analyzed and interpreted, the questions of interviews were developed in a way that explores in depth more details about STEM implementing in the UAE. At the end of the questionnaire there was a question asking for approval to be interviewed to get more details about STEM implementing, a number of N2 = 3 participants accepted to be interviewed. The interviews were done through email; interviewing through email can guarantee the absence of researcher's bias (Creswell 2014). Teachers who agreed to be interviewed received an email including the structured interviews questions (Bell & Waters 2014). There were 13 structured questions that were adapted from Park, et al. (2016); Krajcik and Delen (2017); Bouwana-Gearhart, Perry and Presley (2014); Bruce-Davis, et al. (2014); and Brown, et al. (2011). See Appendix 2.

3.2.3 Research samples

As an explanatory sequential mixed methods, there are two samples; cluster sample for quantitative part and purposive sample for the qualitative part. In the quantitative part, the target population of the study is all science, math, and ICT teachers in K-12 American-system schools in the UAE. This number of participants is difficult to obtain, so the study population was the total number of math, science and technology teachers in the contacted schools. Emails were sent to 17 American-system schools' principals asking them to encourage science, math, and technology teachers in their schools to participate in filling out the questionnaire; seven schools in Dubai, four schools in Sharjah, two schools in Ras Al Khaimah, two in Ajman, two in Abu Dhabi and no schools from Fujairah or Um alQuwain. Each of the contacted schools has on average 25 science, math, and technology teachers teaching from grade 1 to grade 12 and so, the study population is 425 teachers. The paradigm of selecting target population, study population and study sample is adopted from Creswell (2014). The study sample includes teachers from the contacted schools who filled out the questionnaire; four schools from Dubai, three in Sharjah, two schools in Ras Al Khaimah, two schools in Ajman, and two schools in Abu Dhabi agreed to invite its targeted teachers to fill out the questionnaire, a cluster sample N1=144 teachers filled out the study questionnaire.

The qualitative part sample was purposefully selected as it is a follow-up to the quantitative part; it aims to give depth and strength to the study results (Creswell 2014). The number of participants in this part is N2 =3, they were interviewed through phone call and email.

3.3 Ethical consideration

Ethical issues should be anticipated when conducting research (Bryman & Bell 2011). In this study, official consents from schools managements were received and then participants were informed and given the choice to participate. Participants were informed of the questionnaire and interview purposes; to assure more integrity, the questionnaire and the interviews were anonymous, confidentiality was guaranteed, and the information they shared is used for the research purpose; this may give the participants a feeling of security to share their perceptions and practices (Creswell 2014). As participation in the questionnaire was voluntary and competent, participating in the interviews was voluntary and competent as well. At the end of the questionnaire, two questions were posted, asking the participants if they agreed to being interviewed or having one of their STEM classes observed, and teachers who answered yes were contacted for interviews or observation.

3.4 Pilot studies

Creswell (2014) stated the importance of validity and reliability checking of the instrument; instrument validity means that research results are allowed to be generalized; validity checking includes content validity, measures, questions, and format validity (Johnson 2014). In this study validity was checked by a university professor who recommended modifications to some questionnaire items. Reliability of the instrument is another essential factor to ensure that a study's instrument is measuring the needed variables; reliability testing was done by asking 49 teachers to complete the questionnaire and advise with any comments, and then Cronbach's Alpha was calculated: it equals 0.889 which means very high reliability between questionnaire variables. The interview questions were adopted from Park, et al. (2016); Krajcik and Delen (2017); Bouwana-Gearhart, Perry and Presley (2014); Bruce-Davis, et al. (2014); and Brown, et al. (2011).

CHAPTER FOUR

RESULTS AND DATA ANALYSIS

This study investigated STEM-related subjects' teachers' perceptions and implementation of STEM in UAE schools. It required conducting a mixed-methods approach; the quantitative part includes a teachers' questionnaire and the qualitative part includes teachers' interviews.

4.1Quantitative Results

A reliability test of SPSS was done to find the Cronbach's Alpha, 0.889; results showed very high reliability between questionnaire variables.

4.1.1Demographic information of the questionnaire

Demographic data was the first section in the questionnaire; it included teaching experience, the major of teaching, and the grades taught. The questionnaire was sent to 425 teachers who teach science or math or technology (ICT) or any other subject related to STEM teaching, but only 144 teachers responded and filled out the questionnaire. The results showed that 28% of the sample had 1-5 years of experience in teaching, 39% had experience of 6-10 years, 15% of them had 11-15 years of experience, and 18% of them had more than 15 years of experience. The sample included 34% science teachers, 28% math teachers, 16% technology teachers, and 21% of them teach robotics or are class teachers who teach math, science and English to the same class. Twenty percent of the sample was elementary classes teachers, 38% were middle school teachers, and 43% were secondary school teachers (see Appendix 3).

4.1.2 Questionnaire results

The multiple choice questions investigated STEM teaching features in schools. Results showed that a majority of the teachers conduct STEM classes either 3-4 times monthly or every lesson, with a percentage of 26% for each, while there was a category of “other” which means either conducting STEM lessons less than once weekly or by term; this category was the least with a percentage of 13%. This result gives positive indication about frequent implementation of STEM classes in these schools (see table 4 in Appendix 4). The type of curriculum in which STEM is taught showed that a majority of the study sample with a percentage of 67% conduct STEM classes in a regular curriculum, 18% conduct STEM classes through special activity, extra-curricular and after school program got 7% and 4% of the sample size respectively; consequently, it is clear that there is attention to include STEM education in schools’ regular curricula (see table 5 in Appendix 4).

The results of the major subject in which STEM is taught included the category “All” which means that STEM is taught in science, math, and technology; this category was 32% of the sample, whereas teaching STEM in science or math classes got 24% for each. This result shows that one third of the sample conduct STEM classes in its entire major disciplines (see table 6 in Appendix 4).

The results for the connection between the type of subjects showed that 35% of teachers connect math and ICT to science, and 33% connect math, ICT and engineering to science (which means 33% of teachers conduct STEM with all its disciplines), the other one third of the sample connect math and technology to science and they excluding engineering, whereas the connection of “any” school subjects to science was 18% and connection of math to science was 14% (see table 7 in Appendix 4).

The questionnaire was developed to answer the questions of this study which are:

1- What are teachers' perceptions of STEM education in the UAE?

2- What are teachers' practices of STEM education in the UAE?

3- What influence (if any) do demographic variables have on STEM-related subjects' teachers' perceptions of the American schools in the UAE?

Table 1 answers the study's first and second questions: it shows the descriptive analysis for participants' responses to the questionnaire questions, where (SA) means strongly agree, (A) means agree, (U) means uncertain, (D) means disagree, and (SD) means strongly disagree (see the questionnaire in Appendix 1). STEM perceptions were represented in questions 1-7; the majority showed strongly agree or agree responses in all questions. In Q1, strongly agree and agree responses comprised total 98% of the sample, Q2 responses with total 97% of the sample, Q3 with total 90%, Q4 with total 93%, Q5 with total 78%, Q6 with total 76%, and Q7 with total 89% of the sample. These results mean that the majority of the study's sample has a good perception of STEM education.

Group	Questions	SA%	A%	U%	D%	SD%
STEM Perceptions	Q1	61.1	37.5	1.4		
	Q2	52.8	44.4	2.8		
	Q3	36.1	54.2	8.3	1.4	
	Q4	40.3	52.8	5.6	1.4	
	Q5	33.3	44.4	19.4	1.4	1.4
	Q6	38.9	37.5	16.7	6.9	

	Q7	51.4	37.5	8.3	2.8	
Integration	Q8	25	45.8	22.2	6.9	
	Q9	16.7	44.4	27.8	11.1	
	Q10	15.3	62.5	16.7	5.6	
	Q11	41.7	47.2	9.7	1.4	
	Q12	13.9	58.3	22.2	5.6	
	Q13	22.2	51.4	18.1	6.9	1.4
	Q14	9.7	23.6	30.6	20.8	15.3
Engineering Design	Q15	25	34.7	30.6	9.7	
	Q16	19.4	45.8	30.6	4.2	
	Q17	18.1	51.4	25	5.6	
	Q18	16.7	52.8	23.6	6.9	
	Q19	18.1	36.1	36.1	9.7	
	Q20	18.1	40.3	27.8	13.9	
	Q21	6.9	16.7	23.6	34.7	18.1
Collaboration	Q22	19.4	54.2	18.1	6.9	1.4
	Q23	20.8	55.6	13.9	8.3	1.4
	Q24	12.5	48.6	25	11.1	2.8
	Q25	15.3	47.2	22.2	13.9	1.4
	Q26	18.1	25	27.8	22.2	6.9
	Q27	30.6	54.2	8.3	5.6	1.4
	Q28	34.7	50	12.5	1.4	1.4
Problem-solving	Q29	37.5	52.8	8.3		1.4
	Q30	33.3	52.8	12.5		1.4
	Q31	23.6	59.7	13.9	2.8	
	Q32	33.3	51.4	13.9	1.4	
	Q33	18.1	62.5	15.3	4.2	
	Q34	23.6	62.5	12.5	1.4	
	Q35	41.7	51.4	4.2	2.8	
Pedagogical Content	Q36	12.5	22.2	22.2	31.9	11.1
	Q37	9.7	33.3	26.4	19.4	11.1
	Q38	23.6	69.4	5.6	1.4	
	Q39	18.1	70.8	8.3	2.8	
	Q40	18.1	52.8	22.2	5.6	1.4
	Q41	19.4	65.3	12.5	2.8	
	Q42	29.2	61.1	5.6	2.8	1.4

Table 1 shows the descriptive statistics of the questionnaire

Questions about STEM implementation were represented in the questionnaire in questions 8-42 through integration, engineering design, collaboration, problem-solving, and pedagogical content. Integration was examined through questions 8-14, and results showed that in Q8, 71% of the sample either strongly agree or agree with integrating engineering and technology in their STEM classes. Q9 results showed that 61% of the sample either strongly agree or agree that they conduct integrative interdisciplinary STEM classes. Q10 results showed that 78% of teachers teach their students cross-cutting concepts. Q11 results showed that 89% integrate science with any school subject, while the others were either uncertain or disagree with that. Q12 results showed that 72% provide their students with interdisciplinary multi-perspective viewpoints. Q13 showed that 74% give integrated instructions while only 8% do not give integrated instructions. Q14 results showed 36% either disagree or strongly disagree that STEM is an integration of its disciplines only. Engineering design was examined in questions15-2; in questions 15,16,17,18, and 20, results showed that the majority strongly agree or agree with statements about the process of engineering design. In Q19 around 36% showed agree responses with the statement of creating a prototype in every task. Q20: 53% showed disagree or strongly disagree responses about creating of the same prototype by all students. Collaboration was examined through questions 22-28, and in questions 22, 23, 24, 25, 27, and 28 the majority showed good responses to collaboration criteria, while in Q26 the highest percentage was the uncertainty about STEM teaching training that schools offer. Problem-solving was examined through questions 29-35, and a majority of teachers showed well-informed responses to the statements about problem-solving skills. The pedagogical content was examined in questions 36-42; in Q36, 43% of teachers showed disagreement with the statement that math and science core concepts are not essential when teaching STEM; 22% were uncertain about the statement. For more details see table 8 in Appendix 5.

Using SPSS one-way ANOVA test, tables (2-9) answer the study's third question.

Statement	Mean	Standard deviation	Test
Experience	1 – 5 yrs = 3.93 6 – 10 yrs = 3.86 11 – 15 yrs = 3.78 More 15 yrs = 3.95	1 – 5 yrs = 0.28 6 – 10 yrs = 0.47 11 – 15 yrs = 0.22 More 15 yrs = 0.41	One-way ANOVA F = 1.063 P-value = 0.367
Major	Science = 3.93 Math = 3.85 ICT = 3.97 Other = 3.76	Science = 0.34 Math = 0.28 ICT = 0.41 Other = 0.51	One-way ANOVA F =1.939 P-value = 0.126
Level	Elementary = 3.69 Middle school = 3.77 Secondary = 4.06	Elementary = 0.47 Middle school= 0.27 Secondary = 0.34	One-way ANOVA F = 15.510 P-value = 0.000
Frequency used STEM	1 – 2 lessons =3.87 3 – 4 lessons =3.78 3 – 5 lessons = 3.86 Every lesson = 4.05 Other = 3.76	1 – 2 lessons =0.36 3 – 4 lessons =0.34 3 – 5 lessons = 0.53 Every lesson = 0.31 Other = 0.37	One-way ANOVA F = 3.136 P-value = 0.017
Curriculum STEM taught	Extra = 3.78 After school = 3.79 Regular = 3.86 Special = 3.98 Other = 4.15	Extra = 0.14 After school = 0.69 Regular = 0.39 Special = 0.27 Other = 0.54	One-way ANOVA F = 1.436 P-value = 0.225
Major Subject to teach STEM	Science = 3.71 Math = 3.89 ICT = 4.08 All = 4.02 Other = 3.60	Science = 0.32 Math = 0.35 ICT = 0.42 All = 0.30 Other = 0.47	One-way ANOVA F = 7.262 P-value = 0.000
STEM subjects' connection in my school	Answer 1 = 3.74 Answer 2 = 3.79 Answer 3 = 4.03 Answer 4 = 3.89	Answer 1 = 0.20 Answer 2 = 0.34 Answer 3 = 0.45 Answer 4 = 0.34	One-way ANOVA F = 4.397 P-value = 0.005

Table 2 shows the results of significance differences between means for overall STEM.

Table 3: Post hoc tests for **overall STEM**:

Grade level taught

Dependent Variable: overall STEM

Tukey HSD

(I) Grade teach	(J) Grade teach	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Elementary	Middle school	-.07855	.08071	.595	-.2697	.1126
	Secondary	-.37157*	.07891	.000	-.5585	-.1847
Middle school	Elementary	.07855	.08071	.595	-.1126	.2697
	Secondary	-.29302*	.06451	.000	-.4458	-.1402
Secondary	Elementary	.37157*	.07891	.000	.1847	.5585
	Middle school	.29302*	.06451	.000	.1402	.4458

*. The mean difference is significant at the 0.05 level.

Frequency used STEM/month

Dependent Variable: overall STEM

Tukey HSD

(I) Freq. STEM	(J) Freq. STEM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1 – 2	3 – 4	.08756	.08859	.860	-.1573	.3324
	5 – 6	.00959	.10878	1.000	-.2911	.3103
	every lesson	-.17935	.08859	.260	-.4242	.0655
	Other	.10747	.10878	.860	-.1932	.4081
3 – 4	1 – 2	-.08756	.08859	.860	-.3324	.1573
	5 – 6	-.07797	.10565	.947	-.3700	.2140
	every lesson	-.26692*	.08471	.017	-.5010	-.0328
	Other	.01991	.10565	1.000	-.2721	.3119
5 – 6	1 – 2	-.00959	.10878	1.000	-.3103	.2911
	3 – 4	.07797	.10565	.947	-.2140	.3700
	every lesson	-.18894	.10565	.384	-.4809	.1031
	Other	.09788	.12308	.932	-.2423	.4381
every lesson	1 – 2	.17935	.08859	.260	-.0655	.4242
	3 – 4	.26692*	.08471	.017	.0328	.5010
	5 – 6	.18894	.10565	.384	-.1031	.4809

	Other	.28683	.10565	.057	-.0052	.5788
Other	1 – 2	-.10747	.10878	.860	-.4081	.1932
	3 – 4	-.01991	.10565	1.000	-.3119	.2721
	5 – 6	-.09788	.12308	.932	-.4381	.2423
	every lesson	-.28683	.10565	.057	-.5788	.0052

*. The mean difference is significant at the 0.05 level.

Subject in which STEM is taught

Dependent Variable: overall STEM

Tukey HSD

(I) Sub. STEM	(J) Sub. STEM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Science	Math	-.17227	.08504	.259	-.4073	.0628
	ICT	-.36747*	.10630	.006	-.6613	-.0737
	All	-.30678*	.07930	.002	-.5260	-.0876
	Other	.11084	.11134	.857	-.1969	.4186
Math	Science	.17227	.08504	.259	-.0628	.4073
	ICT	-.19520	.10630	.357	-.4890	.0986
	All	-.13451	.07930	.440	-.3537	.0847
	Other	.28311	.11134	.087	-.0246	.5909
ICT	Science	.36747*	.10630	.006	.0737	.6613
	Math	.19520	.10630	.357	-.0986	.4890
	All	.06069	.10177	.975	-.2206	.3420
	Other	.47832*	.12832	.003	.1237	.8330
All	Science	.30678*	.07930	.002	.0876	.5260
	Math	.13451	.07930	.440	-.0847	.3537
	ICT	-.06069	.10177	.975	-.3420	.2206
	Other	.41763*	.10702	.001	.1218	.7134
Other	Science	-.11084	.11134	.857	-.4186	.1969
	Math	-.28311	.11134	.087	-.5909	.0246
	ICT	-.47832*	.12832	.003	-.8330	-.1237
	All	-.41763*	.10702	.001	-.7134	-.1218

*. The mean difference is significant at the 0.05 level.

STEM connection in my school

Dependent Variable: overall

Tukey HSD

(I) Sch. STEM	(J) Sch. STEM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
connection of math to science	connection of math and technology to science	-.05143	.09716	.952	-.3041	.2012
	connection of math, technology and engineering to science	-.28393*	.09774	.022	-.5381	-.0298
	connection of any school subjects to science	-.14542	.10922	.545	-.4294	.1386
connection of math and technology to science	connection of math to science	.05143	.09716	.952	-.2012	.3041
	connection of math, technology and engineering to science	-.23250*	.07421	.011	-.4255	-.0395
	connection of any school subjects to science	-.09399	.08879	.715	-.3249	.1369
connection of math, technology and engineering to science	connection of math to science	.28393*	.09774	.022	.0298	.5381
	connection of math and technology to science	.23250*	.07421	.011	.0395	.4255
	connection of any school subjects to science	.13851	.08942	.411	-.0940	.3710
connection of any school subjects to science	connection of math to science	.14542	.10922	.545	-.1386	.4294
	connection of math and technology to science	.09399	.08879	.715	-.1369	.3249
	connection of math, technology and engineering to science	-.13851	.08942	.411	-.3710	.0940

*. The mean difference is significant at the 0.05 level.

In table 2 results showed that teachers' experience and the major that they teach had no influence on STEM perceptions and implementations; F value for teachers' experience = 1.063, and F value for the major they teach =1.939. On the other hand it is clear that the grades levels that are taught had influences on STEM perceptions and implementations: F value for grade levels taught = 15.51 (high significance); when post hoc test was run as shown in table 3, it showed that secondary and middle school teachers had better perceptions and implementing of STEM than elementary grades teachers. Moreover, it is noticed that frequency of using STEM with F= 3.136, the major subject in which STEM is taught with F= 7.262, and STEM subjects' connection with F= 4.397, had influence on perceptions and practices. The results of post hoc test showed that: 1 - Teaching STEM every lesson or 5-6 times monthly gave positive results more than other options. 2 - Teaching STEM in technology (ICT) classes or in all disciplines' classes showed positive and better influence on STEM perceptions and implementing. 3 - Type of STEM subjects' connection showed that connecting the four STEM disciplines had positive and better impact on STEM teaching more than any other connection.

Teachers' perceptions results

Statement	Mean	Standard deviation	Test
Experience	1 – 5 yrs = 4.31 6 – 10 yrs = 4.34 11 – 15 yrs = 4.09 More 15 yrs = 4.46	1 – 5 yrs = 0.42 6 – 10 yrs = 0.56 11 – 15 yrs = 0.28 More 15 yrs = 0.55	One-way ANOVA F = 2.336 P-value = 0.076
Major	Science = 4.34 Math =4.26 ICT =4.44 Other = 4.31	Science = 0.46 Math =0.43 ICT =0.52 Other =0.61	One-way ANOVA F =0.915 P-value =0.435
Level	Elementary = 4.18 Middle school = 4.23 Secondary = 4.45	Elementary = 0.53 Middle school =0.45 Secondary =0.50	One-way ANOVA F = 4.158 P-value = 0.018

Table 4 shows the significance differences between means for STEM Perceptions

In table 4, grade levels taught showed influence on STEM perceptions, with significance F= 4.158, while teachers' experience and the major they teach had no influence on STEM perceptions as their F- test showed low F values, as shown in the table. The post hoc test results showed that teachers of secondary and middle school had positive and better influence on STEM perceptions than elementary school teachers. Moreover, there are significant differences in means of frequency of using STEM, with F = 3.121, major subject to teach STEM with F = 4.088, and STEM subjects' connection with F = 9.721. The high values of F means that the mentioned variables had influence on STEM perceptions. See table 9 and 10 in Appendix 6.

Integration results

Statement	Mean	Standard deviation	Test
Experience	1 – 5 yrs = 3.86 6 – 10 yrs = 3.76 11 – 15 yrs = 3.68 More 15 yrs = 3.68	1 – 5 yrs = 0.39 6 – 10 yrs = 0.62 11 – 15 yrs = 0.32 More 15 yrs = 0.65	<u>One-way ANOVA</u> F = 0.816 P-value = 0.487
Major	Science = 3.83 Math = 0.74 ICT = 3.93 Other = 3.52	Science = 0.51 Math = 0.49 ICT = 0.45 Other = 0.62	<u>One-way ANOVA</u> F =3.270 P-value = 0.023
Level	Elementary =3.60 Middle school = 3.67 Secondary =3.90	Elementary =0.44 Middle school = 0.54 Secondary = 0.54	<u>One-way ANOVA</u> F = 4.413 P-value = 0.014

Table 5 shows the significance differences between means for Integration

In table 5, teachers' experience had no influence on STEM implementation, while major of teachers with F value = 3.270, and the grades levels they teach with F = 4.413, showed influence on integration concepts and approaches. The post hoc test showed that teachers of ICT, science and math had positive and better implementing of integration concepts than teachers who teach other subjects related to STEM; secondary and middle school teachers showed positive and better implementing for integration than elementary grades teachers. Moreover, frequency of using STEM with F = 5.075, major subject to teach STEM with F = 7.986, and STEM subjects' connection with F = 8.834, showed influence on integration. See tables 11and 12 in Appendix 7.

Engineering design results

Statement	Mean	Standard deviation	Test
Experience	1 – 5 yrs = 3.66 6 – 10 yrs = 3.54 11 – 15 yrs = 3.58 More 15 yrs = 3.51	1 – 5 yrs = 0.51 6 – 10 yrs = 0.75 11 – 15 yrs = 0.52 More 15 yrs = 0.67	One-way ANOVA F = 0.371 P-value = 0.774
Major	Science = 3.68 Math = 3.51 ICT = 3.70 Other = 3.37	Science = 0.53 Math = 0.64 ICT = 0.68 Other = 0.73	One-way ANOVA F =1.934 P-value = 0.127
Level	Elementary =3.28 Middle school =3.35 Secondary =3.90	Elementary =0.60 Middle school = 0.49 Secondary = 0.64	One-way ANOVA F = 17.467 P-value = 0.000

Table 6 shows significance differences between means for Engineering Design

In table 6, results showed that experience and the major in which STEM is taught had no influence on engineering design implementation, while grades levels had influence on implementing engineering design as F value = 17.467 (high significant difference). The post hoc showed that secondary and middle school teachers had positive and better engineering design implementing than elementary grades teachers. In addition, major subject to teach STEM with F = 5.592, and STEM subjects connection with F = 5.633 had influence on the implementing of engineering design. See tables 13 and 14 in Appendix 8.

Collaboration results

Statement	Mean	Standard deviation	Test
Experience	1 – 5 yrs = 3.79 6 – 10 yrs = 3.71 11 – 15 yrs = 3.71 More 15 yrs = 3.87	1 – 5 yrs = 0.60 6 – 10 yrs = 0.73 11 – 15 yrs = 0.42 More 15 yrs = 0.61	One-way ANOVA F = 0.420 P-value = 0.739
Major	Science = 3.66 Math = 3.85 ICT = 3.80 Other = 3.80	Science = 0.61 Math = 0.51 ICT = 0.53 Other = 0.85	One-way ANOVA F = 0.778 P-value = 0.508
Level	Elementary = 3.58 Middle school = 3.68 Secondary = 3.92	Elementary = 0.83 Middle school = 0.58 Secondary = 0.54	One-way ANOVA F = 3.756 P-value = 0.026

Table 7 shows significance differences between means for Collaboration

In table 7, results showed that teachers' experience and the major subject in which STEM is taught had no influence on collaboration, while grades levels had influence on collaboration as the F value = 3.756. The post hoc test showed that secondary and middle school teachers had positive and better implementing of collaboration than elementary grades teachers. Other demographics and variables in the table had shown no significant differences in means, thus no influence on the collaboration factor in STEM education was found. See tables 15 and 16, Appendix 9.

Problem-solving results

Statement	Mean	Standard deviation	Test
Experience	1 – 5 yrs = 4.19 6 – 10 yrs = 4.11 11 – 15 yrs = 4.18 More 15 yrs = 4.19	1 – 5 yrs = 0.43 6 – 10 yrs = 0.61 11 – 15 yrs = 0.44 More 15 yrs = 0.58	One-way ANOVA F = 0.334 P-value = 0.801
Major	Science = 4.22 Math = 4.00 ICT = 4.35 Other = 4.02	Science = 0.51 Math = 0.46 ICT = 0.45 Other = 0.64	One-way ANOVA F =3.193 P-value = 0.026
Level	Elementary =3.94 Middle school = 4.03 Secondary = 4.33	Elementary = 0.66 Middle school = 0.42 Secondary = 0.50	One-way ANOVA F = 7.786 P-value = 0.001

Table 8 shows the significance differences between means for Problem-solving

In table 8, the major of teachers with F = 3.193, and the grades level they teach with F= 7.786 (high significant differences), showed influence on problem-solving strategies while experience showed no influence. The post hoc test showed that ICT and science teachers had positive and better implementing of problem-solving than math teachers; secondary and middle school teachers had positive and better implementing of problem-solving than elementary classes teachers. In addition, the frequency of using STEM with F= 3.469, and major subject to teach STEM with F = 9.274, showed influence on problem-solving implementation. See tables 17 and 18, Appendix 10.

Pedagogical content results

Statement	Mean	Standard deviation	Test
Experience	1 – 5 yrs = 3.77 6 – 10 yrs = 3.70 11 – 15 yrs = 3.52 More 15 yrs = 3.97	1 – 5 yrs = 0.28 6 – 10 yrs = 0.49 11 – 15 yrs = 0.48 More 15 yrs = 0.27	One-way ANOVA F = 5.152 P-value = 0.002
Major	Science = 3.87 Math = 3.76 ICT = 3.63 Other = 3.60	Science = 0.33 Math = 0.37 ICT = 0.45 Other = 0.53	One-way ANOVA F =3.377 P-value = 0.020
Level	Elementary =3.57 Middle school =3.67 Secondary =3.88	Elementary = 0.46 Middle school = 0.45 Secondary = 0.33	One-way ANOVA F = 7.320 P-value = 0.001

Table 9 shows the significance differences between means for Pedagogical content

In table 9 it is clear that all demographics had an influence on pedagogical content being delivered; F value for teachers' experience F = 5.152, the major taught recorded F =3.377, the grades levels taught gave F = 7.320. The post hoc test showed that teachers with experience of 1-5 years or more than 15 years had positive and better pedagogical content than the others. Science, math, and ICT teachers had positive and better pedagogical content than teachers who are class teachers or who are robotics teachers. Secondary and middle school teachers had positive and better pedagogical content than elementary grades teachers. For more details see tables 19 and 20 in Appendix 11.

4.2 Qualitative Results

The interviews questions (see Appendix 2) aimed to get more details in order to fully answer the first study question. The first three interview questions aimed to explore their perceptions about STEM education: teachers were asked about STEM's definition, its importance in real life applications, and STEM's necessity in UAE schools. Participants could answer the STEM education's definition question with well-informed perceptions about it, and all of them agreed that STEM education is needed in UAE schools because, as one participant said, "STEM can increase the level of thinking to critical and apply the studied material to real life applications". When they were asked about the way that the definition of STEM education affects the content and instructions; one of the participants said: "When preparing for a STEM class, content and instructions should support the integration concept", and another teacher said, "STEM should be implemented in projects and critical thinking questions". When they were asked about their preferred instruction strategy to teach STEM, all the participants shared that STEM is implemented through projects every month or every term. When they were asked to summarize a STEM session and how it is managed and operated, none of the participants could give a clear image about STEM sessions in their school; they showed uncertainty. Regarding the key factors of a successful STEM, one teacher said it is cooperation and time management, while others showed naïve answers. Furthermore, none of the participants could show an obvious strategy about how to evaluate if STEM implementation is successful or not. Teachers showed shallow answers to the question about STEM curricular decisions and the standards they follow. When they were asked about engineering design, they gave positive responses; one teacher said, "Designing projects broaden the horizons of thinking skills", but they mentioned that they could not apply engineering design to every task. About collaboration; all participants agreed that they collaborate with others, but on the other hand, they mentioned that they have challenges related to, “Creating common ground between different subjects”, as one teacher said, and another teacher added that their challenge was with “Time, budget and administration flexibility”. About professional development programs, the results showed that not all of participants get training in teaching STEM.

CHAPTER FIVE

DISCUSSION AND CONCLUSION

Chapter Four gave the study findings; this chapter is discussing and interpreting the results. It draws conclusions, and makes recommendations, and it opens to view the study's limitations and propositions for future studies in the same field.

5.1 Discussion

This study was conducted to answer three questions; the first and second questions were about teachers' perceptions and implementations of STEM in UAE American-system schools, and the third question was about the influence of demographics on STEM perception and implementation. The questionnaire gave the researcher an overview about the STEM education situation in American-system schools in the UAE, and then interviews gave more clarification and discussed some critical points.

Most of the teachers who completed the questionnaire showed informed perceptions about STEM education; those teachers could define STEM and showed positive responses to its positive impact on critical thinking, decision-making skills, and problem-solving skills, and this result aligns with what was found by Shernoff, et al.(2017) and Altan and Ercan (2016); their teachers believed that STEM education impacts positively on creativity, inquiry, high-order thinking skills, and problem-solving skills. Similarly, the interviews showed informed understanding of STEM's definition and its potential impacts; they defined STEM education as the integration of science, math, engineering and technology in an authentic context to enhance knowledge and to master skills. This definition matches with Fitzallen's (2015) and Shernoff's, et al. (2017) definitions; they defined STEM as a holistic approach that aims to offer connected and meaningful education by connecting disciplines and enhancing student-centered learning through the using of knowledge and skills of math, science, technology and engineering and then promoting critical thinking, creativity, collaboration and 21st century skills. Regarding STEM implementations in schools, there was a variety of responses, and differences in teachers' perceptions and implementation of STEM education. Integration results showed that a majority of teachers provide their students with cross-cutting concepts and multi-perspective viewpoints in an authentic context; this result aligns with the NGSS (2013) framework which was explained in the literature review chapter, as it advocates that cross-cutting concepts are crucial in STEM education. Teachers believe that STEM should be related to real world applications; this thought aligns with Drake's (1991) integration theory as she advocated for the transdisciplinary approach which connects STEM to real-life applications. Interviews showed that teachers implement multidisciplinary STEM in STEM classes, although 75% of them believe, as was clear from the questionnaire responses, that interdisciplinary integrative STEM enhances better STEM learning than a multidisciplinary approach. Regarding the integrated disciplines in STEM education, one third of teachers integrate science, mathematics, engineering and technology in STEM tasks, while one third integrate other school subjects in STEM tasks. Although STEM education is known as integration of the four disciplines math, science, engineering and technology, in fact many researchers agree that other school subjects should be added to STEM integration (Shernoff, et al. 2017; Fitzallen 2015; Yildirim 2016; Kelley & Knowles 2016).

On engineering design: teachers believed that STEM education is product-focused education; two thirds of teachers in the questionnaire considered engineering concepts and practices as a part of STEM class instructions because they believed it is the best practice of STEM. Those teachers showed that their students could collect information from different disciplines, could pose and refine investigative questions related to the project, and only 36% of teachers agreed that students produce prototypes, test, revise and improve on generated prototypes as shown in table 1. Interviews showed that schools' curricula are based on teaching separate-disciplines classes; a multidisciplinary STEM activity is conducted based on a certain theme through project-based learning. The interviewed teachers preferred conducting project-based learning to enhance concepts understanding and skills mastering. In general, teachers showed naïve implementation for engineering practices, but they showed good implementation for project-based learning, a result that aligns with what was found by Capraro, Capraro and Morgan (2013), Kennedy and Odell (2014), and Gonzales (2015) in their studies. It can be claimed that engineering concepts and practices are discussed in two thirds of STEM education classes in the UAE, but engineering practices are not implemented in every STEM class.

On collaboration: two thirds of teachers showed that they share knowledge that promotes the development of STEM teaching, share resources that help handle STEM teaching, communicate STEM teaching ideas, and discuss work adjustments with other teachers. The majority of teachers, with a percentage of 75% agreed that their students discuss and negotiate their tasks' solutions with their classmates, and improve their communication skills while handling their STEM task (see table 1). On the other hand, the interviewed teachers showed moderate understanding of the standards and curricular decisions they should follow; in fact this confusion should not happen if they have successful collaboration, as they mentioned in the questionnaire. It can be claimed that interview responses related to collaboration did not reach the extremely positive responses to collaboration criteria in the questionnaire. One third of teachers said that there is continuous training about how to teach STEM, while 65% of teachers do not have continuous training or professional development related to STEM. This point was discussed deeply in the interviews; teachers mentioned that they collaborate with others in the school to handle successful STEM classes but there are many difficulties they face, such as time and resources limitations, coordination among subjects, financial shortages and lack of administration support. Park, et al. (2016), Ashton (2017) and Altan and Ercan (2016) shared the same results, as they found a lack of resources and a shortage of time for collaboration and instructional design.

Teachers had an informed understanding of problem-solving skills and implementing of the problem-based learning process, as they reported in the questionnaire. This result aligns with what was found by Morrison, McDuffie and French (2015), that problem-solving is well-implemented in schools. Although teachers showed positive responses to problem-solving skills and problem-based learning in the questionnaire, none of the interviewed teachers mentioned anything about problem-solving skills and its potential impact on students, and none of them mentioned that they implement problem-based learning in their classes, as it seems passive.

In the pedagogical content the majority of teachers showed naïve understanding regarding the essentiality of core concepts of science and math in teaching STEM; 42% of teachers believed that core concepts of math and science are not essential in teaching STEM. This result opposes the NGSS (2013) framework as it focuses on disciplines' core concepts in STEM education. Moreover, 43% of teachers believed that teaching rigorous science and math content is enough to give successful STEM education; it can be claimed that this is a misconception of STEM education, because as was shown in the literature review, enhancing successful STEM education has several features which were recommended by scholars and educators, such as: problem-solving skills which foster critical thinking (Kasza & Slater 2017; Mitts 2016; Tawfik & Trueman 2015; Kennedy & Odell 2014), problems from real-life context (Guzey, Harwell & Moore 2014), existence of project and design (Lesseig, et. al 2016; McDonald 2016; Hernandez, et. al. 2014), and collaboration (Kasza & Slater 2017; Altan & Ercan 2016; Morrison, French & McDuffie 2015; Bouwana-Gearhart, Perry & Presley 2014). On the other hand, all the teachers showed agreement on assuring scientific literacy before giving STEM tasks and they utilize inquiry-based learning strategies; all of teachers showed informed understanding of the essentiality of scientific literacy and inquiry strategies to deliver the pedagogical content of STEM education. This finding aligns with the result found by Osman, Hiong & Vebrianto (2013). It can be said that there is informed understanding regarding inquiry and scientific literacy, but there are still misconceptions of disciplines' core concepts and disciplines' contents.

The above discussion answers the first and the second study's questions. To answer the third question; statistical analysis of one-way ANOVA test demonstrated the influence of teachers' demographics on their perceptions and implementing of STEM education. Results showed that the grade levels taught had influence on overall STEM perception and implementing, with $F = 15.510$; it had influence on STEM perception, STEM integration, collaboration, problem-solving, STEM pedagogical content, and engineering design. Post hoc test results in table 3 showed that secondary and middle school teachers had positive and better perceptions and implementing of overall STEM education than elementary school teachers.

Furthermore, results showed that a teacher's major had an impact on their STEM integration and problem-solving practice: technology (ICT), science and math had positive and better implementing of integration than teachers who teach other subjects related to STEM. In addition, technology and science teachers showed positive and better practice of problem-solving than math teachers.

It is clear that teachers' experience, grade levels taught, and teacher's major had influence on STEM pedagogical content; teachers with experience of 1-5 years or more than 15 years had positive and better pedagogical content than others. Science, math, and ICT teachers had positive and better pedagogical content than other teachers; secondary and middle school teachers had positive and better pedagogical content than elementary grades teachers (see tables 19& 20 in appendix11).

It is obvious that secondary and middle school teachers showed positive and better perceptions and implementing of STEM education than elementary school teachers in all categories, although many scholars and researchers recommend focusing on STEM education from early schooling years (McDonald 2016; English & King 2015).

5.2 Conclusion

This study was conducted to examine teachers' perceptions and implementing of STEM education in American-system schools in the UAE, and to investigate demographics' influence on teachers' perceptions and implementation of STEM education. Teachers' perceptions and implementing of STEM education results showed that teachers in UAE have well-informed perceptions of STEM education, and well-informed understanding of STEM's definition and its potential impacts on students and community. Teachers showed well-informed and positive implementing of integration concepts according to NGSS (2013) and Drake (1991); on the other hand, they implement multidisciplinary STEM although they believe that integrative interdisciplinary STEM enhances better STEM learning; moreover, STEM is being implemented as a part of curricula or as an activity per month or per term. There is a variety of subjects chosen to be integrated in STEM class; the percentage of teachers who include science, math, engineering, and technology in STEM classes does not exceed 33% of UAE STEM teachers, the remaining two thirds are divided equally between implementing STEM with science, math, and technology, and implementing STEM with science and other school subjects. Thus, they adopt the National Science Foundation (NSF) opinion about STEM disciplines: that economics, politics, sociology and psychology could be added to STEM education.

Engineering concepts and practices are discussed in two thirds of STEM classes; teachers showed informed implementation for project-based learning but they could not represent engineering design in every task. Teachers have well-informed implementing of problem-solving skills and the problem-based learning process. There are informed understandings of inquiry-based learning and scientific literacy; but there are misconceptions of disciplines' core concepts and disciplines' contents needed in STEM education according to NGSS (2013). There is a lack of successful collaboration related to STEM education between different parties in schools; this causes confusion and misconceptions in STEM curriculum and instructional decision, and difficulties in managing time, funding, and efforts. There is a shortage of professional development programs related to STEM teaching in a majority of UAE schools. Although teachers rated many questionnaire items with extreme agreement to informed and positive implementing of STEM education, their implementation of these items did not match their well-informed and positive perceptions of STEM education.

It was found that some demographics have influence on STEM education perception and implementation, as was revealed from the findings. Grade levels taught had influence on overall STEM perceptions and implementing; grade levels taught had influence on STEM perception, STEM integration, collaboration, STEM pedagogical content, problem-solving and engineering design, particularly in that secondary and middle school teachers have positive and better responses to STEM perception, integration, collaboration, problem-solving and engineering design than elementary school teachers. Teacher's major have impact on STEM integration and problem-solving practice; in particular, technology (ICT), science and math teachers have positive and better implementing of integration than teachers who teach other subjects related to STEM. Technology and science teachers showed positive and better practice of problem-solving than math teachers. All demographics have influence on STEM pedagogical content. In general, it can be said that secondary and middle school teachers showed positive and better perceptions and implementing of STEM education than elementary school teachers in all categories although many educators, such as McDonald (2016) and English & King (2015), recommend STEM education from early schooling levels.

5.3 Recommendations

STEM is substantially in demand; it is recommended to be well-perceived and well-implemented by teachers. A professional development plan to provide teachers with training and support is crucially needed, hence, if teachers are well-trained to teach STEM, they will deliver successful

STEM education. Han, S. et. al. (2015) state that students learn better if their teacher is well-skilled with STEM instruction. Beside the practical side of STEM teaching, STEM pedagogical content must be well-perceived, and this study shows teachers' misconceptions of STEM pedagogical content in addition to confusion in curricular and standards decisions. These points can be worked out if they are included in the professional development program.

For future research in this field, it is recommended to carry out semi-structured interviews, so that the interviewer can get in-depth with participants to present extensive description of STEM practices in schools. In addition observation inspection of STEM classes in schools that have STEM education is recommended to increase the validity and accountability of the results. In general; more researches and studies are needed in STEM education field.

5.4 Limitations

One of this study's limitations is that the researcher could not have participants from Fujairah and Um AlQuwain emirates. It would be better if the sample size in the questionnaire could be expanded and increased. The other limitation is that teachers' responses to the interview questions were generally shallow; teachers were motivated about STEM education in their schools, but when interviewing them, their answers seemed undetailed, confusing and shallow. Observation inspections for STEM classes in different schools were supposed to be conducted, but they could not be held due to the refusal of either schools' managements or teachers themselves.

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Appendix 1

Teachers Questionnaire

This questionnaire investigates STEM perceptions of science, math and ICT teachers and the way they implement STEM in their schools. The information is used for academic research only and confidentiality is guaranteed. So kindly, answer all questions.

A) Demographics

-Teaching experience

□1-5 yrs. □6-10 yrs. □11-15 yrs. □More than 15 yrs.

-The major you teach

□Science □Math □ICT □Other

-Grade level you teach

□Elementary □Middle school □Secondary

B) Choose one of the choices in questions 1-4. (Note: There are no correct and wrong answer)

1-Frequency of the use of STEM /month in my classes

1=1-2 lessons 2=3-4 lessons 3=5-6 lessons 4=every lesson 5=other

2- The curriculum in which STEM is taught

1=extra-curricular 2=after school program 3=regular curricular
4-special activity 5= others

3-The subject in which STEM is taught

1=science 2=math 3=ICT 4= all 5=others

4-STEM education in my school is

1=connection of math to science 2=connection of math and technology to science
3=connection of math, technology and engineering to science
4- connection of any school subjects to science.

C) What is your thought about STEM education? After you read statements (1-7), decide whether you strongly agree, agree, uncertain disagree, or strongly disagree with it.
(SA) Strongly Agree; (A) Agree; (U) Uncertain; (D) Disagree; (SD) Strongly Disagree

No	Statement	Response				
		SA	A	U	D	S
STEM Perceptions						
1	STEM education has a relation with what we experience in the real world.					
2	STEM has positive impact on critical thinking.					
3	STEM has a positive impact on decision-making skills.					
4	STEM improves problem-solving skills.					
5	STEM education is product-focused education.					
6	Teaching STEM disciplines simultaneously at the same session enhances better STEM learning than teaching separated disciplines classes.					
7	STEM education is a connection between subjects within an authentic context to enhance students learning.					

D) Respond to the statements (8-42) with regard to how you implement STEM at your school
(SA) Strongly Agree; **(A)** Agree; **(U)** Uncertain; **(D)** Disagree; **(SD)** Strongly Disagree

No	Statement	Response				
		SA	A	U	D	SD
Integration						
8	Technology and engineering are presented in STEM classes.					
9	STEM disciplines are taught at the same session (integrative interdisciplinary).					
10	Students learn concepts that cut across disciplines.					
11	STEM tasks can be integration between science and other school subjects.					
12	Students are provided with interdisciplinary multi-perspective viewpoints.					
13	Integrated instructions are provided in STEM classes.					
14	Science, math, technology and engineering are the only subjects which can be integrated.					

Engineering and Design						
15	Engineering concepts and practice are parts of my STEM class.					
16	Students collect information related to the design from different disciplines.					
17	Students pose and refine investigative questions related to the design.					
18	Students apply discipline-based concepts in formulating the idea of the design.					
19	Students produce prototypes in each project task.					
20	Students test, revise and improve generated prototype.					
21	All students must produce the same design.					
Collaboration						
22	Teachers of STEM disciplines share knowledge that promotes development of STEM teaching.					
23	Teachers of STEM disciplines share resources that help handle STEM teaching.					
24	Teachers of STEM disciplines communicate STEM teaching ideas to each other.					
25	Teachers of STEM disciplines discuss work adjustments with each other.					
26	There is continuous training for disciplines' teachers about how to teach STEM.					
27	Students discuss and negotiate their tasks' solutions with their classmates.					
28	Students improve their communication skills while handling their STEM task.					
Problem-solving						
29	Problem-based learning is an important element of teaching STEM					
30	I guide my students to develop interdisciplinary viewpoints about the given problem					
31	Students can define the problem and what they need to solve it.					
32	Students do research and gather information from different disciplines about the given problem.					
33	Students develop probable solutions supported with evidence.					
34	Students share, communicate and refine their solutions.					
35	Problem-solving tasks challenge students to think critically.					
Pedagogical content						

36	Core concepts of math and science are not essential when teaching STEM.					
37	Teaching rigorous science and math content is enough to give successful STEM.					
38	I promote inquiry skills in my classes by raising questions for student to investigate.					
39	Students present results and reflect on them in inquiry instructions					
40	Scientific literacy is assured before giving any task.					
41	Scientific literacy promotes knowledge and skills for personal and societal decisions.					
42	Inquiry process in science provides more questions and requires higher thinking skills					

Thanks for participation

Appendix 2

Interviews questions

1- What is STEM education?

2- How does your definition of STEM education affect the content and instructions in your classes?

3-Do you think that STEM education is needed in UAE schools? Why?

4- Tell me about STEM in your school, (adopted approach, included subjects, frequency of implementing, strategies, and effectiveness)

5- How would you summarize STEM class in your school?

6-What evidence do you have for effectiveness of STEM in your school?

7 - What factors have been key to the success of STEM?

8-How are STEM curricular decisions made? What standards do you follow in the design of STEM courses?

9-How can you estimate the successfulness of STEM course?

10-Design is the key idea in STEM (Krajcik & Delen 2017), what do think of this statement?

11-What challenges do teachers face when implementing STEM education?

12-Do you ever collaborate with other teachers? How?

13-Do you have any type of professional development support in STEM education in your school? if yes, give example.

Appendix 3

Data analysis of the questionnaire

Distribution of sample size by Demographics; tables (1-3)

Table 1: Distribution of sample size by teaching experience:

Total Years' Experience	Total number	Percentage%
1 – 5 years	40	27.8
6 – 10 years	56	38.9
11 – 15 years	22	15.3
More than 15 years	26	18.1

Table 2: Distribution of sample size by major teach:

Major teach	Total number	Percentage%
Science	50	34.7
Math	40	27.8
ICT	24	16.7
Other	30	20.8

Table 3: Distribution of sample size by level teach:

Level teach	Total number	Percentage%
Elementary	28	19.4
Middle school	54	37.5
Secondary	62	43.1

Appendix 4

Distribution of sample size by STEM teaching features; tables (4-7)

Table 4: Distribution of sample size by frequency use STEM in classes:

Frequency use STEM/week	Total number	Percentage%
1 – 2 lessons	32	22.2
3 – 4 lessons	38	26.4
5 – 6 lessons	18	12.5
Every lesson	38	26.4
Other	18	12.5

Table 5: Distribution of sample size by curriculum teach STEM:

Curriculum teach STEM	Total number	Percentage%
Extra-curricular	10	6.9
After school program	6	4.2
Regular curricular	96	66.7
Special activity	28	18.4
Others	4	2.8

Table 6: Distribution of sample size by major subject to teach STEM:

Subject teach STEM	Total number	Percentage%
Science	34	23.6
Math	34	23.6
ICT	16	11.1
All	46	31.9
Other	14	9.7

Table 7: Distribution of sample size by STEM subjects connection:

School STEM education	Total number	Percentage%
Connection of math to science	20	13.9
Connection of math and IT to science	50	34.7
Connection of math, IT and engineering to science	48	33.3
Connection of any school subjects to science	26	18.1

Appendix 5

Descriptive statistics for questions 1- 42:

Table 8: Descriptive statistics by all questions in the questionnaire

Group	Questions	Strongly Agree		Agree		Uncertain		Disagree		Strongly disagree	
		#	%	#	%	#	%	#	%	#	%
STEM Perceptions	Q1	88	61.1	54	37.5	2	1.4				
	Q2	76	52.8	64	44.4	4	2.8				
	Q3	52	36.1	78	54.2	12	8.3	2	1.4		
	Q4	58	40.3	76	52.8	8	5.6	2	1.4		
	Q5	48	33.3	64	44.4	28	19.4	2	1.4	2	1.4
	Q6	56	38.9	54	37.5	24	16.7	10	6.9		
	Q7	74	51.4	54	37.5	12	8.3	4	2.8		
Integration	Q8	36	25	66	45.8	32	22.2	10	6.9		
	Q9	24	16.7	64	44.4	40	27.8	16	11.1		
	Q10	22	15.3	90	62.5	24	16.7	8	5.6		
	Q11	60	41.7	68	47.2	14	9.7	2	1.4		
	Q12	20	13.9	84	58.3	32	22.2	8	5.6		
	Q13	32	22.2	74	51.4	26	18.1	10	6.9	2	1.4
	Q14	14	9.7	34	23.6	44	30.6	30	20.8	22	15.3
Engineering Design	Q15	36	25	50	34.7	44	30.6	14	9.7		
	Q16	28	19.4	66	45.8	44	30.6	6	4.2		
	Q17	26	18.1	74	51.4	36	25	8	5.6		
	Q18	24	16.7	76	52.8	34	23.6	10	6.9		
	Q19	26	18.1	52	36.1	52	36.1	14	9.7		
	Q20	26	18.1	58	40.3	40	27.8	20	13.9		
	Q21	10	6.9	24	16.7	34	23.6	50	34.7	26	18.1
Collaboration	Q22	28	19.4	78	54.2	26	18.1	10	6.9	2	1.4
	Q23	30	20.8	80	55.6	20	13.9	12	8.3	2	1.4
	Q24	18	12.5	70	48.6	36	25	16	11.1	4	2.8
	Q25	22	15.3	68	47.2	32	22.2	20	13.9	2	1.4
	Q26	26	18.1	36	25	40	27.8	32	22.2	10	6.9
	Q27	44	30.6	78	54.2	12	8.3	8	5.6	2	1.4
	Q28	50	34.7	72	50	18	12.5	2	1.4	2	1.4
Problem-solving	Q29	54	37.5	76	52.8	12	8.3			2	1.4
	Q30	48	33.3	76	52.8	18	12.5			2	1.4
	Q31	34	23.6	86	59.7	20	13.9	4	2.8		
	Q32	48	33.3	74	51.4	20	13.9	2	1.4		
	Q33	26	18.1	90	62.5	22	15.3	6	4.2		

	Q34	34	23.6	90	62.5	18	12.5	2	1.4		
	Q35	60	41.7	74	51.4	6	4.2	4	2.8		
Pedagogical content	Q36	18	12.5	32	22.2	32	22.2	46	31.9	16	11.1
	Q37	14	9.7	48	33.3	38	26.4	28	19.4	16	11.1
	Q38	34	23.6	100	69.4	8	5.6	2	1.4		
	Q39	26	18.1	102	70.8	12	8.3	4	2.8		
	Q40	26	18.1	76	52.8	32	22.2	8	5.6	2	1.4
	Q41	28	19.4	94	65.3	18	12.5	4	2.8		
	Q42	42	29.2	88	61.1	8	5.6	4	2.8	2	1.4

Appendix 6

Results of STEM perceptions; tables (9& 10)

Table 9: Test of the significance difference between means for **STEM perceptions**:

Statement	Mean	Standard deviation	Test	Comments
Experience	1 – 5 yrs = 4.31 6 – 10 yrs = 4.34 11 – 15 yrs = 4.09 More 15 yrs = 4.46	1 – 5 yrs = 0.42 6 – 10 yrs = 0.56 11 – 15 yrs = 0.28 More 15 yrs = 0.55	One-way ANOVA F = 2.336 P-value = 0.076	There is **no significant difference** in the STEM perceptions by experience.
Major	Science = 4.34 Math =4.26 ICT =4.44 Other = 4.31	Science = 0.46 Math =0.43 ICT =0.52 Other =0.61	One-way ANOVA F =0.915 P-value =0.435	There is **no significant difference** in the STEM perceptions by major.
Level	Elementary = 4.18 Middle school = 4.23 Secondary = 4.45	Elementary = 0.53 Middle school =0.45 Secondary =0.50	One-way ANOVA F = 4.158 P-value = 0.018	There is **significant difference** in the STEM perceptions by level. Seconda = Middle> Elem
Frequency used STEM	1 – 2 lessons =4.46 3 – 4 lessons =4.16 3 – 5 lessons = 4.41 Every lesson = 4.41 Other = 4.10	1 – 2 lessons =0.41 3 – 4 lessons =0.45 3 – 5 lessons = 0.53 Every lesson = 0.51 Other = 0.57	One-way ANOVA F = 3.121 P-value = 0.017	There is **significant difference** in STEM perceptions by frequency used STEM Other =every lesson >(5-6) = (3-4) = (1-2)
Curriculum STEM taught	Extra = 4.06 After school = 3.95 Regular = 4.32 Special = 4.41 Other = 4.57	Extra = 0.07 After school = 0.96 Regular = 0.50 Special = 0.42 Other = 0.33	One-way ANOVA F = 2.041 P-value = 0.092	There is **no significant difference** in the STEM perceptions by curriculum STEM taught.
major subject to teach STEM	Science = 4.04 Math = 4.36 ICT = 4.54 All = 4.39 Other = 4.43	Science = 0.48 Math = 0.50 ICT = 0.48 All = 0.44 Other = 0.51	One-way ANOVA F = 4.088 P-value =0.004	There is **significant difference** in STEM perceptions by major subject STEM taught. ICT >other= all= math>sci
STEM subjects connection in my school	Answer 1 = 4.16 Answer 2 = 4.10 Answer 3 = 4.57 Answer 4 = 4.37	Answer 1 = 0.44 Answer 2 = 0.49 Answer 3 = 0.43 Answer 4 = 0.46	One-way ANOVA F = 9.721 P-value = 0.000	There is **significant difference** in STEM perceptions by subjects' connection. Answer 3 > Answer 4 = Answer 1 = Answer 2

Table 10: Post hoc tests for STEM **perceptions**:

Grade level taught:

Multiple Comparisons

Dependent Variable: Perceptions

Tukey HSD

(I) Grade teach	(J) Grade teach	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Elementary	Middle school	-.04384	.11352	.921	-.3127	.2251
	Secondary	-.26333*	.11099	.050	-.5262	-.0004
Middle school	Elementary	.04384	.11352	.921	-.2251	.3127
	Secondary	-.21949*	.09074	.044	-.4344	-.0046
Secondary	Elementary	.26333*	.11099	.050	.0004	.5262
	Middle school	.21949*	.09074	.044	.0046	.4344

*. The mean difference is significant at the 0.05 level.

Frequency of using STEM/ month

Multiple Comparisons

Dependent Variable: Perceptions

Tukey HSD

(I) Freq. STEM	(J) Freq. STEM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1 – 2	3 – 4	.29746	.11612	.083	-.0235	.6184
	5 – 6	.04266	.14259	.998	-.3514	.4368
	every lesson	.04934	.11612	.993	-.2716	.3703
	Other	.36012	.14259	.091	-.0340	.7542
3 – 4	1 – 2	-.29746	.11612	.083	-.6184	.0235
	5 – 6	-.25480	.13848	.355	-.6375	.1279
	every lesson	-.24812	.11103	.173	-.5550	.0588
	Other	.06266	.13848	.991	-.3201	.4454
5 – 6	1 – 2	-.04266	.14259	.998	-.4368	.3514
	3 – 4	.25480	.13848	.355	-.1279	.6375
	every lesson	.00668	.13848	1.000	-.3761	.3894
	Other	.31746	.16132	.287	-.1284	.7633
every lesson	1 – 2	-.04934	.11612	.993	-.3703	.2716
	3 – 4	.24812	.11103	.173	-.0588	.5550
	5 – 6	-.00668	.13848	1.000	-.3894	.3761
	Other	.31078	.13848	.170	-.0720	.6935

Other	1 – 2	-.36012	.14259	.091	-.7542	.0340
	3 – 4	-.06266	.13848	.991	-.4454	.3201
	5 – 6	-.31746	.16132	.287	-.7633	.1284
	every lesson	-.31078	.13848	.170	-.6935	.0720

Subject in which STEM is taught:

Multiple Comparisons

Dependent Variable: Perceptions

Tukey HSD

(I) Sub. STEM	(J) Sub. STEM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Science	Math	-.29412	.11591	.088	-.6145	.0262
	ICT	-.49370*	.14489	.008	-.8941	-.0932
	All	-.34308*	.10808	.016	-.6418	-.0443
	Other	-.38655	.15176	.086	-.8060	.0329
Math	Science	.29412	.11591	.088	-.0262	.6145
	ICT	-.19958	.14489	.643	-.6000	.2009
	All	-.04896	.10808	.991	-.3477	.2498
	Other	-.09244	.15176	.973	-.5119	.3270
ICT	Science	.49370*	.14489	.008	.0932	.8941
	Math	.19958	.14489	.643	-.2009	.6000
	All	.15062	.13871	.814	-.2328	.5340
	Other	.10714	.17489	.973	-.3762	.5905
All	Science	.34308*	.10808	.016	.0443	.6418
	Math	.04896	.10808	.991	-.2498	.3477
	ICT	-.15062	.13871	.814	-.5340	.2328
	Other	-.04348	.14587	.998	-.4467	.3597
Other	Science	.38655	.15176	.086	-.0329	.8060
	Math	.09244	.15176	.973	-.3270	.5119
	ICT	-.10714	.17489	.973	-.5905	.3762
	All	.04348	.14587	.998	-.3597	.4467

*. The mean difference is significant at the 0.05 level.

STEM connection in my school:

Multiple Comparisons

Dependent Variable: Perceptions

Tukey HSD

(I) Sch. STEM	(J) Sch. STEM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
connection of math to science	connection of math and technology to science	.06000	.12117	.960	-.2551	.3751
	connection of math, technology and engineering to science	-.41429*	.12189	.005	-.7312	-.0974
	connection of any school subjects to science	-.21648	.13621	.388	-.5707	.1377
connection of math and technology to science	connection of math to science	-.06000	.12117	.960	-.3751	.2551
	connection of math, technology and engineering to science	-.47429*	.09254	.000	-.7149	-.2337
	connection of any school subjects to science	-.27648	.11073	.065	-.5644	.0114
connection of math, technology and engineering to science	connection of math to science	.41429*	.12189	.005	.0974	.7312
	connection of math and technology to science	.47429*	.09254	.000	.2337	.7149
	connection of any school subjects to science	.19780	.11152	.290	-.0922	.4878
connection of any school subjects to science	connection of math to science	.21648	.13621	.388	-.1377	.5707
	connection of math and technology to science	.27648	.11073	.065	-.0114	.5644
	connection of math, technology and engineering to science	-.19780	.11152	.290	-.4878	.0922

*. The mean difference is significant at the 0.05 level.

Appendix 7

Results of STEM integration; tables (11& 12)

Statement	Mean	Standard deviation	Test	Comments
Experience	1 – 5 yrs = 3.86 6 – 10 yrs = 3.76 11 – 15 yrs = 3.68 More 15 yrs = 3.68	1 – 5 yrs = 0.39 6 – 10 yrs = 0.62 11 – 15 yrs = 0.32 More 15 yrs = 0.65	One-way ANOVA F = 0.816 P-value = 0.487	There is **no significant difference** in the STEM integration by experience.
Major	Science = 3.83 Math =0.74 ICT =3.93 Other = 3.52	Science = 0.51 Math =0.49 ICT =0.45 Other =0.62	One-way ANOVA F =3.270 P-value =0.023	There is **significant difference** in the STEM Integration by major: ICT = Science = Math > Other
Level	Elementary =3.60 Middle school =3.67 Secondary =3.90	Elementary =0.44 Middle school =0.54 Secondary =0.54	One-way ANOVA F = 4.413 P-value = 0.014	There **is significant difference** in the STEM integration by level. Seconda= Middle> Elem
Frequency used STEM	1 – 2 lessons =3.62 3 – 4 lessons =3.62 3 – 5 lessons = 3.80 Every lesson = 4.06 Other = 3.62	1 – 2 lessons =0.52 3 – 4 lessons =0.42 3 – 5 lessons = 0.54 Every lesson = 0.46 Other = 0.67	One-way ANOVA F = 5.075 P-value = 0.001	There is **significant difference** in the investigation of integration by frequency used STEM. Other =every lesson =(5-6) = (3-4) > (1-2)
Curriculum STEM taught	Extra = 3.54 After school = 3.81 Regular = 3.76 Special = 3.78 Other = 3.93	Extra = 0.22 After school = 0.92 Regular = 0.50 Special = 0.64 Other = 0.41	One-way ANOVA F = 0.529 P-value = 0.714	There is **no significant difference** in the STEM integration by curriculum STEM taught.
major subject to teach STEM	Science = 3.52 Math = 3.69 ICT = 4.04 All = 3.99 Other = 3.41	Science = 0.35 Math = 0.67 ICT = 0.47 All = 0.45 Other = 0.33	One-way ANOVA F = 7.986 P-value = 0.000	There is **significant difference** in the investigation of integration by major subject STEM taught. ICT = all > Math = Science = Other

STEM subjects connection in my school	Answer 1 = 3.36 Answer 2 = 3.73 Answer 3 = 4.00 Answer 4 = 3.66	Answer 1 = 0.66 Answer 2 = 0.42 Answer 3 = 0.52 Answer 4 = 0.43	One-way ANOVA F = 8.834 P-value = 0.000	There is **significant difference** in the STEM integration by STEM subjects' connection. Answer 3 > Answer 2 > Answer 4 > Answer 1

Table 11: Test of the significance difference between means for **integration**

Table 12: Post hoc tests for STEM **integration**:

Major of teacher:

Multiple Comparisons

Dependent Variable: Integration

Tukey HSD

(I) Major	(J) Major	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Science	Math	.09857	.11035	.808	-.1884	.3855
	ICT	-.09429	.12918	.885	-.4302	.2416
	Other	.31048	.12014	.052	-.0019	.6229
Math	Science	-.09857	.11035	.808	-.3855	.1884
	ICT	-.19286	.13432	.479	-.5421	.1564
	Other	.21190	.12564	.335	-.1148	.5386
ICT	Science	.09429	.12918	.885	-.2416	.4302
	Math	.19286	.13432	.479	-.1564	.5421
	Other	.40476*	.14247	.026	.0343	.7752
Other	Science	-.31048	.12014	.052	-.6229	.0019
	Math	-.21190	.12564	.335	-.5386	.1148
	ICT	-.40476*	.14247	.026	-.7752	-.0343

*. The mean difference is significant at the 0.05 level.

Grade level taught:

Multiple Comparisons

Dependent Variable: Integration

Tukey HSD

(I) Grade teach	(J) Grade teach	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Elementary	Middle school	-.06992	.12114	.833	-.3569	.2170
	Secondary	-.30118*	.11844	.032	-.5817	-.0206
Middle school	Elementary	.06992	.12114	.833	-.2170	.3569
	Secondary	-.23127*	.09683	.048	-.4606	-.0019
Secondary	Elementary	.30118*	.11844	.032	.0206	.5817
	Middle school	.23127*	.09683	.048	.0019	.4606

*. The mean difference is significant at the 0.05 level.

Frequency of using STEM:

Multiple Comparisons

Dependent Variable: Integration

Tukey HSD

(I) Freq. STEM	(J) Freq. STEM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
1 - 2	3 – 4	-.00799	.12104	1.000	-.3425	.3266
	5 – 6	-.17758	.14863	.754	-.5884	.2332
	every lesson	-.44408*	.12104	.003	-.7786	-.1095
	Other	-.00298	.14863	1.000	-.4138	.4078
3 - 4	1 – 2	.00799	.12104	1.000	-.3266	.3425
	5 – 6	-.16959	.14435	.766	-.5686	.2294
	every lesson	-.43609*	.11574	.002	-.7560	-.1162
	Other	.00501	.14435	1.000	-.3940	.4040
5 - 6	1 – 2	.17758	.14863	.754	-.2332	.5884
	3 – 4	.16959	.14435	.766	-.2294	.5686
	every lesson	-.26650	.14435	.352	-.6655	.1325
	Other	.17460	.16816	.837	-.2902	.6394
every lesson	1 – 2	.44408*	.12104	.003	.1095	.7786
	3 – 4	.43609*	.11574	.002	.1162	.7560
	5 – 6	.26650	.14435	.352	-.1325	.6655
	Other	.44110*	.14435	.022	.0421	.8401
Other	1 – 2	.00298	.14863	1.000	-.4078	.4138
	3 – 4	-.00501	.14435	1.000	-.4040	.3940

	5 – 6	-.17460	.16816	.837	-.6394	.2902
	every lesson	-.44110*	.14435	.022	-.8401	-.0421

*. The mean difference is significant at the 0.05 level.

Subject in which STEM is taught:

Multiple Comparisons

Dependent Variable: Integration

Tukey HSD

(I) Sub. STEM	(J) Sub. STEM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Science	Math	-.16807	.11811	.614	-.4945	.1584
	ICT	-.51471*	.14764	.006	-.9228	-.1066
	All	-.47278*	.11014	.000	-.7772	-.1684
	Other	.11285	.15465	.949	-.3146	.5403
Math	Science	.16807	.11811	.614	-.1584	.4945
	ICT	-.34664	.14764	.136	-.7547	.0614
	All	-.30471*	.11014	.050	-.6091	-.0003
	Other	.28091	.15465	.368	-.1465	.7083
ICT	Science	.51471*	.14764	.006	.1066	.9228
	Math	.34664	.14764	.136	-.0614	.7547
	All	.04193	.14135	.998	-.3487	.4326
	Other	.62755*	.17822	.005	.1350	1.1201
All	Science	.47278*	.11014	.000	.1684	.7772
	Math	.30471*	.11014	.050	.0003	.6091
	ICT	-.04193	.14135	.998	-.4326	.3487
	Other	.58563*	.14865	.001	.1748	.9965
Other	Science	-.11285	.15465	.949	-.5403	.3146
	Math	-.28091	.15465	.368	-.7083	.1465
	ICT	-.62755*	.17822	.005	-1.1201	-.1350
	All	-.58563*	.14865	.001	-.9965	-.1748

*. The mean difference is significant at the 0.05 level.

STEM connection in my school:

Multiple Comparisons

Dependent Variable: Integration

Tukey HSD

(I) Sch. STEM	(J) Sch. STEM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
connection of math to science	connection of math and technology to science	-.37429*	.13055	.024	-.7137	-.0348
	connection of math, technology and engineering to science	-.64881*	.13133	.000	-.9903	-.3073
	connection of any school subjects to science	-.30220	.14676	.172	-.6838	.0794
connection of math and technology to science	connection of math to science	.37429*	.13055	.024	.0348	.7137
	connection of math, technology and engineering to science	-.27452*	.09971	.033	-.5338	-.0153
	connection of any school subjects to science	.07209	.11931	.931	-.2381	.3823
connection of math, technology and engineering to science	connection of math to science	.64881*	.13133	.000	.3073	.9903
	connection of math and technology to science	.27452*	.09971	.033	.0153	.5338
	connection of any school subjects to science	.34661*	.12016	.023	.0342	.6590
connection of any school subjects to science	connection of math to science	.30220	.14676	.172	-.0794	.6838
	connection of math and technology to science	-.07209	.11931	.931	-.3823	.2381
	connection of math, technology and engineering to science	-.34661*	.12016	.023	-.6590	-.0342

*. The mean difference is significant at the 0.05 level.

Appendix 8

Results of engineering design; tables (13& 14)

Statement	Mean	Standard deviation	Test	Comments
Experience	1 – 5 yrs = 3.66 6 – 10 yrs = 3.54 11 – 15 yrs = 3.58 More 15 yrs = 3.51	1 – 5 yrs = 0.51 6 – 10 yrs = 0.75 11 – 15 yrs = 0.52 More 15 yrs = 0.67	One-way ANOVA F = 0.371 P-value = 0.774	There is **no significant difference** in the STEM engineering design by experience.
Major	Science = 3.68 Math =3.51 ICT =3.70 Other = 3.37	Science = 0.53 Math =0.64 ICT =0.68 Other =0.73	One-way ANOVA F =1.934 P-value =0.127	There is **no significant difference** in the STEM engineering design by major.
Level	Elementary =3.28 Middle school =3.35 Secondary =3.90	Elementary =0.60 Middle school =0.49 Secondary =0.64	One-way ANOVA F = 17.467 P-value = 0.000	There **is significant difference** in the STEM Engineering Design by level Seconda= Middle> Elem
Frequency used STEM	1 – 2 lessons =3.50 3 – 4 lessons =3.42 3 – 5 lessons = 3.56 Every lesson = 0.77 Other = 0.62	1 – 2 lessons =0.79 3 – 4 lessons =0.46 3 – 5 lessons = 0.96 Every lesson = 0.49 Other = 0.49	One-way ANOVA F = 1.636 P-value = 0.169	There is **no significant difference** in the investigates of engineering design by frequency used STEM.
Curriculum STEM taught	Extra = 3.26 After school = 3.76 Regular = 3.56 Special = 3.59 Other = 4.29	Extra = 0.40 After school = 0.66 Regular = 0.61 Special = 0.73 Other = 0.82	One-way ANOVA F = 2.055 P-value = 0.090	We found that there is **no significant difference** in the STEM engineering design by curriculum STEM taught.
major subject to teach STEM	Science = 3.45 Math = 3.69 ICT = 3.82 All = 3.68 Other = 2.94	Science = 0.50 Math = 0.75 ICT = 0.75 All = 0.52 Other = 0.45	One-way ANOVA F = 5.592 P-value = 0.000	There is **significant difference** in the investigates of engineering design by major subject STEM taught: ICT= Math=all = science > Other

STEM subjects connection in my school	Answer 1 = 3.57 Answer 2 = 3.41 Answer 3 = 3.86 Answer 4 = 3.37	Answer 1 = 0.49 Answer 2 = 0.60 Answer 3 = 0.69 Answer 4 = 0.57	One-way ANOVA F = 5.633 P-value = 0.001	There is **significant difference** in engineering design by STEM subjects' connection: Answer 3 > Answer 1 = Answer 2 = Answer 4

Table 13: Test of the significance difference between means for **engineering design**

Table 14: Post hoc tests for STEM **engineering design**:

Grade level taught:

Multiple Comparisons

Dependent Variable: Engineering

Tukey HSD

(I) Grade teach	(J) Grade teach	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Elementary	Middle school	-.07899	.13437	.827	-.3973	.2393
	Secondary	-.62311*	.13138	.000	-.9343	-.3119
Middle school	Elementary	.07899	.13437	.827	-.2393	.3973
	Secondary	-.54412*	.10740	.000	-.7985	-.2897
Secondary	Elementary	.62311*	.13138	.000	.3119	.9343
	Middle school	.54412*	.10740	.000	.2897	.7985

*. The mean difference is significant at the 0.05 level.

Subject in which STEM is taught:

Multiple Comparisons

Dependent Variable: Engineering

Tukey HSD

(I) Sub. STEM	(J) Sub. STEM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Science	Math	-.23529	.14612	.493	-.6392	.1686
	ICT	-.36765	.18265	.265	-.8725	.1372
	All	-.22945	.13626	.447	-.6060	.1472
	Other	.51501	.19131	.060	-.0138	1.0438

Math	Science	.23529	.14612	.493	-.1686	.6392
	ICT	-.13235	.18265	.950	-.6372	.3725
	All	.00585	.13626	1.000	-.3708	.3824
	Other	.75030*	.19131	.001	.2215	1.2791
ICT	Science	.36765	.18265	.265	-.1372	.8725
	Math	.13235	.18265	.950	-.3725	.6372
	All	.13820	.17486	.933	-.3451	.6215
	Other	.88265*	.22048	.001	.2733	1.4920
All	Science	.22945	.13626	.447	-.1472	.6060
	Math	-.00585	.13626	1.000	-.3824	.3708
	ICT	-.13820	.17486	.933	-.6215	.3451
	Other	.74445*	.18389	.001	.2362	1.2527
Other	Science	-.51501	.19131	.060	-1.0438	.0138
	Math	-.75030*	.19131	.001	-1.2791	-.2215
	ICT	-.88265*	.22048	.001	-1.4920	-.2733
	All	-.74445*	.18389	.001	-1.2527	-.2362

*. The mean difference is significant at the 0.05 level.

STEM connection in my school:

Multiple Comparisons

Dependent Variable: Engineering

Tukey HSD

(I) Sch. STEM	(J) Sch. STEM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
connection of math to science	connection of math and technology to science	.16571	.16165	.735	-.2546	.5860
	connection of math, technology and engineering to science	-.28571	.16261	.299	-.7085	.1371
	connection of any school subjects to science	.19780	.18172	.697	-.2747	.6703
connection of math and technology to	connection of math to science	-.16571	.16165	.735	-.5860	.2546

science	connection of math, technology and engineering to science	-.45143*	.12346	.002	-.7725	-.1304
	connection of any school subjects to science	.03209	.14773	.996	-.3520	.4162
connection of math, technology and engineering to science	connection of math to science	.28571	.16261	.299	-.1371	.7085
	connection of math and technology to science	.45143*	.12346	.002	.1304	.7725
	connection of any school subjects to science	.48352*	.14878	.008	.0967	.8704
connection of any school subjects to science	connection of math to science	-.19780	.18172	.697	-.6703	.2747
	connection of math and technology to science	-.03209	.14773	.996	-.4162	.3520
	connection of math, technology and engineering to science	-.48352*	.14878	.008	-.8704	-.0967

*. The mean difference is significant at the 0.05 level.

Appendix 9

Results of collaboration; tables (15& 16)

Statement	Mean	Standard deviation	Test	Comments
Experience	1 – 5 yrs = 3.79 6 – 10 yrs = 3.71 11 – 15 yrs = 3.71 More 15 yrs = 3.87	1 – 5 yrs = 0.60 6 – 10 yrs = 0.73 11 – 15 yrs = 0.42 More 15 yrs = 0.61	One-way ANOVA F = 0.420 P-value =0.739	There is **no significant difference** in collaboration by experience.
Major	Science = 3.66 Math =3.85 ICT =3.80 Other = 3.80	Science = 0.61 Math =0.51 ICT =0.53 Other =0.85	One-way ANOVA F =0.778 P-value =0.508	There is **no significant difference** in collaboration by major.
Level	Elementary =3.58 Middle school =3.68 Secondary =3.92	Elementary =0.83 Middle school =0.58 Secondary =0.54	One-way ANOVA F = 3.756 P-value = 0.026	There is **significant difference** in collaboration by level. Secondary = Middle school > Elementary
Frequency used STEM	1 – 2 lessons =3.90 3 – 4 lessons =3.68 3 – 5 lessons = 3.56 Every lesson = 3.91 Other = 3.60	1 – 2 lessons =0.43 3 – 4 lessons =0.72 3 – 5 lessons = 0.85 Every lesson = 0.50 Other = 0.67	One-way ANOVA F = 1.901 P-value = 0.114	There is **no significant difference** in the investigates of collaboration by frequency used STEM.
Curriculum STEM taught	Extra = 4.09 After school = 3.29 Regular = 3.71 Special = 3.90 Other = 4.07	Extra = 0.60 After school = 0.80 Regular = 0.61 Special = 0.60 Other = 0.74	One-way ANOVA F = 2.337 P-value = 0.058	There is **no significant difference** in collaboration by curriculum STEM taught.
major subject to teach STEM	Science = 3.59 Math = 3.80 ICT = 3.88 All = 3.89 Other = 3.55	Science = 0.50 Math = 0.46 ICT = 0.54 All = 0.75 Other = 0.83	One-way ANOVA F = 1.734 P-value =0.146	There is **no significant difference** in the investigates of collaboration by major subject STEM taught.
STEM subjects connection in my school	Answer 1 = 3.67 Answer 2 = 3.68 Answer 3 = 3.79 Answer 4 = 3.95	Answer 1 = 0.41 Answer 2 = 0.59 Answer 3 = 0.77 Answer 4 = 0.56	One-way ANOVA F = 1.188 P-value = 0.317	There is **no significant difference** in collaboration by STEM subjects' connection.

Table 15: Test of the significance difference between means for **collaboration**

Table 16: Post hoc tests for STEM **collaboration**:

Grade level taught:

Multiple Comparisons

Dependent Variable: Collaboration

Tukey HSD

(I) Grade teach	(J) Grade teach	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Elementary	Middle school	-.09562	.14416	.785	-.4371	.2459
	Secondary	-.34003*	.14095	.045	-.6739	-.0062
Middle school	Elementary	.09562	.14416	.785	-.2459	.4371
	Secondary	-.24441	.11523	.089	-.5174	.0285
Secondary	Elementary	.34003*	.14095	.045	.0062	.6739
	Middle school	.24441	.11523	.089	-.0285	.5174

*. The mean difference is significant at the 0.05 level.

Appendix 10

Results of problem-solving; tables (17& 18)

Statement	Mean	Standard deviation	Test	Comments
Experience	1 – 5 yrs = 4.19 6 – 10 yrs = 4.11 11 – 15 yrs = 4.18 More 15 yrs= 4.19	1 – 5 yrs = 0.43 6 – 10 yrs = 0.61 11 – 15 yrs = 0.44 More 15 yrs=0.58	One-way ANOVA F = 0.334 P-value = 0.801	There is **no significant difference** in problem-solving by experience.
Major	Science = 4.22 Math =4.00 ICT =4.35 Other = 4.02	Science = 0.51 Math =0.46 ICT =0.45 Other =0.64	One-way ANOVA F =3.193 P-value =0.026	There is **significant difference** in problem-solving by major: ICT= Science= Other> Math
Level	Elementary =3.94 Middle school =4.03 Secondary =4.33	Elementary=0.66 Middle school =0.42 Secondary =0.50	One-way ANOVA F = 7.786 P-value = 0.001	There is **significant difference** in problem-solving by level.: Second= Middle> Elem
Frequency used STEM	1–2 lessons =4.03 3–4 lessons =4.10 3–5 lessons= 4.10 Every lesson = 4.39 Other = 3.94	1–2 lessons=0.52 3–4 lessons=0.48 3–5 lessons=0.68 Every lesson = 0.44 Other = 0.52	One-way ANOVA F = 3.469 P-value = 0.010	There is **significant difference** in the investigates of problem-solving by frequency used STEM. Other =every lesson =(5-6) > (3-4) = (1-2)
Curriculum STEM taught	Extra = 4.00 After school= 4.05 Regular = 4.11 Special = 4.30 Other = 4.21	Extra = 0.39 After school=0.74 Regular = 0.57 Special = 0.33 Other = 0.74	One-way ANOVA F = 0.918 P-value = 0.456	There is **no significant difference** in problem-solving by curriculum STEM taught.
major subject to teach STEM	Science = 3.92 Math = 4.02 ICT = 4.55 All = 4.35 Other = 3.80	Science = 0.47 Math = 0.51 ICT = 0.37 All = 0.37 Other = 0.77	One-way ANOVA F = 9.274 P-value =0.000	There is **significant difference** in the investigates of problem-solving by major subject STEM taught. ICT>all>Math=Sci = Oth

STEM subjects connection in my school	Answer 1 = 4.03 Answer 2 = 4.11 Answer 3 = 4.16 Answer 4 = 4.24	Answer 1 = 0.41 Answer 2 = 0.51 Answer 3 = 0.63 Answer 4 = 0.45	One-way ANOVA F = 0.691 P-value = 0.559	There is **no significant difference** in problem-solving by STEM subjects' connection.

Table 17: Test of the significance difference between means for **problem-solving**

Table 18: Post hoc tests for STEM **problem-solving**:

Major of teacher:

Multiple Comparisons

Dependent Variable: Problem-solving

Tukey HSD

(I) Major	(J) Major	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Science	Math	.22286	.11003	.184	-.0632	.5090
	ICT	-.12238	.12881	.778	-.4573	.2125
	Other	.20381	.11979	.327	-.1077	.5153
Math	Science	-.22286	.11003	.184	-.5090	.0632
	ICT	-.34524	.13393	.053	-.6935	.0030
	Other	-.01905	.12528	.999	-.3448	.3067
ICT	Science	.12238	.12881	.778	-.2125	.4573
	Math	.34524	.13393	.053	-.0030	.6935
	Other	.32619	.14205	.104	-.0432	.6955
Other	Science	-.20381	.11979	.327	-.5153	.1077
	Math	.01905	.12528	.999	-.3067	.3448
	ICT	-.32619	.14205	.104	-.6955	.0432

Grade level taught:

Multiple Comparisons

Dependent Variable: Problem-solving

Tukey HSD

(I) Grade teach	(J) Grade teach	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Elementary	Middle school	-.08768	.11806	.739	-.3673	.1920
	Secondary	-.38841*	.11543	.003	-.6618	-.1150
Middle school	Elementary	.08768	.11806	.739	-.1920	.3673
	Secondary	-.30073*	.09437	.005	-.5243	-.0772

Secondary	Elementary	.38841*	.11543	.003	.1150	.6618
	Middle school	.30073*	.09437	.005	.0772	.5243

*. The mean difference is significant at the 0.05 level.

Frequently used STEM:

Multiple Comparisons

Dependent Variable: Problem-solving

Tukey HSD

(I) Freq. STEM	(J) Freq. STEM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1 – 2	3 – 4	-.07096	.12310	.978	-.4112	.2693
	5 – 6	-.06845	.15116	.991	-.4863	.3493
	every lesson	-.36419*	.12310	.029	-.7044	-.0240
	Other	.09028	.15116	.975	-.3275	.5081
3 – 4	1 – 2	.07096	.12310	.978	-.2693	.4112
	5 – 6	.00251	.14680	1.000	-.4032	.4083
	every lesson	-.29323	.11771	.099	-.6186	.0321
	Other	.16124	.14680	.807	-.2445	.5670
5 – 6	1 – 2	.06845	.15116	.991	-.3493	.4863
	3 – 4	-.00251	.14680	1.000	-.4083	.4032
	every lesson	-.29574	.14680	.265	-.7015	.1100
	Other	.15873	.17102	.886	-.3140	.6314
every lesson	1 – 2	.36419*	.12310	.029	.0240	.7044
	3 – 4	.29323	.11771	.099	-.0321	.6186
	5 – 6	.29574	.14680	.265	-.1100	.7015
	Other	.45447*	.14680	.020	.0487	.8602
Other	1 – 2	-.09028	.15116	.975	-.5081	.3275
	3 – 4	-.16124	.14680	.807	-.5670	.2445
	5 – 6	-.15873	.17102	.886	-.6314	.3140
	every lesson	-.45447*	.14680	.020	-.8602	-.0487

*. The mean difference is significant at the 0.05 level.

Subject in which STEM is taught:

Multiple Comparisons

Dependent Variable: Problem-solving

Tukey HSD

(I) Sub. STEM	(J) Sub. STEM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Science	Math	-.09244	.11594	.931	-.4129	.2280
	ICT	-.62920*	.14493	.000	-1.0298	-.2286
	All	-.42346*	.10812	.001	-.7223	-.1246
	Other	.12845	.15180	.916	-.2911	.5480
Math	Science	.09244	.11594	.931	-.2280	.4129
	ICT	-.53676*	.14493	.003	-.9373	-.1362
	All	-.33102*	.10812	.022	-.6298	-.0322
	Other	.22089	.15180	.593	-.1987	.6405
ICT	Science	.62920*	.14493	.000	.2286	1.0298
	Math	.53676*	.14493	.003	.1362	.9373
	All	.20575	.13875	.575	-.1777	.5892
	Other	.75765*	.17495	.000	.2741	1.2412
All	Science	.42346*	.10812	.001	.1246	.7223
	Math	.33102*	.10812	.022	.0322	.6298
	ICT	-.20575	.13875	.575	-.5892	.1777
	Other	.55191*	.14591	.002	.1486	.9552
Other	Science	-.12845	.15180	.916	-.5480	.2911
	Math	-.22089	.15180	.593	-.6405	.1987
	ICT	-.75765*	.17495	.000	-1.2412	-.2741
	All	-.55191*	.14591	.002	-.9552	-.1486

*. The mean difference is significant at the 0.05 level.

Appendix 11

Results of Pedagogical content tables (19& 20)

Statement	Mean	Standard deviation	Test	Comments
Experience	1 – 5 yrs = 3.77 6 – 10 yrs = 3.70 11 – 15 yrs = 3.52 More 15 yrs = 3.97	1 – 5 yrs = 0.28 6 – 10 yrs = 0.49 11 – 15 yrs = 0.48 More 15 yrs = 0.27	One-way ANOVA F = 5.152 P-value =0.002	There is **significant difference** in the pedagogical content by experience. More 15 yrs = 1-5 yrs > 6 – 10 yrs = 11 – 15 yrs
Major	Science = 3.87 Math =3.76 ICT =3.63 Other = 3.60	Science = 0.33 Math =0.37 ICT =0.45 Other =0.53	One-way ANOVA F =3.377 P-value =0.020	There is **significant difference** in the pedagogical content by major Science = Math = ICT > Other
Level	Elementary =3.57 Middle school =3.67 Secondary =3.88	Elementary =0.46 Middle school =0.45 Secondary =0.33	One-way ANOVA F = 7.320 P-value = 0.001	There **is significant difference** in the pedagogical content by level. Secondary = Middle sch> Element
Frequency used STEM	1 – 2 lessons =3.73 3 – 4 lessons =3.73 3 – 5 lessons = 3.76 Every lesson = 3.77 Other = 3.71	1 – 2 lessons =0.47 3 – 4 lessons =0.42 3 – 5 lessons = 0.53 Every lesson = 0.37 Other = 0.36	One-way ANOVA F = 0.074 P-value = 0.990	There is **no significant difference** in pedagogical content by frequency used STEM.
Curriculum STEM taught	Extra = 3.71 After school = 3.86 Regular = 3.68 Special = 3.94 Other = 3.86	Extra = 0.10 After school = 0.46 Regular = 0.46 Special = 0.29 Other = 0.16	One-way ANOVA F = 2.415 P-value = 0.052	There is **no significant difference** in the pedagogical content by curriculum STEM taught.
major subject to teach STEM	Science = 3.75 Math = 3.78 ICT = 3.66 All = 3.81 Other = 3.49	Science = 0.28 Math = 0.28 ICT = 0.54 All = 0.48 Other = 0.59	One-way ANOVA F = 1.858 P-value =0.121	There is **no significant difference** in pedagogical content by major subject STEM taught.

STEM subjects connection in my school	Answer 1 = 3.67 Answer 2 = 3.74 Answer 3 = 3.77 Answer 4 = 3.74	Answer 1 = 0.27 Answer 2 = 0.40 Answer 3 = 0.49 Answer 4 = 0.45	One-way ANOVA F = 0.276 P-value = 0.843	There is **no significant difference** in the investigation of pedagogical content by STEM subjects' connection.

Table 19: Test of the significance difference between means for **pedagogical content**

Table 20: Post hoc tests for STEM **pedagogical content**:

Experience of teacher:

Multiple Comparisons

Dependent Variable: Pedagogical content

Tukey HSD

(I) Exper.	(J) Exper.	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1 – 5	6 – 10	.06735	.08361	.852	-.1501	.2848
	11 – 15	.25195	.10720	.092	-.0268	.5307
	more than 15	-.19560	.10174	.223	-.4602	.0689
6 – 10	1 – 5	-.06735	.08361	.852	-.2848	.1501
	11 – 15	.18460	.10162	.270	-.0796	.4488
	more than 15	-.26295*	.09585	.034	-.5122	-.0137
11 – 15	1 – 5	-.25195	.10720	.092	-.5307	.0268
	6 – 10	-.18460	.10162	.270	-.4488	.0796
	more than 15	-.44755*	.11700	.001	-.7518	-.1433
more than 15	1 – 5	.19560	.10174	.223	-.0689	.4602
	6 – 10	.26295*	.09585	.034	.0137	.5122
	11 – 15	.44755*	.11700	.001	.1433	.7518

*. The mean difference is significant at the 0.05 level.

Major of teacher:

Multiple Comparisons

Dependent Variable: Pedagogical content

Tukey HSD

(I) Major	(J) Major	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Science	Math	.11143	.08718	.578	-.1153	.3381
	ICT	.23762	.10206	.097	-.0278	.5030
	Other	.26857*	.09491	.027	.0218	.5154
Math	Science	-.11143	.08718	.578	-.3381	.1153
	ICT	.12619	.10612	.635	-.1497	.4021
	Other	.15714	.09926	.392	-.1010	.4152
ICT	Science	-.23762	.10206	.097	-.5030	.0278
	Math	-.12619	.10612	.635	-.4021	.1497
	Other	.03095	.11255	.993	-.2617	.3236
Other	Science	-.26857*	.09491	.027	-.5154	-.0218
	Math	-.15714	.09926	.392	-.4152	.1010
	ICT	-.03095	.11255	.993	-.3236	.2617

*. The mean difference is significant at the 0.05 level.

Grade level taught:

Multiple Comparisons

Dependent Variable: Pedagogical content

Tukey HSD

(I) Grade teach	(J) Grade teach	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Elementary	Middle school	-.09524	.09400	.570	-.3179	.1274
	Secondary	-.31336*	.09191	.002	-.5311	-.0957
Middle school	Elementary	.09524	.09400	.570	-.1274	.3179
	Secondary	-.21813*	.07513	.012	-.3961	-.0402
Secondary	Elementary	.31336*	.09191	.002	.0957	.5311
	Middle school	.21813*	.07513	.012	.0402	.3961

*. The mean difference is significant at the 0.05 level.