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STEM EDUCATION:AN EXAMINATION OF SCHOOL LEADERS’ AND TEACHERS’ PERCEPTIONS ON STEM IMPLEMENTATION IN UAE SCHOOLS

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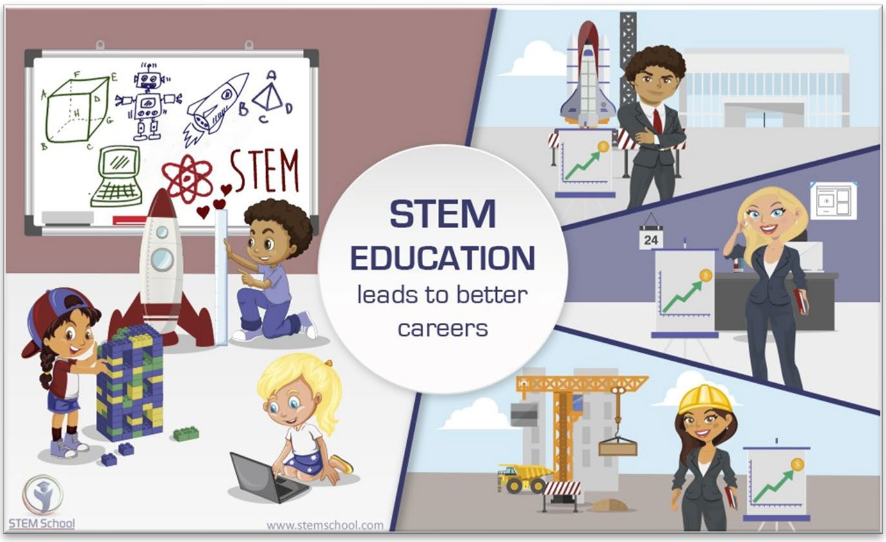

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Cover: STEM Teaches critical thinking, innovation and prepare qualified STEM professionals.

(Photo: Sara Elkeir Elhassan Hamad)

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Declaration of Original Work

I, Sara Elkeir Elhassan Hamad, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this dissertation entitled "*STEM Education: An Examination of School Leaders' and Teachers' Perceptions on STEM Implementation in UAE Schools"*, hereby, solemnly declare that this the original research work done by me under the supervision of Professor Hassan Tairab, in the College of Education at UAEU. This work has not previously been presented or published or formed the basis for the award of any academic degree, diploma, or a similar title at this or any other university. Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my dissertation have been properly cited and acknowledged in accordance with appropriate academic conventions. I further declare that there is no potential conflict of interest with respect to the research, data collection, authorship, presentation, and/or publication of this dissertation.

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Abstract

STEM education in the UAE is currently receiving growing attention due to the massive economic growth, which created a need for STEM-qualified graduates. Accordingly, UAE educational policymakers and curriculum developers advocate developing and implementing STEM education at all educational levels. The research emphasized that STEM education positively affects students' ability to solve problems, be innovative, think critically, and be technology literate. This study aims to examine school leaders' and STEM teachers' perceptions of STEM implementation practices in the UAE context. A sequential explanatory, mixed-method design was employed to collect the data from the school's leaders and teachers, quantitively using a survey and qualitatively using semi-structured interviews. The sample of the quantitative phase consists of 43 STEM schools, including 19 schools in Abu-Dhabi, 19 schools in Al-Ain, and 5 schools in Al Dhafra educational region were selected purposively as they are exclusively STEM education schools. In total, 463 participants responded to the study survey representing diverse positions, gender, years of experience, etc. The participants included 421 teachers, 21 principals, and 21-unit heads. The sample of the qualitative phase involved 9 participants; 6 were teachers, and 4 of the participants represented school leaders. The findings revealed that the participants have positive perceptions of STEM meaning, value, purpose, and implementation practices. The results also indicated that there is a need for solid leadership to manage STEM implementation, preparation and involvement of the stakeholders, and STEM professional development. Moreover, the study findings revealed that lack of time, heavy teaching loads, and a lack of supportive STEM school culture are factors that challenge STEM implementation. Finally, the study suggested a three-level framework for successful STEM implementation in the UAE.

Keywords: STEM Education, STEM Teachers Readiness, School Readiness, Challenges, UAE.

Title and Abstract (in Arabic)

تعليم العلوم والتكنولوجيا والهندسة والرياضيات: فحص مفاهيم قادة المدارس والمعلمين حول ممارسات العلوم والتكنولوجيا والهندسة والرياضيات في مدارس الإمارات العربية المتحدة

الملخص

حظى تعليم العلوم والتكنولوجيا والهندسة والرياضيات (STEM) في الإمارات العربية المتحدة باهتمام متزايد حاليًا بسبب النمو الاقتصادي الهائل الذي خلق الحاجة إلى الخريجين المؤهلين في مجالات العلوم والتكنولوجيا والهندسة والرياضيات (STEM). وبناءً على ذلك، فإن صانعي السياسات التعليمية ومطوري المناهج في دولة الإمارات العربية المتحدة يؤيدون تطوير وتنفيذ تعليم العلوم والتكنولوجيا والهندسة والرياضيات على جميع المستويات التعليمية. أكد البحث على أن تعليم العلوم والتكنولوجيا والهندسة والرياضيات (STEM) يؤثر بشكل إيجابي على قدرة الطلاب على حل المشكلات، والإبداع، والتفكير النقدي، والإلمام بالتكنولوجيا. تهدف هذه الدراسة إلى فحص مفاهيم قادة المدارس ومعلمي العلوم والتكنولوجيا والهندسة والرياضيات حول ممارسات تطبيق مناهج العلوم والتكنولوجيا والهندسة والرياضيات في سياق دولة الإمارات العربية المتحدة. تم استخدام تصميم مختلط تفسيري لجمع البيانات من قادة المدارس والمعلمين، باستخدام الاستبانات للمسح الكمي ونوعيًا باستخدام المقابلات شبه المنظمة. تتكون عينة المرحلة الكمية من 43 مدرسةSTEM، بما في ذلك 19 مدرسة في أبو ظبي، و19 مدرسة في العين، و5 مدارس في منطقة الظفرة التعليمية تم تحديدها لأنها مدارسSTEM. إجمالاً، استجاب 463 مشاركًا لاستطلاع الدراسة يمثلون مناصب متنوعة، والجنس، وسنوات الخبرة. وكان من بين المشاركين 421 معلمًا، و 21 مديرًا، و 21 رئيس وحدة. عينة المرحلة النوعية ضمت 9 مشاركين. 6 من المعلمين، و 4 من المشاركين يمثلون قادة المدارس. كشفت النتائج أن المشاركين لديهم مفاهيم إيجابية عن معنىSTEM، والغرض، وممارسات التنفيذ. أشارت النتائج أيضًا إلى أن هناك حاجة لقيادة قوية لإدارة تنفيذ العلوم والتكنولوجيا والهندسة والرياضيات، وإعداد ومشاركة أصحاب المصلحة، والتطوير المهني في مجالات العلوم والتكنولوجيا والهندسة والرياضيات. علاوة على ذلك، كشفت نتائج الدراسة أن ضيق الوقت، وأعباء التدريس، ونقص الثقافة المدرسية الداعمة في مجالات العلوم والتكنولوجيا والهندسة والرياضيات (STEM) من العوامل التي تعيق تطبيق العلوم والتكنولوجيا والهندسة والرياضيات. أخيرًا، اقترحت الدراسة إطارًا من ثلاثة مستويات للتنفيذ الناجح للعلوم والتكنولوجيا والهندسة والرياضيات في دولة الإمارات العربية المتحدة.

مفاهيم البحث الرئيسية: تعليم العلوم والتكنولوجيا والهندسة والرياضيات، استعداد معلمي العلوم والتكنولوجيا والهندسة والرياضيات (STEM) جاهزية المدارس التحديات، الإمارات العربية المتحدة.

Author's Contribution

The contribution of Sara Al Hamad to the dissertation was as follows:

I. Participated in planning of the work, had main responsibility for the data collection and processing, and evaluation of results.

II. Participated in planning of the work, had main responsibility for the experimental work, data collection and processing, and evaluation of results.

III. Sole responsibility for planning the research and conducting the experiments.

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I would like to thank my committee for their guidance, support, and assistance throughout my preparation of this thesis, mainly my advisor Prof. Hassan Tairab.

Finally, I must express my very profound gratitude to my parents and my husband for providing me with unfailing support and continuous encouragement throughout my years of study and through researching and writing this thesis. Special acknowledgment to my beloved sister Hana for her unwavering support and an enormous help. This accomplishment would not have been possible without them.

Dedication

To my beloved parents and family

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List of Abbreviations

ADEK	Abu Dhabi Department of Education and Knowledge
ANOVA	Analysis of Variance
HoD	Head of Department
IBL	Inquiry-based Learning
ICASE	The International Council of Associations for Science Educators
MOE	Ministry of Education
MSAT	Mathematics, Science, and Technology
NCLB	No Child Left Behind
NGSS	The Next Generation Science Standards
NSF	National Science Foundation
PCK	Pedagogical Content Knowledge
PISA	Program for International Student Assessment
SPSS	Statistical Package for Social Sciences
STEAM	Science, Technology, Engineering, Art and Mathematics
STEM	Science, Technology, Engineering, and Mathematics
TCK	Technological Content Knowledge
TIMSS	Trends in International Mathematics and Science Study
TPACK	Technological Pedagogical and Content Pedagogical Knowledge
UAE	The United Arab Emirates
UK	The United Kingdom
US	The United States of America

Chapter 1: Introduction

1.1 Overview

Science, Technology, Engineering, and Mathematics (STEM) education is the road map of a technological revolution at the core center of educators across the globe (Al Murshidi, 2019; WEF, 2016). Moreover, McDonald (2016) indicated that there had been a strong emphasis on providing students with sound and relevant education in STEM. STEM Education is globally recognized because it allows for well-qualified and highly skilled graduates (McDonald, 2016), which will contribute to the country's development by providing the necessary workforce vital for handling the country's needs (Wan Husin et al., 2016). Taking the United Arab Emirates (UAE) as an example, the government of the UAE believes that promoting advanced sciences, such as STEM education, is the best investment for their citizens in shaping their creativity and intellect (Al Murshidi, 2019; Kubat, 2018).

STEM education linked to fostering innovation Belbase et al. (2021) cites that the STEM approach is not only an instructional strategy; it is an innovative and transformative approach to school education and community development in different parts of the world. Innovation is a highly interactive and multidisciplinary process that rarely befalls in isolation and is strongly connected to life (OECD, 2010a). Hence, stakeholders on the vital connection between STEM education and economic innovation (Kuenzi, 2008; OECD, 2010b). STEM education in K-12 settings nurtures interdisciplinary knowledge and skills relevant to all domains in life and prepares students to contribute to a knowledge-based economy (National Research Council, 2011). STEM education aims to equip the current generation with innovative mindsets such as those of scientists and engineers, technologically proficient workers, and scientifically literate citizens. STEM education is essential in developing skills that are currently indispensable, such as problem-solving, self-improvement, and systematic thinking skills (Bybee, 2013; Roberts, 2012).

Innovation is primarily derived from advances in STEM disciplines (NAS, 2011); an increasing number of jobs at all levels require a certain level of STEM knowledge (Lacey & Wright, 2010). In order to cope with the demands of the current digital age, nations need an innovative STEM workforce to be competitive in the 21st century. STEM education has significantly contributed to producing competent individuals and providing them with solid capabilities and qualifications. Using STEM disciplines in unison is a powerful approach for explaining different situations in everyday life, which is essential in solving problems. This context urges students to make sense of the world holistically rather than in fragments (Morrison, 2006). Real-world problems are rarely solved with knowledge from one subject area. Thus, STEM education has positively enhanced students' ability in problem-solving, research-questioning, critical thinking, entrepreneurship, communication, and innovative thinking (Choi & Hong, 2013; Morrison, 2006). In a similar vein, STEM integration, via the implementation of engineering design activities, supports the development of students' 21st-century skills, including effective communication, innovation, and synthesis of information (Green, 2014). Indeed, STEM is a significant component of human culture development (Rutherford & Ahlgren, 1990).

Studies have indicated that using an interdisciplinary or integrated curriculum provides access to more relevant, less fragmented, and more stimulating experiences for learners (Stohlmann et al., 2012). The National Academy of Engineering and the National Research Council reported that integrating engineering into the K-12 curriculum can improve achievement in mathematics and science, increase awareness of engineering, a better understanding of engineering design, and increase technological literacy. Other studies show links to a positive impact on student attitude and interest in school, improved learning motivation, and increased achievement (Stohlmann et al., 2012).

Coping with the rapid changes in the world mandates all individuals to a level of STEM literacy, enabling them to make informed decisions (Ellis, 2008). From this view, STEM integration is a burgeoning field in both developed and developing countries (El-Deghaidy & Mansour, 2015). El-Deghaidy and Mansour (2015) believe that STEM education will result in qualified STEM professionals who can fulfill global market needs through creative solutions for significant global challenges such as sustainable energy sources, efficient healthcare, etc. (Boe et al., 2011).

The United Arab Emirates (UAE) Vision 2021 was launched in 2010 by the UAE government to position the UAE among the best countries in the world by the Golden Jubilee of the Union in 2021. The UAE Vision 2021 stated that "innovation, research, science, and technology pillars a knowledge-based, highly productive, and competitive economy". A competitive economy driven by knowledge and innovation is one of the UAE's vision 2021 pillars, which explicitly implies a diversified and flexible knowledge-based economy powered by skilled Emiratis and strengthened by a world-class talent to ensure long-term prosperity for the UAE. In general, this vision seeks for the UAE to be one of the leading global economies in the world - being resilient and adaptive in the face of unforeseen economic change. Therefore, the vision directs toward renovating the UAE into one of the world's most prominent economic, touristic, and commercial capitals (Al Quraan, 2017). Supporting this government drive, the UAE's National Agenda 2021 identified many sciences, technology, and innovation indicators and set ambitious targets. The UAE Vision 2021 includes the UAE becoming one of the top ten countries in the world in the Global Innovation Index and, secondly, increasing Research and Development expenditure up to three folds by 2021.

Human capital plays a critical role in enhancing innovation, and the UAE is also seeking to increase the share of knowledge workers to 40% of the total workforce and advance its students' rank in mathematics, science, and reading to become among the 20 highest ranked countries by 2021. The primary goal of this plan is the transition of the UAE into a knowledge-based economy by promoting innovation and research and development. On this basis, the UAE has taken it upon itself to renew its whole education system, mainly its teaching of STEM subjects (Mahil, 2016). The UAE is radically enhancing its education system by building new schools, integrating technology into classrooms, and improving its educated workforce Makhmasi et al. (2012). In addition, governmental agencies, such as the Abu Dhabi Department of Education and Knowledge (ADEK) and the Ministry of Education (MOE), have focused on hiring and retaining qualified teachers to prepare highly innovative and STEM talented Emirati generation for a sustainable knowledge-based economy (The Abu Dhabi economic vision 2030, 2008; Abu Dhabi Education Council, 2009).

The Ministry of Education (MOE) in UAE has recently gone through numerous initiatives and programs to develop students' skills and capacities in robotics and artificial intelligence, such as robotics training camp, VEX Robotics Championship, and innovation ambassadors to become innovators and entrepreneurs (MOE, 2021). In the quest to achieve UAE's educational system goal of having highly talented STEM workers as per the 2030 Vision of a self-sufficient and innovative economy (The Abu Dhabi economic vision 2030, 2008).

Thibaut et al. (2018), Bryan et al. (2016), Stohlmann et al. (2012), Duran and Dolme (2016), Li et al. (2019) all suggested numerous approaches to teaching STEM education; integrated STEM education has been reported to have the potential to improve students' motivation for learning STEM. According to Thibaut et al. (2018), integrated STEM education comprises instructional practices that help make associations and connections between the various STEM disciplines. Bryan et al. (2016) further elaborates that integrated STEM is not meant to add to a full curriculum; rather, it enhances the existing curriculum by leveraging the synergies between the disciplines and developing solutions to real-life problems of the world. Stohlmann et al. (2012) described the effective practices and approaches for STEM integration, which involves cooperative learning, inquiry, and Problem-solving. Further, Bryan et al. (2016) highlights the procedures commonly used for integrated STEM instruction; science inquiry, engineering design, and mathematic thinking and reasoning. Inquiry-based learning (IBL) is yet another approach that has been highlighted in literature by many authors as an effective method for STEM instruction. Thibaut et al. (2018) mention that questioning is a vital stage of IBL; this initiates their knowledge building.

Similarly, Duran and Dolme (2016) advocate IBL as an effective tool for engaging students' analytical and critical thinking skills. Another fundamental approach for the current movement of developing and implementing effective STEM education is design and design thinking. Essential to creativity and innovation, the design thinking approach is a person's approach to identifying and solving a problem in this world (Li et al., 2019). The engineering design activities positively influence students' knowledge of STEM as they can better connections between factual knowledge and application (Thibaut et al., 2018). Technology is essential and should be integrated into the curriculum, teaching strategies, and day to day classroom operations to enhance learning outcomes for STEM education

In sustainable STEM education integration, numerous factors may impede or facilitate the implementation process; STEM leaders must consider these factors for successful STEM integration and implementation in UAE schools. El-Deghaidy and Mansour (2015) reported three factors that affect STEM integration: Developing a school culture that enables collaboration among the stakeholders, establishing a productive and supportive STEM community, and improving a teacher's pedagogical skills via continuous professional development. In a similar vein, Kennedy and Odell (2014) posit that teachers must be provided with good opportunities for professional development that will enable them to prepare and guide their students to attaining STEM education competencies. Makhmasi et al. (2012) evaluated the factors influencing the STEM teachers' effectiveness in the UAE. They stressed the need to address teachers' dissatisfaction with the teaching profession in the UAE. Specifically, addressing monetary compensation, curriculum improvement, lack of resources, and providing professional guidance via development courses and seminars is necessary if teachers are more effective in the classroom.

1.2 Statement of the Problem

Teaching and learning STEM is considered an international and national prioritized goal in today's education; thus, students are expected to have a basic understanding of critical skills associated with STEM (Al Murshidi, 2019). Honey et al. (2014) asserted that STEM education positively impacts students' achievement and competencies to succeed in their future careers. STEM can improve student attitudes and interest in school, increasing their motivation to learn and achieve (Stohlmann et al., 2012). As mentioned earlier, STEM education is emphasized globally because it provides well-qualified and highly skilled graduates (McDonald, 2016), contributing to the country's development by providing a qualified workforce for handling its needs (Wan Husin et al., 2016). STEM education is implemented in schools globally due to the values delivered to students and nations alike.

STEM Education initially started in the UAE in 2010. Al Murshidi (2019) has suggested that to survive the rapid technological advancement globally, and the UAE must prepare nationals to face the future era through constant support to advance STEM education. The UAE initiatives have been reflected in Vision 2021, Vision 2030, the fourth industrial revolution, and the artificial intelligence strategy. However, the Trends in International Mathematics and Science Study (TIMSS) 2019 assessment results revealed poor performance of UAE students who scored below the average score of 500 in both Grade 4 and Grade 8 science and math. Results show that grade 4 scored 473 in science and 481 in the math assessment. According to Stanco (2012), the TIMSS results assess students in subject areas of science and mathematics, which serve as an overall measure of achievement for STEM, noting that STEM mainly consists of science and mathematics. The dismal performance of UAE school students on national and international assessments may indicate improper and ineffective implementation of STEM education in UAE schools (Al Murshidi, 2019; Makhmasi et al., 2012).

Moreover, recent statistics on tertiary student enrollment in UAE revealed that, on average, of the 43,000 students enrolled in higher education, only 30% are enrolled in STEM-based fields (Mahil, 2016). These low enrollment percentages may indicate common student interest in STEM fields or directly suggest the above stated; students do not have the required skills needed to pursue further education in STEM-oriented programs. The low enrollment percentages are inconsistent with the UAE's educational system goal of having highly talented STEM workers per the 2030 Vision of achieving a self-sustaining and innovative economy (The Abu Dhabi economic vision 2030, 2008). Notably, the United Arab Emirates Society of Engineers indicated that between 2011 to 2020, there is a need for more than 60,000 engineers from various disciplines to run several industrial sectors in the UAE. This shortage and scarcity of competencies of capable graduates from the STEM fields to facilitate new industry signals the idea that STEM is ineffectively implemented in UAE schools (Al Basha, 2018). Various factors affect the implementation of STEM integration, related to contextual factors (lack of resources, supportive school culture) and pedagogical elements (curriculum improvement, teacher competencies), etc. Hence it is hoped the current research will firstly provide the status of STEM implementation in UAE schools, assessing the factors that may impede or facilitate effective STEM implementation. Effective STEM implementation in schools is imperative if the UAE aims to become a knowledge-based economy fueled by a competent and skilled workforce. The research seeks to identify the factors that may facilitate or impede implementation and bring forth best practices that may be used by school stakeholders in implementing STEM education effectively.

1.3 Purpose of the Study

This study focuses on examining the school leaders' and STEM teachers' perceptions of STEM implementation practices and the factors that may facilitate or impede STEM implementation. It investigates the policy-related concerns to determine needed plans, strategies, and processes. The teachers' concerns about their awareness of knowledge, skills, and value of STEM are addressed along with the matters related to needed resources to effectively implement STEM, like school culture, structure, curriculum, equipped resources, and qualified STEM teachers.

Therefore, the overall purpose of this study is to examine the STEM integration process in the UAE context to identify factors that may facilitate or impede its implementation. Specifically, the study intends to:

1. Examine leaders' and STEM teachers' perceptions about STEM integration in the UAE schools.
2. Compare the actual and the perceived practices described by the study participants.
3. Compare the actual and the perceived practices described by each group [Principals, teachers, and Unit heads].
4. Identify the level of competence needed to implement STEM education
5. Identify the factors impeding STEM integration in UAE schools.
6. Develop a conceptual model of STEM that provides educators with a pathway to understand and enact it effectively.

1.4 Research Questions

In line with the study purpose, the current study attempts to provide answers to the following questions:

1. What are the school principals, unit heads, and teachers' perceptions of actual and preferred STEM practices regarding their definition, purpose, value, and implementation of STEM?

2. Are there any statistically significant differences between the school administrator, unit heads, and teachers in their perceptions regarding the actual and the best STEM practices?

3. Is there any statistically significant difference between the perceptions of the school leaders [principals, unit heads] and teachers in regard to the actual and preferred STEM teaching practices?

4. Is there any statistically significant difference in the teacher's perceptions about their current and preferred competence level in STEM education implementation?

5. What are the factors that may impede the successful implementation of STEM integration in UAE schools?

6. What contributes to the best STEM practice in the UAE context from the participant's perspective?

1.5 Significance of the Study

The significance of the study lies at both national and international levels. STEM education is experienced and taught globally; it has positively affected students' ability to solve problems, be innovative, think critically, be technologically literate, and be a discoverer (Choi & Hong, 2013; Morrison, 2006). Indeed, STEM education will have qualified professionals with competitive capabilities to meet the global market needs and fulfill contemporary industry demands (Boe et al., 2011). Therefore, the current study contributes to the existing international literature on STEM education by providing comprehensive coverage of the STEM conceptualization within the UAE context, highlighting STEM implementation barriers with the possible solutions. As there is a shortage of studies that focus on the actual and preferred practices of STEM education, this study is an essential addition to the available literature covering the primary and preferred practice of STEM implementation as perceived by school leaders and teachers. Consequently, the study will inform the decision-makers about the required administrative procedures that could increase the adequacy of the STEM implementation process, the curriculum developers about the elements of STEM-oriented curriculum, and the teacher's competence level, and suggest STEM-tailored professional development. Moreover, the integration framework proposed in this study can help researchers apply its findings in their contexts, expanding on the worldwide STEM education literature.

On a national level, the research envisions exploring and assessing the current practices of STEM education and its implementation in the UAE, aiming to improve its performance after evaluating the current situation. The study findings will lead to a comprehensive understanding of the STEM implementation processes. It will also highlight all the aspects surrounding this process involving the managerial support status, the teachers' conception and readiness to teach using STEM instructional practice, and the contextual factors impacting the efficiency of STEM education. Al Murshidi (2019) cites that STEM education is essential globally and provides highly competent and skilled graduates, which influences the country by providing the necessary workforce vital for handling the country's needs in the long run. Likewise, effective implementation of STEM in UAE schools is imperative; the UAE aims to be a leading hub for capable and skilled citizens that drive the knowledge-based economy.

STEM education is indeed a panacea for enhanced economic growth and development. Therefore, the study aims to assess the current implementation of STEM education in the UAE and enlighten the decision-makers, curriculum developers, teachers, and stakeholders about the strengths and limitations of the implemented integration process. Furthermore, the results will address the gaps in the current implementation of STEM education in schools and provide evidence-based knowledge and solutions to improve future integration processes.

Policy plays a vital role in the implementation phase; therefore, for successful STEM integration and its implementation, the findings will serve as a foundational basis for developing a conceptual model to provide the policymakers and relevant stakeholders with clear guidelines for successful STEM integration. The research findings will illuminate our understanding of the current STEM practices at UAE schools, which addresses ways of improving these practices.

1.6 Limitation

The area covered in this study is relatively small (Abu Dhabi), consisting of a limited number of public schools, which will undoubtedly affect the results obtained. As a result, the sample perceptions examined in this study may not reflect the actual perceptions of the school leaders and teachers in the UAE context. The sample involved in this study has had a varied understanding of STEM education as not all participants received STEM education training. As a result, it would be challenging to interpret what the results of this study may imply for the participant with more experience with STEM implementation.

Another limitation that can affect the outcomes of the present study is the participant's response in the survey compared to their interview answers, which indicated they were exaggerating the survey result. The conclusion to be drawn from this study is based on participants' responses; accordingly, the authenticity of responses collected to a large extent will influence the findings.

Another limitation is the situation of the COVID-19 pandemic that forced the use of online survey distribution, which led to the limited number of participants in the survey, which was voluntary participation. Finally, this study has focused only on a limited number of public Abu Dhabi educational zone due to time frames and other logistical circumstances. Therefore, the author will interpret the findings within the context of these schools only.

1.7 Delimitation

This study is limited to a selected sample of school leaders and teachers in the Abu Dhabi educational zone limited to 43 public STEM schools within Abu Dhabi, Al

Ai, and Al Dhafra. The data was collected in 2019-2020 using a specifically developed survey.

1.8 Definitions

21st-century skills: defined as the knowledge, skills, and personality trait that are required to effectively function as informed STEM literacy, as defined by Bybee (2010) and the National Academy of Engineering and National Research Council (2014) as the understanding of the concepts of integrating science, technology, engineering, and mathematics and the familiarity with the fundamentals of each discipline. According to the current study, 21st-century skills are required to cope with the highly technologized era and have problem-solving, critical thinking, and STEM literacy competencies.

21st Century Learner: Students that can master more than the core curriculum, which includes the three Rs with the four Cs: critical thinking, creativity, communication, and collaboration, while effectively applying these vital skills in today's technology-infused learning environment (Blair, 2012). For the researcher, a 21st-century learner is a student who can construct his learning by making broader connections of his STEM disciplines skills within authentic problems in the student-centered learning environment. The students can think out of the box using their subjects' skills and analytical thinking skills [problem-solving, critical thinking, and collaborative skills].

STEM: is an acronym for science, technology, engineering, and mathematics at the elementary, secondary, post-secondary, graduate, and postgraduate levels. Science, Technology, Engineering, and Mathematics integrative teaching approach promotes STEM literacy via infusion of student-centered teaching methods such as inquiry-based, problem-based, and project-based. As a result, it will equip students with higher-order thinking skills through involvement in an interactive learning environment that relies on a real-world problem. Moreover, this instructional approach is implemented using a STEM-based curriculum and standards and measures students' learning using STEM-oriented evaluation tools.

STEM-literacy, i.e., the understanding of the nature of science, technology, engineering, and mathematics and the ability to make connections among the four disciplines, should be an educational priority for all students (Bybee, 2010; National Academy of Engineering and National Research Council, 2014).

STEM Implementation: Johnson (2013) defines it as ‘‘an instructional approach, which integrates the teaching of science and mathematics disciplines through the infusion of scientific inquiry, technological and engineering design, mathematical analysis, and 21st-century interdisciplinary themes and skills’’ (pp. 367).

Integrative STEM: Integrative STEM is understanding of teaching and learning aspects between a STEM subject and other school subjects or between two or more STEM subject areas (Sanders, 2009).

Inquiry-based teaching and learning: it is a teaching approach that allows students to discover new concepts through engagement in hands-on activities and by connecting their initial ideas by making predictions, observing, and recording their explanations (Satchwell & Loepp, 2002). Interdisciplinary learning integrates STEM subjects with other traditional issues that blend writing and reading (Morrison, 2006).

Project-based learning: it’s a teaching approach that entails providing students with the end-product specifications. A teacher's role is to act as a coach who facilitates learning by providing guidelines and suggestions for product development (Asghar & Rice, 2013).

Problem-based learning is a student-centered approach that requires students to identify and define a problem without providing a predetermined product. The purpose is to develop problem-solving skills by focusing on experiencing realistic self-directed problem-solving processes (Asghar & Rice, 2013).

STEM schools deliver integrative content by providing “challenging, student-centered, inquiry-based educational experiences that are cross-disciplinary and relevant to the real world”.

This study focuses on examining the school leaders’ and STEM teachers’ perceptions of STEM implementation practices and the factors that may facilitate or impede STEM implementation. It investigates the policy-related concerns to determine needed plans, strategies, and processes. The teachers’ concerns about their awareness of knowledge, skills, and value of STEM are addressed along with the matters related to needed resources to effectively implement STEM, like school culture, structure, curriculum, equipped resources, and qualified STEM teachers.

Chapter 2: Literature Review

2.1 Overview

This chapter dowries a review of past research on STEM implementation in education based primarily on findings in the literature, reviewing previous research studies that addressed leaders' and teachers' awareness about STEM education, the rationale and purpose of STEM education, and effective STEM implementation practices. Furthermore, factors that impede and facilitate STEM education, international and national perceptions of STEM education, and teachers' self-efficacy while implementing STEM education are also included. Notably, the chapter presents the theoretical framework built to answer the questions of the current study.

2.2 Theoretical Framework

The theoretical perspective of this study is based on Ely's (1990) theory on the "conditions that facilitate the implementation of educational technology innovations", serving as a guiding framework to help address the research problem.

Ely (1990) suggested that certain conditions must be in place to implement any educational innovations successfully. Thus, Ely's theory is based on eight guiding conditions that nurture and facilitate the successful implementation of educational innovation initiatives within schools. The first condition is a "dissatisfaction with the status quo" – Ely (1990) states that this could either be an innate feeling or brought about by an induced state (for instance, by marketing campaigns). This condition encompasses emotions that call for change. The second condition is the "existence of knowledge and skills" that are significant for the ultimate user of the innovation – in this case, the teachers enacting STEM in their classrooms. The third condition is the "availability of resources", which includes elements crucial for the implementation to highlight results. Funding and budget are included within this condition. The fourth condition is "availability of time". According to Ely (1990), any implementation process requires time to plan, harness the knowledge, adapt, integrate, and reflect. The fifth condition comprises "rewards and incentives" provided by the stakeholders responsible for implementing STEM. The sixth condition is "participation," which typically means shared decision-making and enhanced communication between all stakeholders in the implementation process.

Ely (1990) stated that participation was reported as a strong condition linked to time, commitment, knowledge and skills, and rewards and incentives. The seventh condition is “Commitment, " which shows the continued support for implementing the innovation. According to Ely (1990), this condition is “usually measured by the perceptions of the implementations rather than a public acknowledgment of policy”. School-level reforms cannot occur without individuals committed to implementing the working conditions needed to create reform-aligned change (Geijsel et al., 2003; Vaishampayan, 2019). Lastly, the eighth condition for successful implementation of education technology is Leadership. Leadership is twofold; the first is the leadership of the organization or school (executive leadership), and the second is the leadership of the teachers who carry out the day-to-day activities (project leadership). Education scholars agree that policy language is not enough to effectively change “how teachers teach, how schools are organized, and how students work together to learn” (Vaishampayan, 2019). Many well-intentioned initiatives have achieved superficial change at best or simply failed. Hence, school leaders must create and maintain the necessary conditions, culture, and structures; facilitate learning and skill-based experiences and opportunities; and ensure collaboration between the school staff and the external community.

The theory described above will enable the researcher to explore and investigate the research questions of this study by analyzing each of the eight conditions listed above and their existence within the UAE school environments. The study will provide a complete picture of STEM implementation status. The first research question focuses on the school leaders' and teachers’ awareness of STEM regarding the meaning, value, and implementation process. Therefore, conditions 1, 6, 7, 8 mainly focus on understanding the implementation process. The second question focuses on the factors that facilitate or impede successful STEM integration in the UAE schools; conditions 3, 4, 5 focus on the factors that may impede or facilitate successful STEM integration. Condition 2 focuses explicitly on the existence of knowledge and skills aligned with the research questions investigating teachers’ competence in implementing STEM.

Together, these conditions allow the researcher to examine each of the research questions in a comprehensive image of the current implementation of STEM integration in UAE schools. Ely (1990) states that the listed eight conditions should exist or be emphasized in the environment wherein the innovation is implemented to facilitate the adoption of the technological innovation, i.e., in the current research context, STEM education in the UAE schools. Table 1 and Figure 1 below illustrates the eight conditions of Ely's (1990) theory that explain the successful implementation of educational innovations.

Table 1: Ely’s (1990) Framework for Implementing Educational Innovation

Condition	Title	Description
Condition 1	Dissatisfaction with the status quo	This condition focus on the need for change.
Condition 2	Existence of knowledge and skills	This condition focus on preparing users for the innovation
Condition 3	Availability of resources	Critical elements for implementation, e.g., funding and budget.
Condition 4	Availability of time	The implementation process requires time to plan, harness the knowledge, adapt, integrate, and reflect
Condition 5	Rewards and incentives.	This condition comprises the existence of “rewards and incentives” provided by the stakeholders responsible for implementing
Condition 6	Participation	This condition means shared decision-making and enhanced communication between all stakeholders in the implementation process
Condition 7	Commitments	This condition depicts evidence of the continued support for implementing the innovation.
Condition 8	Leadership	This condition describes Leadership as twofold; the first is the leadership of the organization or school (executive leadership), and the second is the leadership of the teachers who carry out the day-to-day activities (project leadership).

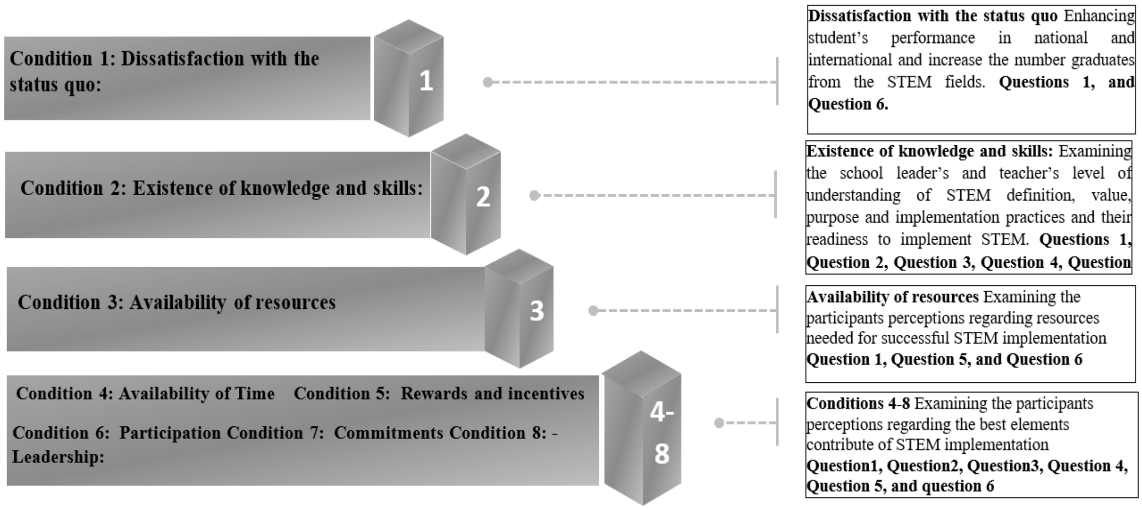

Figure 1: Ely's (1990) Theory Conditions linked to the research questions

2.3 Literature Review

The literature review is organized into sections to reflect the conceptualization of STEM implementation and identify the current understanding of STEM implementation in education. Specifically, the literature discussed studies related to the definition of STEM, the rationale behind STEM education, the effective STEM implementation, and the international and national perspectives on STEM education. The reviewed literature highlights the dominant views about STEM implementation practices and identifies the gaps and unexplored areas.

2.3.1 Studies Related to Definition of STEM

There are various definitions of STEM, as illustrated in the literature below; however, there seems to be inconsistency when defining and fleshing out the meaning of STEM. Thibaut et al. (2018) asserted a lack of consensus regarding the definition of STEM in terms of the nature and the degree of integration and connections between the different STEM disciplines. According to Koonce et al. (2011), STEM is defined based on constituents, the disciplines that constitute STEM, stating that ''STEM stands for the four primary discipline families of Science, Technology, Engineering, and Mathematics … (pp. 2).'' Likewise, Morrison (2006) defined STEM as a "meta-discipline", as it is based on the integration of the four disciplines. English (2016) posits that STEM education is broader than the "convenient integration" of its four disciplines; instead, it incorporates “real world, problem-based learning” that links the disciplines “through cohesive and active teaching and learning approaches” (p. 9). The STEM Task Force Report (2014) has also embraced this viewpoint. In a similar vein, knowledge about these disciplines can qualify an entity with literacy for STEM. Margot and Kettler (2019) defined STEM literacy as “(1) knowledge of Science, Technology, Engineering, and Mathematics position in the modern society; (2) understand the core concepts of each of STEM disciplines; and (3) a having the fundamental of knowledge application.

Adding to the basic definition of STEM, many researchers have also defined it as an “approach”, as evidenced in several studies (Johnson, 2013; Tsupros et al., 2009). Estapa and Tank (2017) defined the STEM teaching approach as a teaching approach based on integrating science and mathematics through the infusion of the practices of scientific inquiry, the interaction of technology and engineering design, and 21st-century interdisciplinary themes and skills’’ (p. 2). Marrero et al. (2014) also believed that STEM education requires the development of Science, Technology, Engineering, and Mathematics concepts, knowledge, and understandings by integrating some or all the four disciplines into one class or unit within an authentic context.

Similarly, STEM education, according to Honey et al. (2014), described the purpose of STEM education as the development of STEM literacy, twenty-first-century capabilities, STEM workforce readiness, ability to make connections among STEM disciplines, and interest and engagement. Moreover, they believed that STEM could be applied through students' engagement in real-world problems and engineering design while tackling the standards in each subject area

Hasanah and Tsutaoka (2019) defined STEM as” an interdisciplinary teaching approach in which academic concepts are taught through real-world lessons in contexts that make connections between school, community, work, and the global enterprise. Merrill (2009) defines STEM education as ‘‘a standard-based, meta-discipline residing at the school level where discipline-specific content is not divided, but addressed and treated as one dynamic, fluid study.” In addition, STEM education can also be defined as a student-centered teaching method that promotes more engagement and active learning strategies. Specifically, focusing on authentic real-life problems will enable students to make strong connections between the four disciplines' knowledge with the permanency of acquired knowledge. Accordingly, this approach is the path to having more critical thinkers, innovative individuals, and influential citizens.

It is evident from the definitions mentioned above that there is no consensus on the meaning of STEM education existing in the literature. However, they are approaching STEM from different viewpoints; (1) based on the integration and interconnectivity of its disciplines, (2) based on STEM being an instructional approach, and (3) based on its nature on content integration via meaningful learning experience and real-world problem-solving and connectivity. Based on the above literature, for this research, STEM is defined as an interdisciplinary teaching approach based on the integration of the following subjects Science, technology; engineering; and mathematics. This will have a powerful impact on enhancing students' critical thinking and analytical skills. Therefore, for the current study, STEM is an interdisciplinary instructional approach that relies on the followings: the combination of STEM disciplines uses STEM-oriented standards curricula, promotes student-centered methods, infuses the general practices of scientific inquiry, and demonstrates robust technical and engineering design, with sharp mathematical analysis, and 21st-century interdisciplinary themes and skills.

2.3.2 Studies Related to Rationale of STEM Education

The rationales for having STEM education as a widespread initiative across the globe are widely discussed in the literature. Hamad et al. (2022) cite that STEM education focuses production of STEM literate graduates with the required competencies for excelling in the technologically oriented future workforce. Falloon (2019) believed that integrated STEM education could be considered a platform for developing important personal and professional competencies, including research inquiry, problem-solving, critical and creative thinking, entrepreneurship, collaboration, teamwork, and communication. Holmlund et al. (2018), in their study, found that STEM programs in the USA have three main goals for STEM education: (a) to have more STEM professionals, (b) a robust STEM-related workforce, and (c) to have citizens with strong STEM literacy.

Many researchers agree that a crucial goal of STEM education is to produce intelligent students who possess STEM knowledge, particularly science and math, and have the required essential problem-solving skills for STEM-related professions (Brown et al., 2012; Nathan & Tran, 2010). There is a common belief that increasing math and science requirements and emerging technology and engineering concepts in education will better prepare students for advanced education and jobs in STEM fields (Brown et al., 2011). STEM learning equips learners with skills and confidence to think and act in relevant aspects of civic life and should prepare individuals who desire advanced learning opportunities in STEM fields for success in higher education institutions (Dejarnette, 2012; Shaughnessy, 2012). Furthermore, STEM education is crucial to developing today's necessary skills; problem-solving, self-improvement, and systematic thinking skills (Bybee, 2010; Roberts, 2012). Falloon (2019) and Holmlund et al. (2018), in agreement that STEM education produces value in two ways: (1) STEM education improves the skill set of the individual and increases their problem-solving capabilities; (2) prepares students to contribute to the workforce as there will be a skill to job alignment. This will further improve the efficiency of the organizations and, therefore, the competitiveness of a nation. However, some researchers have criticized this viewpoint, stating that STEM education was initiated from a purely economic rationale.

The rationales behind promoting STEM have not always been educational and linked to just improving academic outcomes. Blackley and Howell (2015) stated that the United States of America and the United Kingdom, during the early 2000s, implemented several uncoordinated STEM projects to increase the pool of engineers and scientists. Likewise, Williams (2011) agrees and cites that the STEM movement has developed from a non-educational rationale. The initiation of STEM has occurred due to the onset of the global financial crisis, and the solution offered by STEM education will better equip a workforce to deal with the dynamic nature of business and industry in the globalization economy. Accordingly, more schools pushed to seek further training and talent acquisition in engineering and science. It is important to note that the rationale for STEM will depend on the stakeholder involved; for nations, the economic reasoning may be the real focus, whereas, for institutions and educators, a significant focus on developing students and enhancing their skills would be an apt rationale.

2.3.3 Studies on STEM Impact on Student's Performance

Various research studies examined the impact of STEM integration on student outcomes (Boe et al., 2011; Bybee, 2010; Choi & Hong, 2013; Honey et al., 2014; Roberts, 2012; Morrison, 2006; Stohlmann et al., 2012; Yildrim & Mahmut, 2017). The interdisciplinary instructional approach of STEM disciplines enables students to critically explain everyday life situations and solve problems (Hamad et al., 2022). Other researchers indicated that STEM education has positively affected students' ability to solve problems, be innovative, think critically, and be technology literate (Choi & Hong, 2013; Morrison, 2006). Belbase et al. (2021) study findings indicated that the STEM approach has several advantages, such as: equipping students with essential skills including problem-solving, creativity, critical analysis, teamwork, independent thinking, taking the initiative, communication, and digital literacy; providing students the cognitive and meta-cognitive tools to explore creative methods of problem-solving, and those skills will empower students in their future careers.

STEM education allows students to learn in-depth, contributing to their academic success (Yildrim & Mahmut, 2017). Stohlmann et al. (2012) and Thibaut et al. (2018) indicated that interdisciplinary teaching provides learners more relevant, more connected, and engaging experiences. Other studies show links to the positive impact on student attitude and interest in school, improved learning motivation, and increased achievement (Stohlmann et al., 2012). Honey et al. (2014) asserted that STEM education positively impacts students' achievement, but with a small effect size. In line with the above views, Kang (2019), in his study, also indicated that STEM has a positive effect on student learning where students are effective in both cognitive and practical learning. Building on the previous studies' findings, STEM integration in education will increase engagement and interest in STEM disciplines learning, leading to an increase in student attainment and achievement.

Moreover, integrated STEM education will involve students in exploring the interconnections between science, technology, engineering, and mathematics, which will enable them to understand how those disciplines operate within real-world contexts. Consequently, students acquire long-life competence by engaging in active approaches that value students' real-life experiences. In particular, the students will gain an in-depth understanding of each subject's content and skills in integrated courses more than in isolated content teaching. They will be able to make deep connections between the four STEM subjects, enhancing students' overall achievement.

2.3.4 Studies Related to STEM Impact on Students' Interest in STEM Career Orientations

Several research studies have concluded that STEM integration impacts students' interest and engagement in science learning and STEM careers (Freeman, 2006; Lehman et al., 2014; Stohlmann et al., 2012; Tseng et al., 2013). STEM education promotes interest in STEM-related fields. Hamad et al. (2022) reported that teaching science and mathematics by integrating the engineering design process improves knowledge acquiring and critical thinking skills and promotes interest in science and engineering careers. Moreover, Hamad's findings described STEM education can positively enhance students' interest in STEM field careers and is essential for student success as they progress into future STEM courses and programs. That can further increase students' competencies for STEM-related occupations and allow a better understanding of scientific and engineering works (Tseng et al., 2013). Overall, and drawing on these considerations, STEM education will increase the number of prepared students to enter the college and enthusiastically join one of the STEM disciplines to gain a degree in math, science, engineering, or technology. Indubitably, this will benefit the globalization of businesses and industries' requirements that mainly focus on having workers with the core knowledge and skills necessary for the job, in addition to essential skills such as critical thinking and problem-solving

In essence, STEM integration will result in increased engagement and interest in STEM disciplines, which will lead to improved student outcomes in STEM disciplines. Students' chance to explore the interconnections between science, technology, engineering, and mathematics will empower them to realize how those fields run within real-world environments. Consequently, Students acquire extended life competence by engaging in active approaches that value students' real-life experiences is evident from the definitions mentioned above that there is no consensus on the meaning of STEM education existing in the literature. However, they are approaching STEM from different viewpoints; (1) based on the integration and interconnectivity of its disciplines, (2) based on STEM being an instructional approach, and (3) based on its nature on content integration via meaningful learning experience and real-world problem-solving and connectivity. Based on the above literature, for this research, STEM is defined as a

2.3.5 Studies on Effective STEM Implementation - Administration and Quality Assurance

Averill (2018) conducted a quantitative study that examined the perceptions of administrators and teachers regarding the implementation of STEM. The study instrument was an online survey administered through Survey Monkey via email to all K-8 teachers and administrators within the district. The study participants' responses revealed that STEM training is inadequate or needed resources for STEM to occur in their schools. Additionally, most STEM opportunities occur after school. According to Averill (2018), any educational initiative's success depends on those in leadership roles (Rogers, 2007; Scott, 2012). Educational leaders play an essential role in implementing STEM education through program implementation and maintenance (Sanders, 2009; Scott, 2012). At the same time, Belbase et al. (2021) indicated the importance of having skilled STEM leadership to lead curriculum development and teachers' preparation for STEM programs. These study findings align with Brown et al. (2011), who described that there is no vision for STEM education managed by visionary leaders of the STEM implementation process. Good leaders must work with the various stakeholders of their organizations to develop and carry out a shared vision and mission. While these requirements are valid for all K-12 administrators, there is evidence that visionary leadership is essential for those in STEM-focused schools (Davis, 2015). Davis's findings also showed that STEM schools must have mission statements that are aligned STEM implementation process. Scott also reported that STEM schools were led by confident, visionary principals committed to positively affecting the lives of their students.

The literature proposed that several factors are likely to lead to an unsuccessful STEM integration, including the first one being the lack of skilled leaders who can implement official strategic plans with clear indicators to manage and follow up the STEM integration. The second is the lack of dedicated hiring procedures to ensure STEM-qualified teachers. Moreover, tailored professional development training programs that enable teachers to successfully enact STEM in their classroom can be considered a factor likely to lead to unsuccessful STEM integration. The previous studies approached the administrative issues, but none provided an in-depth analysis of the barrier entitled under this umbrella and how to overcome those barriers. The current study will address the administration aspects by examining all the raised concerns previously within one study using a mixed-method study design which will provide in-depth coverage of the status of the organizational factors involved in STEM implementation.

Natarajan et al. (2021) studied attention and theorized a conception of school leadership that emphasizes support for STEM integration in K-12 classrooms. In their study, they examined the literature from leadership studies. They compared it within the nature of STEM to conclude the qualities of STEM leadership from the school and curriculum levels. The study tried to highlight concerns related to STEM leadership conceptualization and the desired outcomes of STEM leaders. The study findings indicated the importance of utilizing distributed leadership (building collective and group leadership), while instructional leaders should be granted autonomy to all four disciplines. They also reported the need for teacher-level leadership teachers were involved in shared decision-making. They also believed that teachers to handle this role need to be prepared with pedagogical knowledge of STEM education to implement STEM education effectively. They concluded that STEM leadership should concentrate on developing agency in the teachers, building a community of STEM specialists, and creating a shared and robust STEM identity. Matters of culture and context, collaboration, and courage are essential considerations within STEM leadership to build a sustainable STEM community and identity in STEM schools.

Furthermore, they asserted that STEM teachers' interdisciplinary work needs to be actively recognized. The need to establish new teaching roles called "STEM teachers" is created with the legitimization of their roles and identities.

Munje et al. (2020), in their study, discussed the importance of prioritizing education quality, especially in science and mathematics, positions effective teaching and learning as a significant school leadership goal. The focus is on Effective curriculum implementation through distributed leadership effectively. They employed a qualitative case study that explored the roles of Head of Departments (HoDs) in four South African high schools to determine how opportunities were created for teaching and learning science and mathematics in the context of distributed leadership. Data was collected using unstructured interviews with 13 participants. In distributed leadership structures, the findings show that HoDs in science and mathematics played the roles of instructional leaders, school-based subject and classroom specialists, and accountability for learner performance in their departments. They also indicated that HODs could support other school leadership players, including teachers in the classroom and principals, to improve teaching and learning through distributed leadership structures.

2.3.6 Studies Related to STEM Implementation - Pedagogy and Curriculum

Moore et al. (2014) reviewed STEM-related literature, analyzed state content standards, and consulted with experts in STEM fields to determine the effective teaching methods for STEM education in the classrooms. Margot and Kettler (2019) discussed Moore's framework that includes six factors for adequate K-12 STEM education: (a) inclusion of science and math concepts, (b) student-centered pedagogy, (c) use of engaging lessons, (d) incorporation of engineering design, (e) students learn from making mistakes, and (f) use of cooperative learning. According to Belbase et al. (2021), STEAM incorporates all the STEM elements plus adding an A for the Art element. They defined STEAM as an interdisciplinary approach to teaching and learning math, science, engineering, arts, and technology-based by employing instruction that engages students in experiential learning. STEM or STEAM are teaching approaches based on interactive activities through undertaking activities, project-based learning by designing and implementing projects related to the real world, and inquiry learning that integrates demonstration of problems, designing resolutions through investigation testing the designs.

The curriculum contains cross-curricular real-world challenges for students to solve. Christenson (2011) reported that Judith Ramey, the National Science Foundation's education and human resources division director, agreed on the acronym STEM. She justified that STEM employs math and science as the bookends for engineering and technology (Margot & Kettler, 2019). Margot and Kettler (2019) state that STEM integrated content must be explicit within and across the disciplines. Students must have intentional instruction in the connectedness of science, technology, engineering, and mathematics. STEM education also includes the use of the engineering design process. There are various forms of this process, but they all have a cyclical process of evaluating students.

According to Shulman (1986), pedagogical content knowledge (PCK) reflects teachers' ability to integrate pedagogical knowledge and content knowledge to make the content facilitate the learning process. More recently, the framework was modified to include technology, namely TPACK and "TPACK framework; these technologies can be regarded as technological content knowledge (TCK)" (Septiandari et al., 2020, p. 3). Therefore, teachers must integrate both TPACK and STEM education in their STEM lesson design. TPACK was developed by Koehler and Mishra (2009) to understand the best way to incorporate what teachers should know about technological knowledge into existing practice. Their specialized technological pedagogical and content pedagogical knowledge (TPACK) framework suggests instead of looking at technology as something separate only to be added in when convenient, technology knowledge is just as important as knowing what to teach and how to teach. A teacher with an understanding of how to conduct, pedagogical knowledge, and what they are to teach, content knowledge, is the primary focus of teacher training programs (Koehler & Mishra, 2009, p. 62).

is evident from the definitions mentioned above that there is no consensus on the meaning of STEM education existing in the literature. However, they are approaching STEM from different viewpoints; (1) based on the integration and interconnectivity of its disciplines, (2) based on STEM being an instructional approach, and (3) based on its nature on content integration via meaningful learning experience and real-world problem-solving and connectivity. Based on the above literature, for this research, STEM is defined as an

2.3.7 Studies on STEM Instructional Approaches

Thibaut et al. (2018) asserted that the lack of consensus about STEM learning and teaching should be addressed. They conducted a systematic review of 405 existing literature about learning theories for instructional practices in integrated STEM. They reported several authors who discussed STEM integration from different angles (Roehrig et al., 2012; Satchwell & Loepp, 2002; Wang et al., 2011) and developed a five-principles framework containing the instructional practices used to integrate STEM in classrooms. Wang et al. (2011) conducted a multi-case study to examine teachers' beliefs about classroom practices using STEM integration. The study sample included three middle schools selected from teachers involved in STEM education training. Wang et al. (2011) distinguished between multidisciplinary and interdisciplinary teaching approaches. The study findings indicated that in a multidisciplinary approach, each subject's concepts and skills are learned in isolation from other disciplines, and students' role in making connections among the different disciplines.

Moreover, Wang's findings indicated that an interdisciplinary approach focuses on integrating the different disciplines through the real-world problem. Contrastingly, Satchwell and Loepp (2002) came up with a different definition that distinguishes interdisciplinary approaches from integrated approaches rather than multidisciplinary approaches. According to them, interdisciplinary curricula rely on instruction within one domain while implicitly supporting the connections to the other disciplines. Integrated curricula, on the other hand, explicitly integrate concepts from more than one discipline while applying equal attention to two or more fields. Thibaut et al. (2018) have a similar distinction between content and context integration. According to them, content integration is all about integrating the four disciplines into a single class activity from the different subjects.

In contrast, context integration focuses on one subject concept taught using contexts from other subjects. Thibaut's findings indicated that STEM is the integration of the content and practices of disciplinary knowledge, which include pedagogical aspects of mathematics and science through the incorporation of the engineering design of relevant technologies. Thibaut's findings described the characteristics that distinguish integrated STEM instruction from other teacher pedagogy:

- The concept of learning is related to one or more of the STEM disciplines.
- The utilization of engineering practices includes relevant scientific and mathematical concepts.
- The development of 21st-century skills is emphasized; and
- The highlighting of cooperative learning within authentic learning.

In the same line, Rockland et al. (2010) indicated that discovery, problem-solving, and inquiry-based learning all play substantial roles in STEM integration. In addition, they asserted that to recruit and educate students for the STEM workforce, more emphasis on programs and educational strategies would prepare students for the challenges ahead—the teacher's use of STEM instructional strategies that promote student-centered problem-based learning strategies. Wang et al. (2011) highlighted that STEM teaching must emphasize both the content knowledge and the inclusion of problem-solving skills and the discovery of learning mechanisms.

2.3.8 Studies on STEM Teaching Strategies

Kang (2019) investigated the impact of STEM on teaching and learning and reported that integrated STEM programs commonly utilize student-centered instructional approaches within complex real-world problems where students actively apply knowledge and skills in practices from multiple disciplines. While Wang et al. (2011) described, STEM teaching needs to focus on content knowledge and include problem-solving skills and inquiry-based instruction.

Similarly, El-Deghaidy and Mansour (2015) described the purpose of STEM education as fostering student-centered teaching through the incorporation of inquiry, project-based, and problem-based learning. Similarly, Al Basha (2018) believed that STEM emphasizes learning by utilizing problem-based, project-based, or inquiry-based learning approaches. Stanley (2017) shared a similar result that indicated that STEM is implemented via “student-centered, inquiry-based educational learning by incorporating integrated disciplines within real-world problems. Correspondingly, Belbase et al. (2021) described STEAM as an integrated approach to teaching and learning maths, science, engineering, arts, and technology, through hands-on activities and project-based learning. Thibaut et al. (2018), in their reviewed literature, suggested nine categories of STEM instructional practices that focus on the integration of STEM content, focus on problems, inquiry, design, teamwork, student-centered, hands-on, assessment, and 21st -century skills, as described in Figure 2, cited from Thibaut et al. (2018).

Category	Instructional practices (extracted from papers)*
Integration of STEM content	- Multidisciplinary approach - Interdisciplinary approach - Content integration - Context integration - Integrated curriculum with equal attention to two or more disciplines - Curriculum integration with focus on content knowledge - Explicit assimilation/ integration of concepts from more than one discipline. - Integration of technology - Translation of representations from different STEM disciplines - Connections among learning goals, principles, concepts and skills across discipline specific domains - Infusing/merging of two or more STEM content areas
Focus on problems	- Problem-based learning - Problem-centered learning - Project-based learning - Defining, formulating, evaluating and solving problems - Meaningful/motivating/engaging context - Focusing on big ideas, concepts, themes - Open-ended, real-world, authentic problems
Inquiry	- Posing questions - Planning and carrying out investigations - Collecting, analysing and interpreting data/information - Discovery learning - Inquiry-based instruction - Scientific inquiry - Authentic scientific practices/processes
Design	- Learning through design - Design-based learning - Developing and using models - Designing solutions - Engineering design - Design justification - Opportunities to learn from failure and to redesign based on that learning
Teamwork	- Collaborative learning - Cooperative learning - Communicating information - Teamwork - Working in small groups - Working with others - Interdependence in group work
Student-centered	- Student-centered pedagogies
Hands-on	- Hands-on learning - Hands-on activities - Effective use of manipulatives
Assessment	- Understanding student misconceptions & capabilities - Use assessment as a part of instruction - Performance and formative assessment - Writing for reflection - Building on previous knowledge
21st century skills	- Development of 21st century skills

Figure 2: STEM Teaching and Learning Categories

Thibaut et al. (2018) summarizes the reviewed studies' outcome and categorizes the different STEM teaching and learning categories found in each article, as shown in Figure 2. The first category is the instructional practices that support making connections between STEM disciplines. The analysis indicated different terminology regarding integration, such as multidisciplinary and interdisciplinary approaches. According to them, concepts and skills are learned separately in each discipline in a multidisciplinary approach. Students are supposed to connect the content taught in different classrooms independently. An interdisciplinary approach is based on a real-world problem and focuses on interdisciplinary content. Thibaut et al. (2018) also reported that STEM content requires the integration of the four disciplines into one teaching lesson or activity, while context integration focuses on teaching a concept from one subject and uses contexts from others to make the content more relevant".

They acknowledge that Pearson (2017) considered that integration of STEM content should be explicit because students do not integrate concepts across other disciplines independently. Moreover, students' understanding of any STEM disciplines should support students' understanding of the concepts in each subject to connect ideas across disciplines (Thibaut et al., 2018). Therefore, they agreed with Pearson (2017), who believed that integrated STEM education should focus on learning objectives and standards in any STEM subjects, not inadvertently undermining student learning.

The second category of STEM instruction practices is supposed to use real-world problems tied to an engaging and motivating context. This kind of instruction has several terminologies, such as problem-centered, problem-based, and project-based learning. All these approaches are student-centered, promote active learning and promote the use of authentic, real-world problems.

Thibaut et al. (2018) described that Inquiry involves instructional practices. In inquiry-based learning, students participate in hands-on activities to discover and understand a new concept. Moreover, they clarified that inquiry-based learning originated in science education, where it usually entails students' participation in authentic science practices. However, it is not restricted to this domain but can be implemented in mathematical or technological contexts. Furthermore, Thibaut et al. (2018) explained that the fourth category, design, refers to technical or engineering design, actively engaging students in engineering design challenges. Additionally described fifth category, Cooperative learning entails the promotion of teamwork and collaboration.

Student-centered. The next category is related to student-centered pedagogies that foster better understanding and skills acquisition through active participation in learning activities. The teaching practices in the seventh category focus on hands-on learning in which students have actively experienced learning. The eighth category deals with assessment and requires assessing students with authentic tasks that enable them to connect key concepts studied in mathematics, science, and technology and should include a scoring rubric.

21st-century skills. The final category comprises '21st-century skills, portraying the knowledge and skills required to effectively function as citizens, workers, and leaders in the 21st-century workplace.

2.3.10 Studies on STEM Education and Inquiry-Based Learning

Inquiry teaching and learning is a broad area of pedagogical practices. This study focused on the widely used practices associated with STEM, such as inquiry-based, problem-based, and project-based. According to Kelley and Knowles (2016), integrative STEM is a system of four pulleys to carry a load. The four pulleys to lift the burden are scientific inquiry, mathematical thinking, technology, and engineering design. Thibaut et al. (2018) reported several views about inquiry-based learning discussed by several researchers (Buck et al., 2008); Inquiry-based learning enables students to engage in hands-on activities that help them explore new concepts and develop new understandings (Satchwell & Loepp, 2002). Therefore, inquiry learning is purposely used to promote knowledge acquisition (Wells, 2016). Students are challenged to examine their existing ideas by taking things apart, making predictions, observing, and recording their explanations (Satchwell & Loepp, 2002).

Even though inquiry-based learning is initiated in science education, it usually requires that students be involved in science practices within real-life problems and not limited to this domain only. Still, it can occur in other contexts, such as mathematical or technological contexts (Satchwell & Loepp, 2002). Thibaut et al. (2018) study findings indicated several vital aspects of inquiry-based learning. Questioning is an essential part of inquiry-based learning as it stimulates knowledge building (Wells, 2016). In inquiry learning, students must connect to their prior knowledge and identify their needs to reach their required knowledge (Stump et al., 2016; Wells, 2016). Students should use this prior knowledge to generate new ideas, design and conduct investigations, and discover new concepts in parallel to this.

Moreover, they need to dot the experiments, but students also need to reveal their knowledge related to the explored concepts (Thibaut et al., 2018). Authentic inquiry experiences can be difficult for high school students as they don't possess the required knowledge or are at the appropriate intellectual level (Thibaut et al., 2018). Moreover, discovery learning without guidance might be ineffective because students may not acquire the content to be learned (Mayer, 2004). Therefore, teachers need to guide by encouraging students to know their analytical and research skills competencies that enable them to have solutions to their problems (Thibaut et al., 2018).

2.3.11 Studies on Problem-Based Learning and STEM Education

Belbase et al. (2021) believed that the STEM approach is based on interactive activities through hands-on activities, project-based learning by designing and implementing projects related to the real world, and inquiry learning that entails the identification of problems and developing solutions through experimentation and testing the designs. According to Thibaut et al. (2018) study outcomes, different terms indicate problem-based involving problem-centered learning, problem-based learning, and project-based learning. Even though all these approaches are student-centered, promote active learning, and advocate using authentic, real-world problems, they are different methods (Asghar & Rice, 2013). Project-based learning provides students with the final product expectations, and teachers act as facilitators and guide students to achieve their final products (Asghar & Rice, 2013). On the other hand, there is no predefined product in problem-based learning, and students are expected to discover and define the problem independently. Problem-based learning aims to enable students to develop problem-solving skills by going through a realistic self-directed problem-solving process (Thibaut et al., 2018). Therefore, the teacher's job is to scaffold and guide the students to achieve their targets (Asghar & Rice, 2013). Problem-based learning is open-ended compared to project-based learning; problem-centered education is based on applying and transferring knowledge to authentic contexts, considering problem-solving skills as an additional outcome (Merrill, 2009; Van Merriënboer & Kirschner, 2017).

2.3.12 Studies on STEM Integrative Teaching Materials

Thibaut et al. (2018) reported that the Integration of STEM content focuses on making a connection between the different STEM disciplines**.** Specifically, by distinguishing between multidisciplinary and interdisciplinary approaches. According to Thibaut et al. (2018), a multidisciplinary concept of one subject is learned separately, and students' role is to connect the content taught in different subjects on their own. In contrast, the interdisciplinary approach emphasizes the utilization of real-world problems through integrated content and skills. Wang et al. (2011) discussed that STEM integration in the classroom relies on curriculum integration, as they believed that curriculum integration is complex and challenging. They exemplified that curriculum integration is derived from educators' awareness that real-world problems must be delivered in an authentic context rather than in isolation. Moreover, they reported STEM integration exposed students to real-world situations that promote meaningful learning and broader connectivity, and in-depth learning.

Drake and Burns (2004) presented a comprehensive curriculum integration model to integrate curriculum. The model relies on (1) examining the standards from two or more content areas; (2) selecting one or two broad-based standards from each discipline and using the overlapping standards as the theme for an interdisciplinary unit, (3) creating a web to identify related standards from each content area (4) defining learning objectives for units of study, and (5) Designing a culminating assessment such as a project. Similarly, the current study emphasizes integrating STEM disciplines requires bringing the four disciplines. However, content integration needs to be presented explicitly situated within real-world problems.

2.3.13 Studies on Factors Promoting STEM Implementation

Research design and dissertation methodology dictate what you need to answer your research questions. Descriptive designs are typically used as preliminary studies to describe particular phenomena about which there has been little research and generally have rather basic statistical procedures. Descriptive studies lack randomization and control and cannot be used to determine causation and other implications.

2.3.13.1 Studies on the Factors that Facilitate STEM Implementation

Honey et al. (2014) reported that the fundamental skills needed for STEM education depend on the expertise of teachers and their strong content knowledge of various STEM subjects being taught. Moreover, they also pointed out the expertise of teachers is the critical factor that determines whether STEM education produces positive student outcomes (Honey et al., 2014). Educators need specialized STEM content knowledge and are well prepared and trained to determine talented students in STEM areas (National Science Board, 2010).

Berlin and White (2012), the study suggested STEM teacher education programs need to include: (a) need to be exposed to more STEM concepts and skills; (b) to STEM-related instructional methods and resources; (c) have in-depth knowledge of STEM content; and (d) more collaboration strategies. This will enhance the teacher readiness level to enact STEM in their classrooms. They will be equipped with the needed competencies of STEM teaching, such as the skills, the required knowledge, and how to incorporate both effectively to implement STEM successfully.

Thibaut et al. (2018) described that STEM education requires restructuring the interdisciplinary curriculum, using materials and resources, and having a supportive school culture. STEM teaching and learning can be costly and time-consuming, and qualified teachers can teach and implement the interdisciplinary approach.

Margot and Kettler's (2019) study findings suggested factors that contribute to the successful STEM implementation. Teachers' years of experience are inconsistently related to their perceptions of STEM integration or education; specifically, they reported that teachers with more years tend to value STEM more than newer teachers. They also found that teachers' age, gender, and STEM experiences may, as older teachers have a more positive attitude toward incorporating engineering design inside the classroom, male teachers perceive the importance of technology in STEM fields more than females. STEM implementation using application activities based on cross-curricular activities will lead to better students' attainments (Falloon, 2019). An additional finding is that teachers believe STEM education is intuitively motivating to students as involving students in challenges leads to inspiring and empowering students' abilities, increasing their interest, and enhancing their academic achievement. According to Belbase et al. (2021), teachers' efficacy beliefs and how they value STEM impact their willingness to engage and implement STEM curricula.

Therefore, developing a specified STEM curriculum with explicit learning outcomes will facilitate the STEM teaching process and prepare teachers to accept the new teaching and learning practice by introducing them to the needs and values of those strategies. Furthermore, training the teacher to acquire the knowledge and the skills to be more confident in enacting the new STEM approaches and changing school culture to value and support the integration by providing time and space to assure effective integration of STEM approaches. STEM pedagogical knowledge is essential to ensure successful STEM implementation (Moore et al., 2014). In addition, the enactment of STEM in the classroom uses explicit teaching approaches that integrate real-life experience using discovery, problem-solving, and inquiry-based learning (Honey et al., 2014). Although all the reviewed studies above highlight crucial factors that play an essential role in facilitating the STEM implementation process, those studies address a few aspects individually. The current research has a broad scope that examines all the above factors that impede the successful STEM implementation process through the study questions. Figure 3 illustrates the factors facilitating STEM implementation.

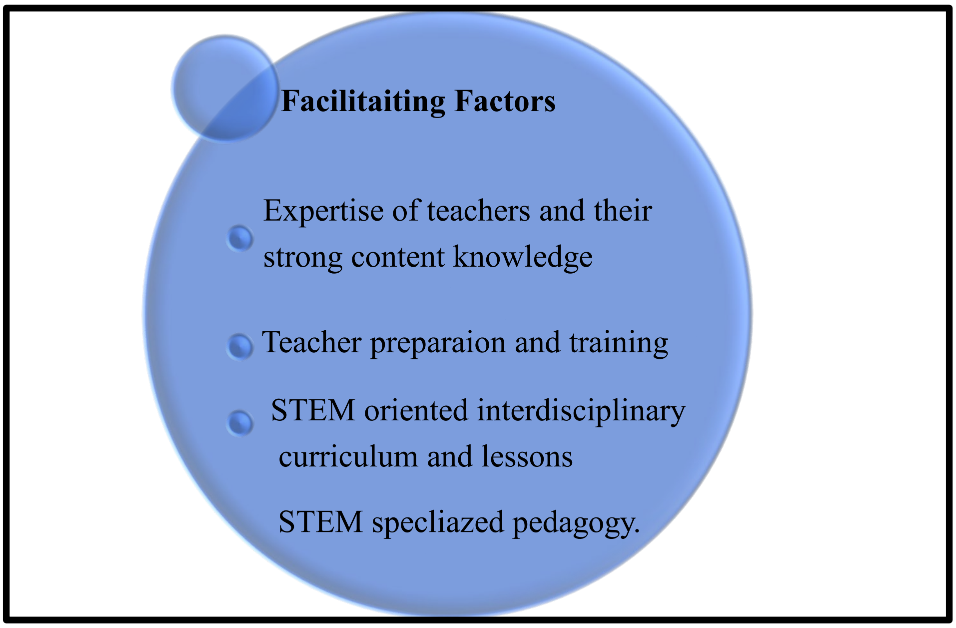

Figure 3: Factors Facilitating STEM Implementation

2.3.13.2 Studies on Factors Impeding STEM Implementation

Wang et al. (2011) indicated that the lack of guidelines and implementation framework is one of the biggest educational challenges for K-12 for STEM implementation inside the classroom. According to Austin (2019), current STEM education approaches lack standards-focused, ready-to-teach teacher and student materials and frequent teacher training. Tsui (2007), in his synthesis of existing research, reported multiple barriers to need to be resolved to increase participation in STEM. These challenges are categorized as cultural, structural, and organizational practices. Another barrier is inadequate teacher preparation determined by identifying STEM-related training pieces (Davis, 2015).

Currently, several K-12 teachers do not have a strong understanding of engineering concepts and the ability to apply those concepts to have in-depth discussions on any related concepts to educate and motivate students toward STEM careers (Brown et al, 2012; Pinnell et al., 2013).

Teacher self-efficacy is recognized as a factor that influences effective instruction and student success (Tschannen-Moran & Barr, 2004). Concurrently to the previous research, Teacher self-efficacy is defined as how teachers feel confident; they can bring about learning outcomes (Avery & Meyer, 2012). In general, traditional models of teaching and teacher development have been slow to change to fit the needs of teachers in STEM classrooms (Epstein & Miller, 2011). In addition, they also reported that those models are deficient in producing teachers ready for the rigorous challenges of STEM learning environments, especially at elementary levels (Epstein & Miller, 2011). Similarly, NCLB legislation indicated the shortage of highly qualified science and math teachers. It has still been challenging to find elementary teachers capable of teaching science, math, engineering, and technology fidelity (Sanders, 2009). For this purpose, research on STEM implementation raised attention to the enormous impact teacher self-efficacy has on student success. It would be helpful to know how certain professional developmental factors impact teacher self-efficacy in STEM learning environments (Tschannen-Moran & Barr, 2004).

Margot and Kettler (2019) asserted that providing in-depth problem-solving through STEM education. Authentic experiences require that teachers are equipped with STEM pedagogy and aware of the importance of engineering design, and teachers have to be familiar with their subject matter and the other subjects.

El-Deghaidy et al. (2017) described that teacher self-efficacy plays an important role in teachers' success in STEM teaching. In this line of argument, Diefes-Dux et al. (2007) referred to teachers’ lack of confidence and low self-efficacy in mathematics and science and their fear of teaching engineering. This resulted in teachers feeling reluctant to engage in professional development programs. Teachers’ competence in STEM content knowledge might be a crucial factor for STEM integration in schools, and pedagogical content knowledge is another critical factor contributing to STEM implementation success.

Owens (2014) study outcomes asserted that time restraints, inadequate preparation, and a misunderstanding of expectations associated with STEM are the challenges and obstacles that impede the important STEM implication. Moreover, the results indicated the importance of proper guidance and leadership. Kubat (2018), in his study, reported teacher’s barriers that prevent the successful implementation of STEM integration in science classrooms; these included: class size, broad curriculum: and teachers' lack of the needed knowledge to teach using the STEM approach.

Wang et al. (2011) study findings revealed that professional development is needed if STEM integration is sustainable. Margot and Kettler (2019) suggested that “teachers believe inadequate assessment tools, time allocation, and STEM subjects’ knowledge are barriers to STEM initiatives. The findings of Margot and Kettler also revealed that teachers thought they didn’t have the subject matter for STEM teaching, and the STEM training provided was inadequate. El-Deghaidy et al. (2017) described that the inflexibility of students' schedules is another barrier to STEM integration. The adequacy of curriculum pacing can impact teachers implementing STEM education within authentic STEM lessons. The increased workload associated with STEM planning is also considered a barrier to STEM implementation.

El-Deghaidy et al. (2017) study results revealed teachers perceived external and internal factors that can impact teachers’ practices of STEM. The external factors were the lack of resources available that influenced large class sizes and the time allocated for STEM teaching and learning. In addition, there are contextual factors related to class size, resources availability, and availability of STEM- curricula for STEM activities. The external factors overlapped with internal constraints about teachers’ pedagogical content knowledge (PCK), including the lack of instructional knowledge about STEM and the lack of understanding of other STEM disciplines.

Successful integration of STEM education requires STEM leadership that can drive curriculum development and teacher preparation that supports STEM programs. However, the review indicated a lack of STEM education vision to guide the implementation process. Moreover, visionary leaders must involve the various stakeholders of their organizations to develop and carry out a shared vision and mission.

2.3.14 Studies on International Perspectives on STEM Education

STEM education has gained enormous attention over the previous two decades; it has received the attention of policymakers in many countries (Winn, Choi & Hand

2016). Recently, extensive attention has been given to STEM education because of the global industrial, economic, technological, and educational competitiveness. The new generation is required to prevail over future challenges and handle this competitiveness competently. Holmlund et al. (2018) indicated that STEM receives huge attention in education reform attempts and within the widespread media across the world. The International Council of Associations for Science Educators (ICASE 2013) called the member countries to collaborate to enhance the quality of STEM education (Kennedy & Odell, 2014).

Moreover, Thibaut et al. (2018) stressed the value of offering students a solid STEM. According to Thibaut et al. (2018), reviewed literature indicated that the importance of providing STEM education is to have qualified STEM professionals who can contribute to the growth of the economy and the fulfillment of the contemporary demands such as ensuring sufficient and sustainable energy, efficient healthcare, and well-considered technology development as cited the study of Boe et al. (2011). Moreover, they also found that all citizens should be equipped with the competencies to cope with an information-based and highly technological society, as cited by the National Society of Professional Engineers (2013). STEM literacy is defined as the familiarity with the STEM discipline's integration nature and the knowledge of each discipline's fundamental concepts (Bybee, 2010; National Academy of Engineering and National Research Council, 2014). The STEM teaching approach is a promising way of teaching using an integrated curriculum that provides students with an engaging and stimulating learning experience (Bybee, 2010; National Academy of Engineering and National Research Council, 2014).

Consequently, this approach positively impacts student performance. Moreover, Thibaut's findings revealed that integrated content could enhance students' interest in STEM, as discussed by Mustafa et al. (2016) and Riskowski et al. (2009). Their findings also indicated that using of integrated curriculum enhances students' motivation toward STEM learning, as indicated by Wang et al. (2011). Based on Thibaut's findings, different studies discussed that an increased push toward STEM disciplines could increase the number of STEM graduates (Mustafa et al., 2016; National Academy of

Engineering and National Research Council, 2014; Riskowski et al., 2009; Wang et al., 2011). According to the authors, STEM teaching faces several challenges: implementing an integrated STEM approach, profound restructuring of the curriculum and lessons, and providing the required materials and resources for STEM implementation. Therefore, Thibaut's reviewed research findings revealed that having a supportive school culture for the STEM approach requires a costly and time-consuming process (Mustafa et al.,2016; National Academy of Engineering and National Research Council, 2014; Riskowski et al., 2009; Wang et al., 2011).

Thibaut's findings contributed to developing an instructional framework consisting of five classifiable but related key principles: nature of STEM content integration, problem-focused learning, inquiry-focused learning, design-focused learning, and cooperative learning. According to the international perceptions, educators around the world believe that the STEM teaching approach is a potential teaching method that promotes; students' interest in STEM disciplines; enhances their learning abilities as it allows broader connections among the four STEM disciplines, strengthens their problem-solving skills, and prepare them to be critical and innovators citizens. However, they all agreed that there is no common consensus regarding the definition of STEM education, and several factors impact the success of the STEM education process. Several countries have a significant initiative on STEM education, such as the USA, South Korea, and Turkey.

In the USA, the National Science Foundation (NSF) has played a significant role in the STEM education movement by emphasizing the conduction of research related to STEM implementation. Attention to STEM education has increased, calling for improvements in the quality of curriculum and instruction (Honey et al., 2014). However, K-12 education in the United States lacks the rigor of STEM (Top & Sahin, 2015). According to Stanley (2017), STEM is a significant component of human culture. All humans need to be STEM literate to cope with the engineering world we live in and be informed, citizens. Stanley pointed out that STEM education will positively impact the American economy. Relying on STEM degrees, workers earn more and experience lower unemployment rates than comparable workers (National

Science Board, 2012). According to Stanley (2017), the poor performance of American students on national and international science assessments has raised the attention for improvements in science programs. In addition to the lackluster performance on assessments, the U.S. high-tech trade deficit continues to grow, and foreign competitors filed over half of the nation's technology patent applications in 2010. STEM education received colossal attention and became a national discourse topic (Kuenzi, 2008). The discourse indicated that the importance of preparing K-12 students to pursue STEM pathways in higher education to increase America's potential for innovation is one of the commonalities discussed (Thomasian, 2011). Although STEM education is an old initiative within the US education context, it is still behind its success status. However, many studies highlight the implementation's progress and the barriers that impede the practical implementation. Therefore, the above studies drew the guidelines road map of the current study.

In South Korea, Students are well known for their exceptional success in the Program for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS). Notably, Korea reached the highest mean score in mathematics among the countries. However, Korean students are notorious for their low-interest levels in and enjoyment of learning science and mathematics. In line, Kang (2019), in his review study, discussed that Science, Technology, Engineering, Arts, and Mathematics [STEM] integration in education in South Korea is an approach to preparing a quality STEM workforce and literate citizens for a highly technology-based society. In his literature review, he examined the STEM education initiative in South Korea and investigated its effects on learning and teaching. Studies in South Korea found that teacher professional development courses increased teachers' recognition of the initiative and their confidence in teaching STEM. Teacher interviews revealed that coaching in classroom practices within teachers' professional development was helpful. Although studies reported that many science teachers adopted STEM in science teaching, there was a lack of research on how teachers taught STEM lessons, let alone the connections between teachers' perceptions of STEM and their classroom practices. As for STEM's effects on student learning, several meta-analyses showed that students' experiences with STEM were effective in both cognitive and affective learning. The result was higher in affective domains. Interviews with college students who had STEM experiences in grade school showed that the effects could be long-term. Kang (2019) indicated meta-analysis studies failed to identify significant mediating factors, which required further in-depth research on how contextual variables function in student learning.

Park et al. (2016), in their study, examined teachers' perceptions and practices of science, technology, engineering, arts, and mathematics (STEM) education in South Korea, via a survey of teachers in STEM model schools. Results revealed that most Korean teachers, incredibly experienced teachers, and male teachers had a positive view of the role of STEM education. Park's findings revealed that Korean teachers highlighted various challenges in implementing STEM education, such as finding time to carry out STEM lessons, increased workloads, and lack of administrative and financial support. The findings also suggest that sufficient support from the government, the reconstruction of the curriculum, and the national assessment system are necessary to promote STEM education.

STEM Education in Turkey was discussed by Kubat (2018), who believed that STEM education involves integrated instructional practices that will comply with the work of professionals in real life in STEM disciplines. In addition, he thought that the education systems in Turkey should aim to equip student's problem-solving, creativity, research-questioning, critical thinking, entrepreneurship, and communication skills, and STEM education facilitates the learning and use of these skills. Several studies' findings revealed that STEM education positively impacts students' problem-solving skills, innovative skills, and critical thinking skills (Choi & Hong, 2013; Morrison, 2006).

The study indicated that STEM education aims to educate qualified individuals in science, mathematics, and engineering. According to (Kubat, 2018; Fllis & Fouts, 2001; Thomas, 2014); STEM education provides chances for interdisciplinary work, improves student intellectual skills, provides qualified individuals needed for the business world, and contributes to countries' economic and technological development.

STEM education allows students to learn in-depth. STEM education students' academic achievement (Yildrim & Mahmut, 2017). Students' scientific process skills support the development of problem-solving skills (Robinson, Dailey, Hughes & Cotabish, 2014). STEM education will equip individuals with the knowledge and skills necessary to be successful contributors to and benefactors of a twenty-first-century economy (Kubat, 2018).

Unfortunately, the study findings showed that science teachers have a positive attitude towards using STEM education, but they are not enacting STEM effectively in their classes. Some teachers did not know what STEM education was and how it was applied. Lack of physical resources was one of the teachers' challenges when implementing STEM education.

2.3.15 Studies Related to National/Regional Contexts

Elayyan and Al-Shizawi (2019) investigated the science teachers' perceptions of integrating the STEM approach in cycle two schools in the Sultanate of Oman. A descriptive methodology was conducted using a questionnaire of 19 items divided into two parts: Achieving requirements of 21stcentury skills and associating science education with economic issues. After verifying the psychometric Characteristics of the questionnaire, it was applied to the sample of 147 science teachers (71 male and 76 female). The findings revealed that science teachers positively perceive integrating STEM in teaching science. Elayyan's findings indicated that STEM education aims to equip students with effective skills and competencies. To keep pace with modern scientific developments, to have an opportunity to compete in the labor market. The study findings recommended incorporating engineering design in the science curricula and initiating workshops to prepare n the teachers to use authentic teaching strategies.

Madani and Forawi (2019) investigated teachers' perceptions and instructional practices regarding the new mathematics and science curricula. A mixed-method design was used to collect the data via a questionnaire distributed in 547 schools during the quantitative phase and teacher interviews in the qualitative phase. Unfortunately, STEM in Saudi Arabia was not successful due to a lack of concerns about STEM meaning, purpose, and guiding framework of STEM implementation. Although STEM is perceived as an approach intended to improve g mathematics and science curricula, it still lacks clarity in terms of any intervention or modification related to STEM disciplines. Elayyan and Al-Shizawi (2019) claimed that in 2009, the Ministry of Education (MOE) introduced a new mathematics and science curriculum in a joint effort with Obeikan Research Development Company as an adapted series of science and mathematics textbooks. The new adapted curricula integrated meaningful connections between students' real-life and their educational experiences by implementing new teaching practices that involve student-centered investigation strategies and problem-based learning.

El-Deghaidy et al. (2017), in their study, explored science teachers' views regarding Science, Technology, Engineering, and Mathematics (STEM) pedagogy and its interdisciplinary nature and the contextual factors that facilitate and hinder such pedagogy in their schools. A qualitative study collected data via interview protocol within focus group discussions. The study results highlighted the following contextual issues: teacher self-efficacy, pedagogical knowledge, issues related to establishing a collaborative school culture, and familiarity with STEM education among school administrators, students, and parents. Findings reported teachers' concerns about their under-preparedness to enact STEM practices and indicated how to incorporate engineering design within science teaching. The study recommended developing a professional development model to facilitate the implementation of STEM education in schools, with the participation of partners from universities and industries as a necessary step for enacting a STEM integrated model.

El-Deghaidy and Mansour (2015) examined science teachers' perceptions about STEM education and interdisciplinary teaching to identify the factors that facilitate and hinder such a form of instruction in Saudi Arabia schools. The qualitative study collected data by an instrument that included focus groups, teacher-reflection, and an interview protocol. A professional development model was proposed to provide effective training related to STEM pedagogical content knowledge and application strategies in the classroom. Furthermore, the study showed that STEM integration required a different school culture than that in non-STEM schools. As suggested by the authors, the STEM school culture requires collaboration among stakeholders and building a collaborative and supportive STEM community in the school. The cultural exchange of experience and constant dialogue between teachers and administrators was highly emphasized in this STEM school. Al Murshidi (2019) conducted a theoretical review to address STEM education from relevant literature. The study reviewed 63 articles, including government reports, news publications, primary research studies, and theoretical analysis. These materials examined the current stance of STEM education in the UAE and the challenges faced and projected possibilities. Findings revealed that the UAE had made initiatives in STEM challenged by the lack of UAE nationals' interest in STEM fields and the unaffordability of STEM education among all age groups and income earners. The study recommended the need for more initiative in promoting more developments in the personal and professional for teachers of STEM. The study also recommended the importance of exposing all age groups to STEM.

Al Basha (2018) investigated teachers’ perceptions and implementations of STEM-related subjects in American-system schools in the UAE. A mixed-methods was conducted by collecting data using a questionnaire. The study surveyed 144 in-service teachers of science, mathematics, and technology, and then interviews with some teachers were done. Al Basha’s results indicated that teachers have positive perceptions of STEM education. Teachers believe that STEM is implemented using project-based learning as a part of curricula or as an activity; the engineering steps are incorporated; however, they are underrepresented.

Mousa (2016) employed an explanatory sequential mixed-methods study to examine the female Saudi mathematics teachers' subject matter knowledge and pedagogical content knowledge of STEM implementation. Mousa’s study also examined mathematics teachers’ attitudes and obstacles in implementing STEM education. The study included 98 female mathematics teachers for the quantitative phase and 6 for the qualitative phase in Jeddah, Saudi Arabia. The study findings indicated that teachers possess a good understanding of pedagogical knowledge and an average level of subject matter knowledge. However, they needed systematic support, such as training courses or professional development programs to enable them to implement STEM in their classes. Most of the participants had a positive attitude toward integrated STEM implementation. The qualitative phase findings were similar to the quantitative result. They showed that teachers believed that STEM knowledge, preparation, motivation, and professional development in integrated STEM education and school settings were the most important obstacles that challenged the implementation of integrated STEM education.

Makhmasi et al. (2012) evaluated the factors influencing STEM teachers' effectiveness in the UAE education system. The study employed a survey of twenty-four-question developed by the authors. The study sample was 200 Science, Technology, and Mathematics teachers, from kindergarten to Grade 12, in public and private schools. Subsequently, their study finding revealed the need to address teachers' dissatisfaction with the teaching profession in the UAE. Specifically, addressing monetary compensation, improving the curricula, lack of resources, and providing professional guidance via development courses and seminars is necessary if teachers are more effective in the classroom. Belbase et al. (2021), in their study, examined the current state of integrated science, technology, engineering, arts, and mathematics (STEM) education.

Data were collected using an extensive review of the literature and document analysis. The analysis of STEM learning concepts from the literature provided four main themes. They are (1) STEM education prospects [with three sub-themes STEM movement, the purpose of STEM education, and benefits of STEM education], (2) STEM education priorities them with two sub-themes [curriculum integration in STEM and STEM education as a curriculum reform], (3) STEM education process [with two sub-themes the pedagogical process and assessment in STEM education], (4) STEM education problems [critiques of STEM education and the challenges of STEM education]. Their study presented global STEM/STEM initiatives and movement toward a new direction through integrated pedagogy for meaningful teaching.

2.3.16 Administrator's Perceptions of STEM Education

Patel (2020) examined the school principals' beliefs, understandings, and experiences regarding the curricular innovations and implementations at four STEM elementary schools. The study employed multiple qualitative cases based on five factors: (a) leadership, (b) parent-community ties, (c) professional capacity of faculty and staff, (d) a student-centered learning climate, and (e) ambitious instruction. In particular, the study examined the leaders' perceptions regarding the specifications of a successful STEM school leader and the successful STEM education program, the challenges associated with implementing curriculum programs in general, and the challenges of STEM implementation. The study results will be a source of knowledge for STEM school principals to guide the design and implementation of elementary school STEM education programs.

Davis (2015), in his dissertation, examines the examiner administrators' understandings and perceptions of STEM education and their influence on classroom practices. In his mixed study, both quantitative and qualitative data were collected from 21 administrators. The study findings indicated no consensus on the definition of STEM education. The administrators hold varied perceptions regarding STEM education; not all administrators are prepared to manage the implementation of STEM programming. It the importance to have administrators who are ready to engage in strategic scheduling, careful teacher selection, and planning for equipment and technology replacement. Alumbaugh (2015) conducted a qualitative study to determine administrators' and teachers' perceptions of STEM schools. Data were gathered via interviews with three leaders in professional STEM organizations, four principals from elementary STEM schools, and six teachers from elementary STEM. The study findings indicated that leaders in professional STEM organizations have positive perceptions regarding STEM education, and each leader was a proponent of STEM education at the elementary level.

Moreover, the principles' answers reflected their belief in the prompt role of STEM education in increasing students' engagement and academic achievement. The principals also provided information that showed a shift in teacher attitude toward STEM from being hesitant to give full support. There were limited studies that examined the administrator's perceptions about STEM education. However, the study's outcomes agreed with the other studies that approached the status of STEM education and the elements involved in this process. Particularly the following are on top of them, the ambiguity around the meaning of STEM and successful implementation procedures, the positive impact of the STEM approach on the student's personal and academic attainments.

Natarajan et al. (2021) examined the literature from leadership studies and compared it within the nature of STEM to conclude the qualities of STEM leadership from the school and curriculum levels. The study focused on the critical considerations for STEM leadership and the intended outcomes of STEM leaders. The study findings indicated the importance of utilizing distributed leadership (building collective and group leadership), where space should be granted to all instructional leaders from all four disciplines. They also reported the need for teacher-level leadership teachers were involved in shared decision-making. They also believed that teachers to handle this role need to be prepared with pedagogical knowledge of STEM education to implement STEM education effectively. They concluded that STEM leadership must contribute to building agency in the team, developing a community of STEM practitioners, and creating a robust and common STEM identity. Considerations of culture and context, collaboration, and courage are essential considerations within STEM leadership to build a sustainable STEM community and identity in STEM schools.

Furthermore, they asserted that STEM teachers' interdisciplinary work needs to be actively recognized and the need for the establishment of new teaching roles called "STEM teachers" with the creation the legitimization of their roles and identities. Watson et al. (2020) study examined the perceptions of K-12 school administrators regarding STEM awareness for promoting Science, Technology, Engineering, and Mathematics. A mixed-methods study was conducted and collected from 175 Texas administrators. The overall findings indicated a 77% disconnect between school principals' and superintendents' insights on STEM knowledge in the districts, schools, parents, and communities. In particular, the superintendents report more positive perceptions of their districts' STEM awareness and resources than school principals.

Averill (2018) adopted a quantitative study to investigate the perceptions of K-8 building administrators and teachers of the Catholic diocese in the Southeastern region of the U.S. regarding STEM integration. An online survey was administered through SurveyMonkey via email to all K-8 teachers and administrators within the district. Findings revealed STEM is both a topic and a need within the diocese.

Averill's findings also indicated that the perceptions and understanding of STEM programming could influence program implementation and guide future instructional teaching practices. Moreover, the respondents' perceptions showed that they are not receiving appropriate training or needed resources for STEM implementation. STEM opportunities occur after school hours or in isolated events. A clear vision and definition of STEM implementation are required. Finally, Averill's study recommended further research on the perceptions of STEM implementation within this diocese.

2.3.17 Teacher's Perception of STEM Education

Berlin and White (2012) conducted a quantitative longitudinal study over seven years to analyze the attitudes and perceptions of student teachers preparing to become STEM teachers. Seven cohorts enrolled in the Integrated Mathematics, Science, and Technology (MSAT) Teacher Education program. The sample included 92 preservice mathematics teachers and 137 preservice science and/or technology teachers of 229 subjects. The study findings showed that preservice teachers preparing to teach STEM disciplines valued STEM integration at the onset and the completion of a STEM training program. After the training, teachers felt more optimistic about integrating STEM's feasibility, efficiency, and difficulty.

Owens (2014) used a descriptive case study involving a sample of 12 elementary teachers who were K-5 teachers from two area schools in North Carolina. The study focused on the teachers' perceptions of STEM education, competencies, and professional development. Qualitative data was collected via interviews, document analysis, and field notes. The study findings indicated that teachers had different perceptions of STEM education based on prior experience. Teachers lacked confidence in their knowledge and abilities to integrate STEM effectively. Teachers felt a need for

STEM hands-on training and professional development. Teachers did not have enough time, leadership, and guidance for integrating STEM effectively. However, the above findings indicated that the teachers had different perceptions due to the variation in their prior experience with STEM. However, the overall findings pointed out that the teachers lack the competencies to teach using STEM and the lack of adequate leadership support to facilitate the STEM implementation process.

Alumbaugh's (2015) study findings articulated how teachers find STEM education could increase student engagement and student achievement. The teachers also answered the interview questions that reflected their favor and support for continuing professional development regarding STEM education. Fong (2019) has explored teachers' perceptions of Science, Technology, Engineering, and Mathematics (STEM) Education and its role in today's mathematics classroom. The ultimate findings of the study were that teachers valued STEM career discussion in the classroom as it offers a channel through which knowledge can be transferred, and teachers build rapport with students when they draw upon their own experience with STEM careers.

From this vein, this study will rely on those gabs to develop the study instrument to examine the teachers' perceptions regarding what they know about STEM, how to implement STEM and the barriers that may hinder them from successful stem enacting.

Research design and dissertation methodology dictate what you need to answer your research questions. Descriptive designs are typically used as preliminary studies to describe particular phenomena about which there has been little research and generally have rather basic statistical procedures. Descriptive studies lack randomization and control and cannot be used to determine causation and other implications.

2.4 Summary and Conclusion

The overall literature indicated that STEM education is controversial at the international and the national level (Al Quraan, 2017; Kubat, 2018). However, there was an explicit agreement regarding STEM definition, where most studies indicated no ideal definition of STEM integration. All the definitions describe STEM from different angles, such as instructional perspective, whether multidisciplinary or interdisciplinary, content integration via meaningful learning experience, and real-world problem-solving and connectivity. In general, all the authors agreed that STEM is a teaching approach that positively impacts students' attainment and their attitudes toward STEM disciplines. Overall findings showed STEM integration would result in an increased engagement and interest in STEM disciplines, which will lead to better student attainment and achievement in STEM disciplines learning. Students are exposed to interconnections between science, technology, engineering, and mathematics, which will enable them to understand how these disciplines operate within real-world contexts.

Consequently, students acquire long-life competence by engaging in authentic learning experiences. Moreover, the successful integration of STEM education will increase the number of prepared students to enter the college and enthusiastically join one of the STEM disciplines to gain a degree in math, science, engineering, or technology. It is expected that STEM will benefit globalization of business and industry requirements that mainly focus on having workers with the core knowledge and skills necessary for the job as well as workplace readiness skills such as critical thinking and problem-solving.

According to the reviewed literature, effective STEM implementation requires solid STEM leadership that can manage the curriculum development and teacher preparation that supports STEM programs. STEM in education focuses on both a curriculum and a pedagogy. A curriculum that encompasses integrated content is based on a real-world problem. Qualified Teachers for teaching STEM are one of the critical requirements of successful STEM implementation. Moreover, STEM enactment in the classroom involves incorporating student-centered activities that employ discovery-learning approaches such as inquiry-based learning and problem-based learning. Several factors hinder STEM implementation, such as implementing an integrated STEM approach and profound restructuring of the curriculum and lessons. Integrated STEM education requires the availability of materials and resources that facilitate STEM implementation. Teachers believed that inadequate assessment tools, planning time, and understanding of STEM disciplines are obstacles to STEM initiatives. Teachers also thought they didn’t have the subject matter knowledge of STEM disciplines. And they are not receiving adequate STEM training,

The reviewed literature guided the current study to examine the STEM implementation status and build on the global and national insights of the literature. The literature indicated a shortage of studies within the UAE context that examined both the administrator and teachers’ perceptions. Moreover, within the UAE context, there are limited studies that examined STEM implantation, such as Al Basha (2018), who examined only the teacher’s perception of STEM implementation inside the classroom in private schools. Also, Al Murshidi (2019) investigated the possibilities and challenges of STEM education in the UAE. Additionally, Al Quraan (2017) study identified crucial elements of integrated STEM education and essential factors associated with implementing STEM curriculum in K-12 schools in UAE. Makhmasi et al. (2012) study investigated factors influencing STEM teachers' effectiveness in the UAE. Each of the above studies examined STEM implementation from different perspectives, such as the focus on the teachers’ perceptions and examining the opportunities and challenges of STEM.

Thus, the current study examined the perceptions of the administrators and the teachers from the different angles discussed earlier. The study also investigated the participants’ perceptions regarding the actual and the preferred practice through examining their understanding of STEM definition, the rationale and purpose behind it, and STEM implementation practices. This study also examined the school leaders’ and teachers’ perceptions regarding the STEM implementation process within the public school’s context. At the regional level, the available literature examined STEM implementation from different perspectives El-Deghaidy and Mansour (2015) study examined teachers' perception of STEM possibilities and challenges, El-Deghaidy et al. (2017) study explored science teachers' views about STEM pedagogy and its interdisciplinary nature. Both the local and the regional studies examined STEM by examining a specific perspective regarding STEM, while this study focused on examining the participant perceptions through understanding the status quo of STEM implementation in the school and addressing the preferred practices of STEM implementation. In specific, the study examined the participants' knowledge of STEM definition, the need, and the purpose of STEM. Moreover, the study examined teachers ‘perceptions regarding their actual and preferred level of competence. Then the study examined the factor that impedes STEM implementation and the best practice that can promote STEM implementation from the participants' perspective. The global literature highlighted several factors that can impede STEM implementation, and they were addressed from different perspectives, including (1) leadership-related factors, (2) related pedagogical factors, and (3) school culture involvement of all stakeholders. Therefore, this study examined focused on highlighting the factors that can hinder or promote STEM implementation practices and the impeding factors of the STEM implementation process. This study examined STEM implementation by targeting the school’ administrators, the unit heads, and teachers, which was not investigated whether regionally or globally.

Chapter 3: Methods

3.1 Overview

This chapter presents a detailed description of the research methods that helped in examining STEM implementation in UAE schools by focusing on the participants (a) awareness of STEM education, (b) their understanding of the values of STEM, (c) their understanding of the purpose of STEM and their (d) awareness of the implementation practices that are currently being used in the UAE schools.

Since the research is mixed-method research, this chapter describes the procedures used to collect and analyze data from both quantitative and qualitative phases. The chapter describes the study context, used research design, the study sampling, and the development of the study instruments used in both quantitative and qualitative phases. Data analysis techniques are all highlighted in this chapter.

3.2 Research Context

The current study addresses STEM education by examining the implementation as perceived by the school's leaders and teachers in the public schools in Abu Dhabi educational region. Further, the study aims to identify factors that facilitate or impede STEM integration in the UAE.

The study focused on STEM Schools, which are schools that are exclusively implementing STEM education. The study was conducted in Abu Dhabi, Al-Ain, and Al Dhafra educational regions, as they were easily accessible to the researcher. According to the education system, the core learning years (from Grade 1 to 12) are divided into three cycles: cycle 1 (grade 1- 4); cycle 2 (grade 5-8); and cycle 3 (grade 9-12), therefore, the schools were chosen range is from kindergartens to secondary schools.

The study focused on different cycles of 43 public STEM schools, and they are distributed accordingly in Abu Dhabi (19), Al Ain (19), and the Al Dhafra region (5). The study took place during the academic year 2019-2020. The initial communication was started by the researcher with the MOE operation office in regard to STEM public schools in Abu Dhabi, Al Ain, and Al Dhafra for appropriate context and accessibility purposes. This initiative directs the researcher to the public schools available and accessible for the research purpose. Vision 2021 placed special emphasis on “innovation, research, science, and technology as being the pillars of a knowledge-based, highly productive, and competitive economy” (Innovation - The Official Portal of the UAE Government, 2020) as the UAE is radically enhancing its education system through initiatives such as building new schools, integrating technology into classrooms, and improving its educated workforce. In addition, governmental agencies, such as the Ministry of Education (MOE) and the Abu Dhabi Department of Education and Knowledge (ADEK), are focused on hiring and retaining qualified teachers for preparing a STEM talented Emirati generation in order to create and sustain the knowledge-based economy (The Abu Dhabi economic vision 2030, 2008; Strategic plan for P-12 education, 2009).

3.3 Research Design

This current study adopted a mixed-methods research design, which is mainly about collecting and analyzing quantitative and qualitative data consequently, for the purpose of having an in-depth view of the research problem (Mousa, 2016). The reason behind the use of mixed design is to sketch a more comprehensive portrait of the research problem with support from both quantitative and qualitative data. According to Ivankova et al. (2006), the reasons behind combining the two methods “quantitative and qualitative methods are because they complement each other and allow for a more robust analysis, taking advantage of the strengths of each.” (p. 3). Tashakkori and Charles (2003) also asserted both qualitative and quantitative techniques provide a better understanding of a study problem or issue than either approach alone. The mixed-methods design was used to understand the perceptions of the school leaders and teachers about STEM integration and examine the factors facilitating and impeding the implementation of STEM in education. The current study uses a sequential-explanatory mixed-methods design, which was conducted through two separate phases. The first involves collecting and analyzing quantitative data (by means of the questionnaire) to determine the school leaders’ and teachers’ awareness and perceptions of the STEM implementation process, to compare the current practices and the perceived ones, and to explore the factors facilitating and impeding challenges as described by the participants. The qualitative phase involved conducting semi-structured interviews with a group of school principals and teachers to provide in-depth clarification regarding the collected quantitative data.

3.3.1 Mixed-Methods Sequential Explanatory Design

Kuhn (1970) suggested that mixed-method design is based on the foundations of pragmatism, which deals with the philosophical stance concerning the nature of social phenomena and structures. This was clearly touched by employing the quantitative approach, which is based on a postpositivist worldview, and the qualitative approach, which is based on a constructivist or interpretive worldview. Pragmatism as a worldview arises out of actions, situations, consequences, and concern for "what works" and identifies solutions to the problem (Creswell, 2014). Feilzer (2010) mentioned that the selection of research methods mirrors the researchers' epistemological understanding of the world. Therefore, pragmatic researchers adopt the appropriate research methods that will provide answers to their research questions. Instead of focusing on the method used, pragmatism focuses on the research problem and utilizes all available approaches to address the problem. Therefore, mixed-methods research and pragmatism are closely associated (Creswell & Plano Clark, 2011). This study used a pragmatic mixed methods approach by integrating two methods (quantitative and qualitative) to fully understand the research problem. Therefore, the mixed-methods study was selected to help in the triangulation of results, which uses themes from literature and the results from qualitative and quantitative phases to augment and build on the results, analyzing the data from various facets and identifying the answers to the research questions. Furthermore, by triangulating results from both quantitative and qualitative strands, the findings of the quantitative are expanded and elaborated using the qualitative data, which will affirm the quantitative results and provide in-depth knowledge to uncover the ambiguity of the results from both methods (Creswell & Plano Clark, 2011).

The current study is conducted using a mixed-method sequential explanatory design to examine the schools' administrators' and teachers' perceptions about the status of STEM implementation in the UAE schools. In this way, the study will enhance the validity of findings by (a) triangulating results by using different methods to examine the phenomenon, (b) expanding and elaborating on findings, and (c) uncovering contradictions that can result from the use of different methods (Creswell & Plano, 2011; Greene, Caracelli, & Graham, 1989; Tolan & Deutsch, 2015). The research design used in the current research is explained in Table 2.

Table 2: Mixed Method Design Phases, Procedures, and Outcomes

Phase	Phase	Methods	Outcome	Purpose
Quantitative	Data collection	Questionnaire	Numerical data	To answer research questions 1-5
	Data analysis	Descriptive and Inferential data analysis IBM SPSS ver. 26	Numerical data • Descriptive Data • Inferential Data	• Explain school leaders, teachers, perceptions about STEM integration in UAE schools. • Compare the actual and the perceived practices described by the study participants . • Identify the factors that may impede STEM integration in UAE schools. • Identity to what extent the teachers are competent to implement STEM in their classrooms.
Qualitative	Data Collection	Semi structures interviews	Interview transcripts	• To explain the quantitative findings and uncover their ambiguity
	Data Analysis	• Coding and thematic analysis • NVivo qualitative software v.12	Themes and codes	• To explain the quantitative findings and uncover their ambiguity.
	Integrating of quantitative and qualitative findings	• Integrating the quantitative and qualitative findings • Interpretation and explanation of the quantitative and qualitative results	• The essence of both phases' findings • Discussion • Implications • Future research	• Provide in-depth knowledge about the study phenomenon

3.4 Target Population and Sample: Quantitative

The study aimed to examine the perceptions of the school leaders and teachers about the integration of STEM education in UAE schools. The sampling was done in two main phases: In the first phase, the study focused on selecting the schools that will participate in the study, whereas the second phase dealt with choosing the participants. The current study targeted 43 of the public Sustainable STEM schools. The school sample included 43 STEM schools: 19 schools in Abu Dhabi, 19 schools in Al-Ain, and five schools in Al Dhafra educational region. These were selected in purposefully as they are exclusively STEM education schools. In the second phase, leaders and teachers were selected conveniently from the schools based on their availability as the survey required voluntary participation. The school leaders and STEM teachers were the targeted populations from Abu Dhabi, Al Ain, and Al Dhafra schools. The sample involved 463 participants who responded to the study survey representing diverse positions, gender, years of experience, etc.

The participants included 421 teachers and 21 principals, and 21-unit heads. Of the respondents, 90.7 % were female, and the males were only 9.3%. More than 50% of the participants have more than ten years of experience with different levels of education (Bachelor, Master, and Doctor of Philosophy (Ph.D.) with percentages of 33%, 63%, and 3.2%, respectively. Participants from different specializations participated in this study, such as Science, Technology, Math, Engineering, etc. 49% of the participants were Science teachers, and 19% were from other subjects. Table 3 below summarizes the demographics of the school leaders and teachers selected for the quantitative phase study.

Table 3: Demographic for Quantitative Sample

Demographic variables		Frequency	Percent (%)
School Type	Public	454	98.1
	Private	9	1.9
	Total	463	100.0
School Cycle	Cycle 0	3	.6
	Cycle 1	55	11.9
	Cycle 2	125	27.0
	Cycle 3	28	6.0
	Cycle 4	29	6.3
	Cycle 5	13	2.8
	Cycle 6	8	1.7
	Cycle 7	5	1.1
	Cycle 8	2	.4
	Cycle 9	1	.2
	High school	194	41.9
Gender	Female	420	90.7
	Male	43	9.3
Years of experience	0 - 5 years	141	30.5
	5 - 10 years	48	10.4
	More than 10 years	274	59.2
Educational level	Bachelor	154	33.3
	Masters	294	63.5
	PhD	15	3.2
Specialization	Science	228	49.2
	Technology [IT]	77	16.6
	Math	55	11.9
	Engineering	13	2.8
	Others	90	19.4
Position Title	Teacher	421	90.9
	Unit head	21	4.5
	Principal	21	4.5

Purposive sampling was employed to select STEM schools. Purposive sampling, in other words, is also defined as judgment sampling and is the thoughtful choice of participants due to their knowledge and their qualification. There is no equation or theory to determine the number of participants required; the researcher identifies what needs to be known and the participants that are willing to provide such information (Etikan et al., 2016). While the schools were selected based on the important characteristic that they are exclusively STEM-based schools, the school leaders and teachers were selected based on convenience; the instrument was sent to the Ministry of Education (MOE), which circulated the survey to the STEM schools selected in the chosen regions. Convenience sampling is a non-random sampling where members of the target population meeting criteria, such as their availability or willingness to participate, are included in the study (Etikan et al., 2016). In the case of the current research, convenience sampling is one the easiest methods to access the target population and serve the purpose of the study, hence its usage in the current research.

3.5 Targeted Population and Sample: Qualitative Sampling

The study sample was purposively selected for participation in this study from the schools that participated in the quantitative phase. According to Creswell and Clark (2007), in explanatory design, the qualitative phase of the data collection will be from the same participants in the first (quantitative) phase.

Results are often presented in numerical form and are more reader-friendly if presented graphically in tables and graphs than

3.6 Data Collection: Quantitative Phase

3.6.1 Research Instrument

A Likert-type survey was used in the quantitative phase to provide answers to all research questions. The survey includes five sections: the first section is designed to collect the participant's demographic data. This section contains gender, school type, position, education background, and years of experience. In comparison, the second section (Items 1-34) focuses on the teacher's actual practice of STEM teaching. These section items were developed based on Fraser and Fisher's (1983) manual for building an instrument to measure perceptions of psychosocial characteristics of classroom environment among school students and teachers. Section 3 covers the teacher's preferred practices (Items 1-34). Section 4 (Items 1-6) focuses on the factors of the teacher's readiness to teach using the STEM approach. Finally, Section 5 (Items 1-17) focused on the factors impeding or facilitating the STEM implementation. The survey items were developed based on the overall findings from the reviewed literature by focusing on the existing gaps in the findings and the gaps in the used instruments. As per the literature outcomes, Thibaut et al. (2018) indicated no clear agreement regarding STEM definition, whereas most studies indicated no ideal definition of STEM integration. However, all the definitions describe STEM from different angles, such as instructional perspective, whether to be multidisciplinary or interdisciplinary, the nature of content integration via meaningful learning experience, and real-world problem-solving and connectivity as described (Johnson, 2013; Merrill, 2009; Tsupros et al., 2009).

Moreover, Johnson (2013) indicated that STEM is a teaching approach that positively impacts students' attainment and their attitudes toward STEM disciplines. Effective STEM implementation requires skilled STEM leadership that can drive curriculum development and teacher preparation that supports STEM programs (Marrero et al., 2014; Johnson, 2013). Finally, the reviewed studies' outcomes asserted several factors that hinder STEM implementation, such as implementing an integrated STEM approach and profound restructuring of the curriculum and lessons (Davis, 2015).

The survey items were used to answer the research questions and overcome the previous studies' gaps. Especially gaps related to the lack of consensus about STEM education definition, rationale, and implementation. Moreover, examine the factors that may impact the efficiency of STEM implementation, such as inadequate assessment tools, time allocation, knowledge of STEM disciplines, and Lack of school supporting a culture that promotes and facilitate successful STEM implementation.

The first and second sections dealt with participants' perceptions about STEM integration, which were measured using sub-questions on the meaning, value, purpose, and implementation process. The third section items were designed to examine the participants' perceptions regarding the actual and preferred teacher's competencies level. Mainly the section involved items about the teacher's competence level, the extent of possession for both the needed subject matter, application skills, and other pedagogical requirements, and their willingness to work collaboratively with other STEM teachers. Section 4 items examined the participant's perceptions about the factors that may impede or facilitate the STEM implementation under two different sub-questions about the contextual factors and the teacher preparation and pedagogical factors that may influence the STEM implementation process. Obtained responses under each category will be analyzed quantitatively using SPSS via descriptive analysis (mean, standard deviation, frequency, variance) and inferential statistics to draw generalizations and serve as a foundation for model prediction. By integrating and analyzing the quantitative data collected from all the participants with qualitative results, the overall findings provide a comprehensive understanding of the inspected issue that would be obtained by either type of data separately.

3.6.2 Instrument Domains

As shown in Table 4, the Domains and sub-domains which were used to assess the research questions. Table 5 illustrates the survey categories and items.

Table 4: Study Domains and Sub-Domains

Domain	Sub-Domain	Description
STEM actual perception	• STEM definition • STEM values • STEM purpose • STEM implementation	The domain is designed to examine the current perception of STEM definition, the needs and impact of STEM, and the current implementation practices.
STEM preferred perception	• STEM meaning • STEM value • STEM purpose • STEM implementation	The domain is designed to examine the preferred perception of STEM definition, the needs and impact of STEM, and the current implementation practices.
STEM Teacher's actual and preferred competence level	• Teachers'actual competence level • Teachers' preferred competence level	Domain is designed to examine the teachers' actual and preferred competence level.
STEM Challenges	• Contextual factors • Pedagogical Issues	Domain is designed to examine STEM challenges that were categorized to contextual factors that may impede STEM implementation. Also, to examine the factors to the pedagogical and technical issues that may impede STEM implementation.

Table 5: Survey Categories and Item

Section	Category Items	Items
Section 2, 3 Actual and preferred practices	STEM meaning	1-5
	Value	6-10
	Purpose	11-18
	Implementation	19-33
Section 4 Teacher readiness	Teacher competence level	1-6
Section 5 Challenges	Contextual factors	1-6
	Pedagogical issues	7-17

3.6.2.1 Validity of the Instrument

To ensure the validity of this collected data & procedures to provide content, construct, and backward translation validity was employed. Construct validity was done by building the instrument items to measure STEM education in UAE, relying on the reviewed literature as the foundation for the developed items. Therefore, the items examine the intended construct of STEM integration in the UAE. Content validity was another validation step applied for the developed instrument. In particular, the developed questionnaire was critically examined by three college educators, and some items were amended according to their feedback and recommendations. The survey was also shared with 3 STEM teachers who checked the readability level and wording. They made several changes to make some items readable and easy to comprehend.

Moreover, they suggested adding items in Section 3 about teacher competence level related to teachers' readiness in the education program and about teacher readiness to collaborate with other teachers. Teachers also suggested more items about the STEM implementation challenges, such as the lack of a STEM-oriented curriculum. For example, many wordings were changed based on their feedback, rephrasing several items, and deleting items that are not concisely related to STEM. The items scale was also suggested to be changed from [strongly agree-strongly disagree] to [very often-almost never] for section 1, 2 items that cover the teachers' actual and preferred practices. The backward translation is also used to validate the Arabic translated instrument by back translating into English to match the original English copy. Finally, the Arabic version of the instrument was also checked by 2 Arabic teachers who examined the fluency, the readability, and the corrections of the survey items. They made modifications to some of the statements and the statement's wording.

3.6.2.2 Reliability of the Instrument

Reliability was assessed by examining the internal consistency of the survey items. Such items are normally meant to describe the same construct, making it necessary to correlate respondents 'scores. Cronbach's α is the most common technique used in psychology to measure internal consistency (Price, 2012). This statistic can be used with small-scale questions, such as the 5-point Likert scale common in questionnaires (Price, 2012). This advantage has led Cronbach's α to be common for survey research and was why it was chosen for this study (Price, 2012). The reliability of the instrument was assessed during the pilot study phase.

A. Survey Pilot Study

The developed instrument was piloted for validation purposes in different ways. First, the instrument was translated from English to Arabic to match the language used by the participants. A language expert reviewed the instrument to check the translation. Next, the survey instrument was presented to a panel of 6 experts in curriculum and instruction, science education, and science teachers to check the content reliability and validity. Finally, a pilot study was conducted by surveying 40 teachers to determine the instrument's validity and internal reliability, according to Table 8 below. The pilot study was based on a small sub-sample to validate the developed instrument, the data collection procedures for the main study, and to reduce errors due to improper research design (Adams & Larrinaga-González, 2007).

Moreover, the pilot study involved 40 teachers were surveyed from the STEM public schools using an online survey. These participants had varied demographic characteristics such as gender, school cycle, different educational level, and specialization. The sample involved 38 females, and two males, all of whom have less than five years of experience. Participant specializations included 37 science teachers and three math teachers. The pilot questionnaire responses were analyzed, with minor changes made. For instance, the numbering of items was corrected in both Sections 1, 2. The results indicated that the research design was appropriate and fit for the research objective as illustrated in Table 6.

Table 6: Chronbach Alpha Values for Each Scale

Section	Reliability Statistics	
	Cronbach's Alpha	N of Items
STEM Actual Perception	0.790	33
STEM Preferred Perception	0.949	33
STEM Teacher Actual and preferred competence Level	0.930	12
STEM Challenges	0.981	17

Table 7: Reliability Statistics

Reliability Statistics	
Cronbach's Alpha	N of Items
0.966	95

Internal reliability measures response consistency between different items and to what extent the construct is consistent and dependent. Cronbach's α is the most common technique used in psychology to measure internal consistency (Price, 2012). According to Price (2012), that is common for survey research, which is why it was used for the current study. Different scale subtitles ranged between 0.96 and 0.78, which indicated high internal consistency reliability. Therefore 0.966 Cronbach's α coefficient indicated that the survey items are highly reliable (see Table 7). The demographics of the participants in this study are illustrated in Table 8.

Table 8: Pilot Study Participants (Teachers) Demographic

		Frequency	Percent (%)
School Type	Public	40	100.0
School Cycle	Cycle 1	7	17.5
	Cycle 2	13	32.5
	Cycle 3	6	15.0
	Cycle 4	3	7.5
	Cycle 5	2	5.0
	Cycle 6	1	2.5
	Cycle 7	1	2.5
	High school	7	17.5
	Total	40	100.0
Gender	Female	38	95.0
	Male	2	5.0
	Total	40	100.0
Years of experience	0 - 5 years	40	100.0
Educational level	Bachelor	23	57.5
	MA	17	42.5
	Total	40	100.0
Specialization	Science	37	92.5
	Math	3	7.5
	Total	40	100.0

3.6.2.3 Instrument Administration

The MOE assisted in the online distribution of the survey across the 43 STEM schools in Abu Dhabi in both Arabic and English versions. The virtual data collection was a prolonged and tedious process, and the teacher's responses were feeble. Therefore, hard copies were also distributed in the schools to speed up the data collection process. Four hundred twenty-one surveys were collected from January to March 2021.

3.6.3 Data Collection: Qualitative

The second phase of data collection, the qualitative phase, was used to provide in-depth insights and clarifications related to all research questions relying on the data gathered within the quantitative phase. Furthermore, this study intends to examine

STEM as a phenomenon in a particular site from the study participants' perspective. The current study followed the interpretive paradigm using a qualitative approach, adopting semi-structured interviews rooted in ontological interrogation and the epistemological belief that social reality is constructed by people who participate (Cohen, Manion & Morrison, 2011). The qualitative phase will be conducted through semi-structured interviews and document analysis.

The qualitative phase confirms and triangulates the statistical test results obtained from the quantitative phase. In the mixed-methods sequential explanatory design, the quantitative outcomes decided the participants to be purposefully selected for the qualitative phase and guided the development of questions to be asked to the participants (Creswell, 2014; Ivankova et al., 2006). In this study, the quantitative and qualitative methods were linked twice: first to uncover the available truth about STEM education and then to form the interview questions, select the participants, and shape the interview questions based on the results from the statistical tests in the quantitative phase. Second, the results from the two phases were merged to portray the essence of the overall findings.

3.6.3.1 Participants

The sample of this phase was purposively selected from the sample of the quantitative phase. In particular, the sample involved 10 participants; 6 are teachers, and 4 of the participants represent school leaders such as school principals, unit heads, and vice-principals. The sample has varied characteristics such as gender, years of experience, and education level. According to Table 5, only 3 participants were male, and 6 were females. The teachers involved five mathematics, three science teachers, and 1 Arabic teacher. The researcher communicated with participants to fix the date, time, and virtual meeting mode and then conducted online interviews with each participant.

The qualitative phase confirms and triangulates the statistical test results obtained from the quantitative phase. In the mixed-methods sequential explanatory design, the quantitative outcomes decided the participants to be purposefully selected for the qualitative phase and guided the development of questions to be asked to the participants (Creswell, 2014; Ivankova et al., 2006). In this study, the quantitative and qualitative

methods were linked twice: first to uncover the available truth about STEM education and then to form the interview questions, select the participants, and shape the interview questions based on the results from the statistical tests in the quantitative phase. Second, the results from the two phases were merged to portray the essence of the overall findings. Table 9 shows the demographics of the qualitative sample.

Table 9: Demographics for Qualitative Sample

Demographic variables		Frequency	Total
School Type	Public	3	3
School cycle	Cycle 1	2	9
	Cycle 2	3	
	Cycle 3	4	
Gender	Female	6	9
	Male	3	
Years of experience	0 - 5	0	9
	5 - 10	2	
	More than 10	7	
Educational level	Bachelor	6	9
	Masters	2	
	PhD	1	
Specialization	Science	5	9
	Math	3	
	Others	1	
Position Title	Teacher	4	9
	Unit head	2	
	Principal	4	

3.6.3.2 Semi- Structured Interviews

According to Cohen and Crabtree (2006), an interview is a qualitative method for data collection which involves asking questions and getting answers from selected participants. Semi-structured interviews focus on uncovering the meaning of individuals' lived experiences and revealing the essence of these experiences while giving voice to those experiencing them (Creswell, 1998). Qualitative data were obtained via an online or virtual model from the participants with the aim of examining more particular items raised by the questionnaire survey. Data collection was done using semi-structured interviews with the selected participants of each of the leaders' and teachers' groups. All participants had the opportunity to participate and share their explanations of issues raised in the survey. The discussion was recorded and transcribed via Microsoft Teams. Errors while transcription was then addressed manually. Data were analyzed thematically to draw out patterns of experiences. The thematic analysis process involved: segmenting and labeling the texts, comparing and contrasting codes to develop themes, arranging themes, and finally establishing insightful connections between and among the themes.

3.6.3.3 Interview Protocol

Interview questions included 13 statements developed based on the participants' responses in the quantitative phase outcomes and the gap found in the previous literature review. The interview questions covered aspects related to the level of integration of STEM by the schools, leaders, and teachers' perceptions about STEM, teachers' actual and preferred STEM implementation practices, and the challenges that impede STEM implementation. Two versions of the interview protocol were developed; one targeted the school leader, and the second was designed for the teachers. Each interview has two sections: the demographic sections and the STEM-related questions.

The demographic section collected information such as the participant positions, whether they were teachers or principals, and the educational level of the selected participants in terms of qualification (Bachelor, Master, or Ph.D.). Years of experience are additional demographic characteristics required from each participant. The participant's gender is also one of the necessary demographic attributes. The purpose behind those demographic variables was to examine how they influenced the participant perception regarding STEM implementation. The leader interview protocol included 13 questions that focused on the administrational steps related to STEM integration, including the planning aspects, the implementation and the evaluation of the STEM implementation, the supporting actions within the school environment, and the teacher's readiness to enact STEM in their classes. Finally, the challenges that hinder the process's progress.

The teachers' interview protocol focused on their actual and preferred practices in integrating STEM in their schools and their readiness level to enact STEM in their classes. The factors that facilitate or impede the implementation of STEM in education were also included. The researcher developed two different versions of the interview protocols: the leader's interview protocol and the teacher's interview protocol. The Leaders protocol was used to dig deep into the administration's role in integrating and supporting STEM education. Mainly to what extent leaders are aware of and value STEM integration, how they are implementing it, and what challenges they are associated with the process of progress. While the teacher protocol has 13 items that focus on the teacher's role in the STEM integration, it also highlights the teacher's level of awareness, readiness, implementation practices, and the challenges facing them in their STEM integration.

Most of the questions in this semi-structured interview were developed to explain the variance in all sections of the quantitative results. The quantitative results showed that there is variation between the participants' actual and preferred perceptions regarding STEM meaning, value, purpose, and their perceived implementation process. Therefore, the interview questions were built to clarify the actual STEM and the preferred practices in-depth. Also, the quantitative phase revealed that principal perceptions are different from the teacher's and units' heads. Therefore, more elaboration was required. The teacher's competence levels to implement STEM education were also varied between the teacher's actual competence level and their preferred competence level. For this purpose, the interview questions focused on the teacher's readiness and their need to implement STEM effectively. The quantitative results revealed different factors that impede the implementation of STEM; therefore, more clarification and elaboration were required on those factors. Table 10 illustrates the sections in the semi structured interviews.

Table 10: Sections in the Semi-Structured Interviews

	Administrator's Interview Protocol	Teachers' Interview Protocol
Domains	Items	Items
Awareness level	Items 1-3	Items 1-4
Administration Steps	Items 4-7	Items 5-6
Teacher's Readiness	Items 8-9	Items 7-9
Factors impeding or facilitating STEM integration	Items 10-13	Items 10-13

3.7 Validity and Reliability of the Qualitative Phase

According to Creswell (2014), qualitative validity deals with the accuracy of the findings by applying specific procedures. Firstly, the interview protocol was validated by three experts who reviewed the protocol questions. The primary purpose of this process was to confirm that the developed instrument is assessing what is expected by this study and whether it is appropriate for the sample population in the research study. The semi-structured interview questions were piloted with three teachers to ensure their clarity. Then, an interview guide was created and piloted with doctoral colleagues and science teachers whose feedback was used to clarify the ambiguity of some questions. Due to limited time, the instrument was not piloted again. The instrument was developed in English and then translated to suit the participants' native language. Each participant interview lasted about 20-30 min after taking the participants' permission to record the interview.

3.7.1 Reliability

According to Creswell (2014), qualitative reliability indicates that the researcher's methods and procedures are consistent across different researchers and projects. For the current study, additional procedures were taken to assure the reliability and credibility of the constructed knowledge: 1) the researcher compared transcripts with audio records to make sure that they did not contain any mistakes, 2) the researcher double-checked the codes and definitions, which consisted of writing notes and their definitions and following them during the analysis period. The sampling selection considered the requirement of the explanatory design, which involves selecting the qualitative participants from the quantitative phase sample. As described by Creswell and Clark (2007) in explanatory design, the participants in the qualitative phase of the data collection will be from the same participants in the first (quantitative) phase.

3.8 Data Analysis of Quantitative Phase

The quantitative data were analyzed using descriptive and inferential statistics methods via the Statistical Package for Social Sciences (SPSS). The following are the statistical analyses conducted for the study.

1. Cronbach alpha (α) value is used to determine the reliability of the Likert-scale section of the questionnaire.
2. Descriptive statistics were used to determine the response rates, including frequencies, percentages, means, and standard deviation. The rationale for using descriptive statistics. This is to provide answers to the following research questions:
    - What are the school principals, unit heads, and teachers' perceptions regarding actual and preferred STEM practices in terms of their definition, purpose, value, and implementation of STEM?
    - What is the teacher's competence levels to implement STEM education?
    - What are the factors that may facilitate or impede the successful implementation of STEM integration in UAE schools?
3. Inferential statistics are used to go beyond the data and make predictions in the following question:
    - Are there any statistically significant differences between the actual and the perceived level of STEM implementation of the participating school administrator or principals and teachers?

- Is there any statistically significant difference in the teacher's perceptions about their current and preferred competence level in STEM education implementation?

3.9 Data Analysis of Qualitative Data

For the qualitative data analysis, interview participants were selected through a gatekeeper in the school which facilitated communication with the selected participants. The interviews were conducted firstly by targeting the school principal, and each principal was asked to nominate a teacher from his school to participate in the study. Each participant was given a unique code by encoding his/her position and then adding a number that reflects his order in the interview process. For instance, school leaders were coded as SL1, SL2, SL3, and so on, whereas teachers were coded as T1, T2, T3, etc.

The interviews were conducted with the Microsoft Teams conferencing application—these were about 30 to 35 minutes in duration. The interviews were recorded using Team's recording feature and transcribed using the Microsoft Word transcribing feature. In the following step, the transcripts were sent back to the interview participants and analyzed after their approval to proceed. The interview transcripts were analyzed using the data analysis application NVivo Pro (v.12). The transcripts were uploaded on the NVivo application and divided into categories (School Leaders and Teachers). 'Nodes' were generated according to the main themes of each interview, conducted for both school leaders and teachers, which are directly linked to the questionnaire sections from the quantitative phase. The researcher went through each of the two categories (School leaders and teachers) for the same node (for instance, the teacher's definition of STEM as compared to school leaders' definition of STEM) and attempted to draw out any similarities and differences between the two; these were noted in the results presented in Chapter 4. Thomas (2006) states that the research develops an initial meaning for each category, and memos such as associations, links, and implications are attached to each memo, providing information about the category. These categories can further be connected to other categories forming relationships. The researcher was, in this instance, the coder of data. The researcher undertook training courses available on the NVivo application and learned thematic analysis and data coding through various tutorials to achieve a solid analysis of the qualitative data.

3.10 Summary of Chapter

This chapter presented the methodological component of this study, such as the research design, which followed a mixed-method sequential explanatory and contextual approach. This section provided a detailed description of the study's participants, modes of data collection, the research design and procedures, and the instruments used in data collection in both the quantitative and qualitative phases. This chapter also includes validity and reliability measures taken in the different stages of the data collection process and the data analysis techniques involved in this study.

Chapter 4: Results

4.1 Overview

This chapter presents the study results of both the quantitative and qualitative phases. Overall, the chapter describes the analysis of the data collected to answer the research questions that are mainly concerned with the following:

1. What are the school principals, unit heads, and teachers' perceptions regarding actual and preferred STEM implementation practices in terms of their definition, purpose, value, and implementation of STEM?
2. Are there any statistically significant differences between the school administrator, unit heads, and teachers in their perceptions regarding the actual and the preferred STEM implementation practices?
3. Is there any statistically significant difference between the perceptions of the school leaders [principals, unit heads] and teachers in regard to the actual and preferred STEM implementation teaching practices?
4. Is there any statistically significant difference in the teacher's perceptions about their current and preferred competence level in STEM education implementation practices?
5. What are the factors that may impede the successful implementation of STEM in UAE schools?
6. What contributes to the best STEM practice in the UAE context from the participant's perspective?

4.2 Quantitative Results

The questions listed above were addressed through the methods listed in Chapter 3. They are presented below. Descriptive statistics, ANOVA, and Paired t-tests were the main methods used to answer the research questions.

4.2.1 Question 1: What are the School Principals, Unit Heads, and Teachers' Perceptions Regarding Actual and Preferred STEM Implementation Practices in Terms of Their Definition, Purpose, Value, and Implementation of STEM?

The question examines school leaders such as principals, vice-principals, academic unit seniors, and teachers' level of actual and preferred awareness regarding their meaning, value, purpose, and implementation of STEM. Table 11 highlights the mean scores of the meaning, value, purpose, and implementation of the actual and preferred STEM teaching practices of the stakeholders listed above.

The level of actual practices of principals, unit heads, and teachers regarding STEM meaning was M = 3.90, SD = 0.60, while the preferred meaning level was M = 4.2, SD = 0.5. The level of actual practices regarding STEM Value for the three groups was M = 4.09, SD = 0.50, while the preferred Value level was M = 4.3, SD = 0.5. The actual level for the purpose of STEM has the highest mean value M = 4.2, SD = 0.6 for the three groups, whereas the preferred level of STEM was (M = 4.5, SD = 0.5). The level of Actual practices regarding STEM Implementation was (M = 3.80, SD = 0.60), while the preferred Value level was (M = 4.4, SD = 0.4) for the three groups.

Table 11: Mean values of actual and preferred STEM practices

Scale	N	Actual Mean	Actual SD.	Preferred Mean	Preferred SD.
Meaning	463	3.90	0.60	4.2	0.5
Value	463	4.09	0.50	4.3	0.5
Purpose	463	4.20	0.60	4.5	0.5
Implementation	463	3.80	0.60	4.4	0.4

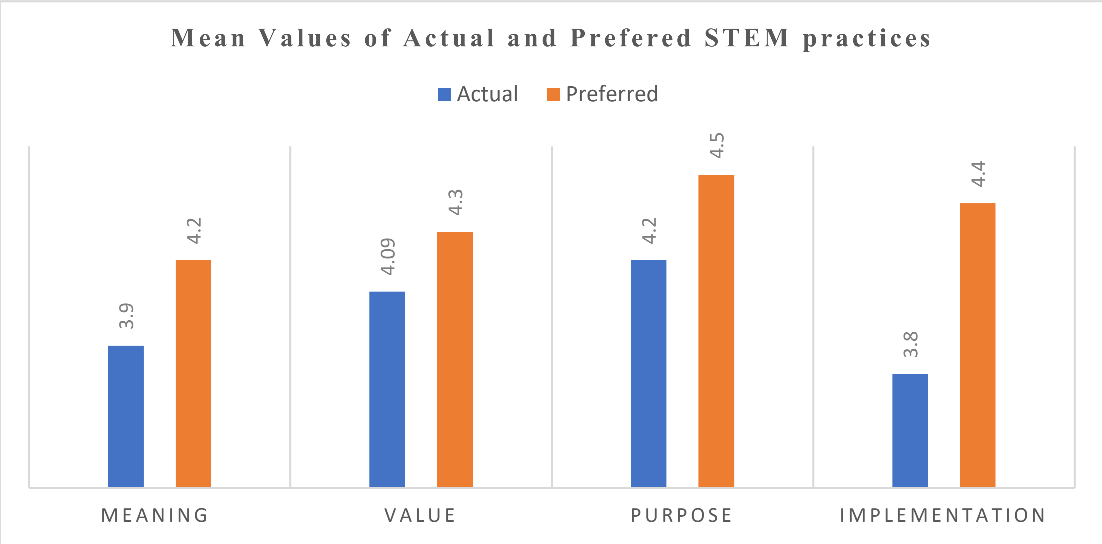

Figure 4: Mean Values of Actual and Preferred STEM practices

Table 12 and Figure 4 depict the mean values of actual and preferred STEM practices for the three groups: Principals, unit heads, and teachers. For principals, Value has the highest mean M = 3.5, whereas, for unit heads and teachers, the purpose has the highest mean M = 4.2, M = 4.2, respectively.

Table 12: School Leader and Teachers' Actual and Preferred STEM Implementation Practices

Position	Mean							
	Meaning		Value		Purpose		Implementation	
	Actual	Preferred	Actual	Preferred	Actual	Preferred	Actual	Preferred
Principals	3.13	3.90	3.50	4.01	3.32	4.10	3.15	4.2
Unit Heads	3.94	4.12	4.03	4.06	4.23	4.49	4.00	4.3
Teachers	3.91	4.7	4.06	4.39	4.24	4.47	3.88	4.4

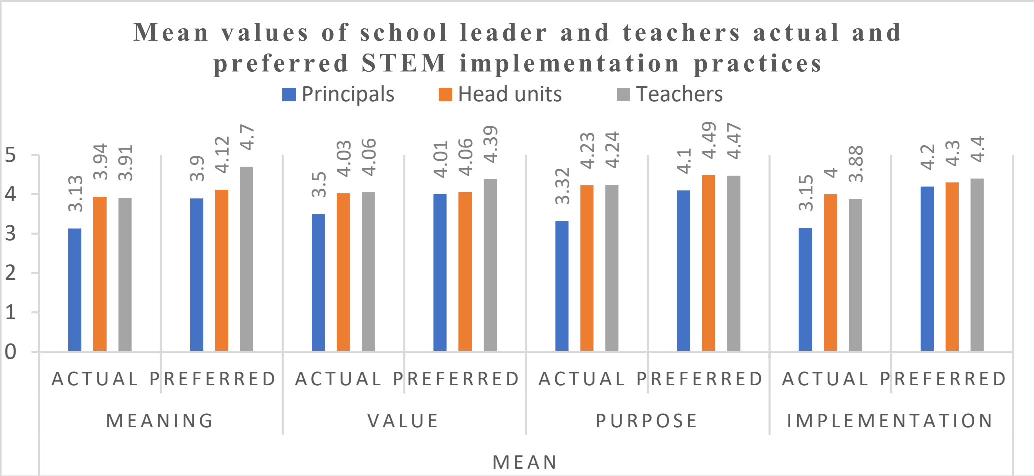

Figure 5: Mean Values of School Leaders and Teachers' Actual and Preferred STEM Teaching Practices

According to Table 12, The principal, unit heads, and teachers scored higher means in the preferred STEM practices than the actual practices regarding the STEM meaning, value, purpose, and implementation. The Actual mean of STEM, meaning as perceived by the principal, unit heads, and teachers, respectively, is M = 3.13, M = 3.94, M = 3.91. The principals had the lowest Mean, while the unit heads had the highest Mean. The Mean preferred Meaning of STEM ranged from the principal mean of 3.9 to the teacher's mean of 4.7. From the table, there is an apparent discrepancy between the principal's actual and preferred mean in regard to STEM meaning. The actual mean of the STEM value ranged from 3.5 scored by the principals to 4.7 scored by the teachers. Furthermore, the preferred mean of STEM value also ranged between 4.01 for the principal to 4.39 for the teachers. The actual mean of the STEM purpose practices ranges from 3.32 for the principals to 4.24 for the teachers. At the same time, the preferred mean of STEM purpose practices indicated that the principal means was 4.1, the lowest mean compared to 4.7 scored by the teachers. The actual mean of STEM implementation practices ranges from 33.15 for the principals to 3.88 for the teachers. While the preferred mean of STEM implementation varies between the principals who score 4.20 and the teachers who score 4.40

Table 13: Actual and Preferred School Leaders and Teachers STEM Implementation Practices: Meaning

	Position Title											
	Teacher				Unit Head				Principal			
	Act	SD	Pr.	SD	Act	SD	Pr.	SD	Act	SD	PR.	SD
STEM should be taught as a science teaching approach	4.03	0.78	4.35	0.72	3.86	0.48	3.86	0.65	3.14	0.36	4.00	0.00
STEM should be taught as an Interdisciplinary approach	3.90	0.87	4.39	0.62	4.00	0.32	4.57	0.51	3.00	0.00	4.10	0.30
STEM should be taught as a Multidisciplinary approach	3.78	0.85	4.14	0.97	3.86	0.65	3.48	0.68	3.24	0.44	3.38	0.50
STEM should be taught as intradisciplinary	3.96	0.80	4.12	0.88	4.05	0.22	3.90	0.70	3.14	0.36	4.10	0.30
STEM should be taught as an instructional approach	3.91		4.35	0.59	3.86	0.48	4.81	0.87	3.14	0.36	3.95	0.50
Act. Actual Practices Pr. Preferred Practices												

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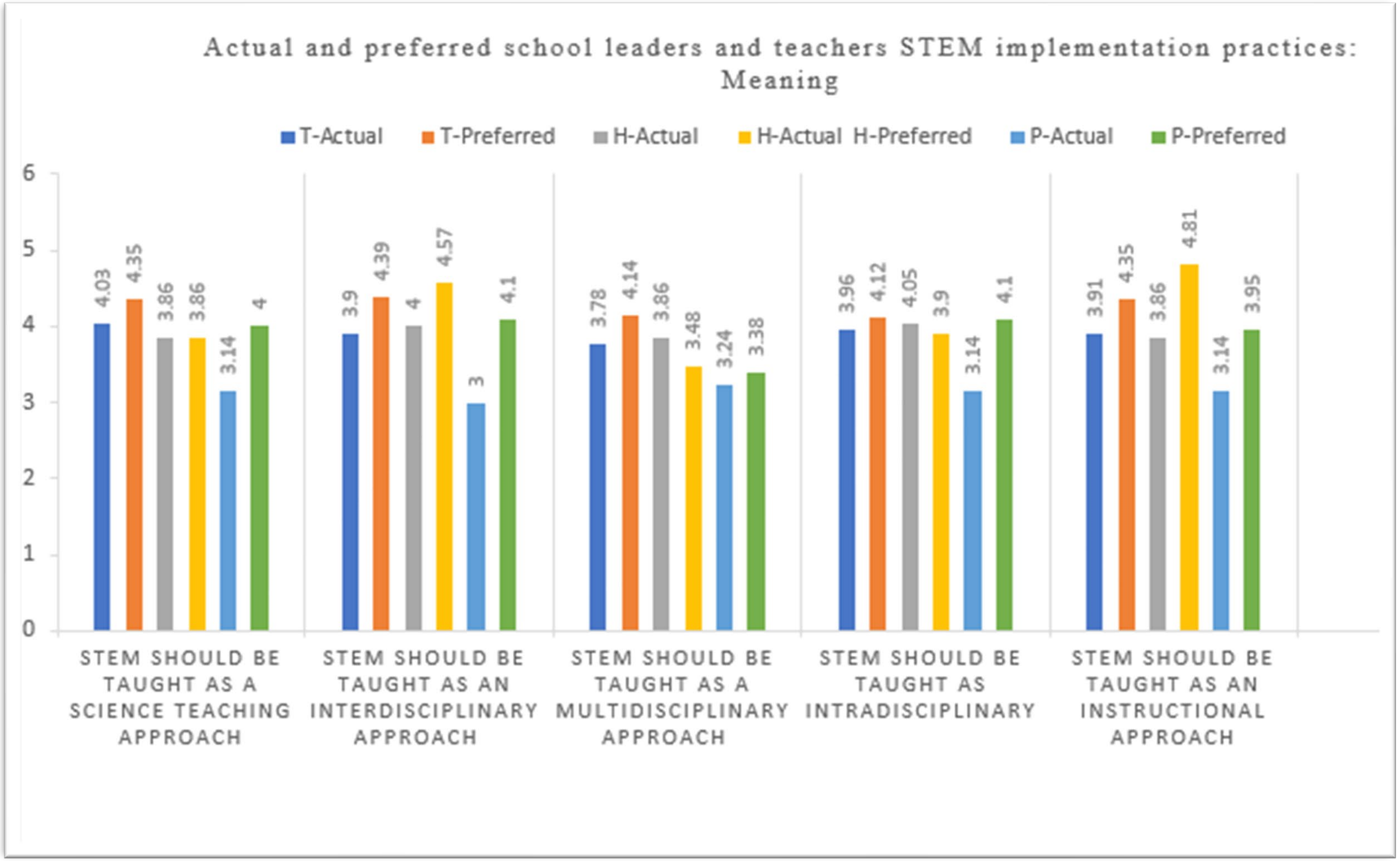

Figure 6: Actual and Preferred School Leaders and Teachers STEM Implementation Practices: STEM-Definition

Table 13 and Figure 6 illustrate the Actual STEM teaching practices in terms of the meaning the three groups attach to STEM. STEM should be taught as a science teaching approach. The actual practices mean ranges between 4.03 as perceived by the teachers to 3.1 as perceived by the principals. At the same time, the mean of the participants ranges between 4.35 as perceived by the teachers to 4.00 by the principal.

STEM should be taught as an interdisciplinary approach as actual practice mean ranges between 4.00 as perceived by Unit Heads to 3.00 as perceived by the principal. At the same time, a preferred practice ranges from 4.57 as perceived by the Unit heads to 4.39 as perceived by the teachers.

STEM should be taught with a multidisciplinary approach. Actual practices mean ranges between 3.86 for the unit heads. While the participant preferred practices mean ranges between 4.14 for the teachers to 3.48 for the unit heads.

STEM should be taught as intradisciplinary as actual practice mean ranges between 4.05 as perceived unit heads to 3.14 as perceived by the principal. The preferred practice ranges between 4.12 as perceived by the teachers to 3.9 by the unit heads.

STEM should be taught as intradisciplinary as actual practice mean ranges from 3.91 as perceived by teachers to 3.14 as perceived by the principal. The preferred practice ranges from 4.81 for the unit heads to 3.95 for the principal.

Table 14: Actual and Preferred STEM Implementation Practices: Values

	Position Title											
	Teacher				Unit Head				Principal			
	T-Act	S.D	T-Pr.	SD. Pr.	U-Act	S.D Act	U-Pr.	S.D Pr.	P-Act	S. D Act	P -Pr.	S.D Pr.
To expand the no. of students who pursue advanced degrees /careers in STEM	3.78	0.84	4.38	0.54	4.00	0.00	4.33	0.91	3.10	0.30	3.95	0.50
To expand the STEM-capable workforce	3.86	0.77	4.35	0.60	4.00	0.00	3.60	0.59	3.71	0.46	3.95	0.50
To improve STEM literacy in all citizens	4.08	0.63	4.41	0.51	4.05	0.22	4.10	0.30	3.71	0.46	3.95	0.50
To spread the innovation culture	4.27	0.58	4.38	0.52	4.05	0.22	4.14	1.01	3.23	0.44	4.10	0.30
To lead to quality education	4.32	0.56	4.43	0.52	4.05	0.22	4.10	0.30	3.71	0.46	4.10	0.30
Act. Actual Practices Pr. Preferred Practices												

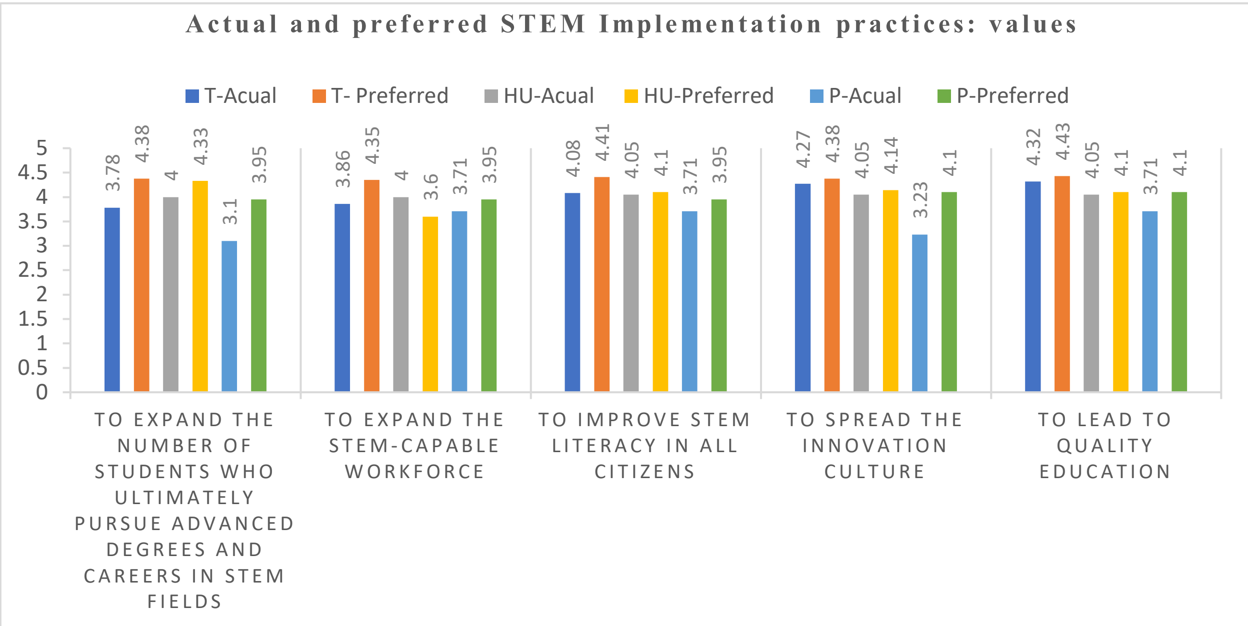

Figure 7: Actual and Preferred STEM Implementation Practices: STEM-Values

Table 14, and Figure 7 present the actual and preferred value of STEM education as perceived by the principals, unit heads, and teachers. STEM value “To expand the number of students who ultimately pursue advanced degrees and careers in STEM fields” actual practices mean between 4.00 and 3.1 as perceived by teachers and principals. While the preferred practices mean ranges from 4.38 for the teachers to 3.95 for the principal. To expand the STEM-capable workforce, the actual preference means ranges between 4.00 as scored by the unit heads, and 3.71, which was scored by the school principals. The preferred practices mean varies between 4.35 scored by the teachers, and 3.60, which was scored by the unit heads.

To improve STEM literacy in all citizens' actual practices, the mean of the teachers, unit heads, and principals were 4.08, 4.05, 3.71, respectively. While the preferred practices mean they were 4.41 as scored by the teachers, 4.10 scored by the unit heads, and 3.95, the principal’s score.

To spread the innovation culture value mean ranges between 4; the actual practices mean ranges between 4.27 as scored by the teachers and 3.23 as scored by the principals. At the same time, the preferred practices perceived by the participants varied between 4.38 by the teachers and 4.1, which the principals scored.

“To lead to quality education,” actual value practices mean ranges between 4.38 by the teachers and 3.71 by the principal. The item's preferred practice ranges from 4.43 for the teachers to 4.1 as scored by both unit heads and principals.

Table 15: Actual and Preferred STEM Implementation Practices: STEM-Purpose

	Position Title											
	Teacher				Unit Head				Principal			
	Act.	S. D	Pr.	SD. Pr.	Act.	S. D	Pr.	SD. Pr.	Act.	S. D	Pr.	SD. Pr.
To enhance students' ability to solve problems.	4.30	0.63	4.51	0.51	4.05	0.22	4.57	0.51	3.38	0.50	4.24	0.44
To enhance students' ability to think critically.	4.37	0.63	4.51	0.53	4.43	0.51	4.57	0.51	3.86	0.36	4.24	0.44
To enhance students' ability to be innovative.	4.36	0.62	4.52	0.51	4.00	0.0	4.52	0.51	3.24	0.44	4.24	0.44
To enhance students' ability to be technology literate.	4.34	0.60	4.47	0.59	4.00	0.00	4.57	0.51	3.24	0.44	3.95	0.92
To enhance student's academic achievement	4.21	0.67	4.45	0.51	4.38	0.74	4.10	0.30	3.71	0.46	4.00	0.00
To enhance students learning through connection between subjects within an authentic context	4.10	0.77	4.43	0.51	4.00	0.00	4.52	0.51	3.00	0.00	4.10	0.30
To enhance decision-making skills.	4.19	0.67	4.46	0.51	4.48	0.51	4.52	0.51	3.14	0.36	4.10	0.30
To enhance long life skills.	4.03	0.77	4.39	0.50	4.48	0.51	4.52	0.51	3.00	0.00	3.95	0.50
Act. Actual Practices Mean Pr. Preferred Practices Mean												

4.2.2 Question 2: Are there any Statistically Significant Differences Between the School Administrators, Unit Heads, and STEM Teachers in their Perceptions Regarding the Actual and the Preferred STEM Implementation Practices?

The question aimed was to understand the differences between actual and perceived levels of STEM implementation between the three groups: principals, unit heads, and teachers. A one-way ANOVA test was conducted to compare the principals', teachers', and unit heads' actual and preferred implementation of STEM. There was a statistically significant difference between these groups at the $p<0.05$ level for the three conditions DF (2,1676), F (29.323), and P = 0.000, illustrated in Table 15 indicated that the mean score for the school principal's actual implementation was M = 3.07, SD =

0.31 which is significantly different to the scores for the teachers M = 3.8, SD = 0.59 and unit heads M = 4.01, SD = 0.21. However, the mean score for the school principal's preferred implementation was M = 4.35, SD = 0.43, which does not have a significant difference from the mean scores of the teachers M = 4.33, SD = 0.43 and unit heads M = 4.33, SD = 0.16.

Table 16: Actual Practices and Preferred Practices

Domain	Participants	N	Mean	Std. Deviation
Actual Implementation	Teacher	421	3.85	0.59
	Unit heads	21	4.01	0.21
	Principal	21	3.08	0.31
	Total	463	3.82	0.59
Preferred Implementation	Teacher	421	4.36	0.43
	Unit heads	21	4.33	0.17
	Principal	21	4.24	0.44
	Total	463	4.35	0.42

Table 17: ANOVA test for Actual and Preferred Implementation

		Sum of Squares	Df	Mean Square	F	Sig.
Actual Implementation	Between Groups	12.77	2	6.39	19.61	0.00
	Within Groups	149.78	460	0.33		
	Total	162.55	462			
Preferred Implementation	Between Groups	0.30	2	0.15	0.85	0.43
	Within Groups	82.39	460	0.18		
	Total	82.69	462			

Table 18: Tukey Post Hoc Results from ANOVA

Multiple Comparisons (Post Hoc Results)							
Dependent Variable	(I) Position Title	(J) Position Title	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Actual Implementation	Teacher	Unit heads	-0.16	0.13	0.20	-0.41	0.09
		Principal	0.77*	0.13	0.00	0.52	1.02
	Unit heads	Teacher	0.16	0.13	0.20	-0.09	0.41
		Principal	0.94*	0.18	0.00	0.59	1.28
	Principal	Teacher	-0.77*	0.13	0.00	-1.02	-0.52
		Unit heads	-0.94*	0.18	0.00	-1.28	-0.59
Preferred Implementation	Teacher	Unit heads	0.03	0.09	0.76	-0.16	0.21
		Principal	0.12	0.09	0.20	-0.07	0.31
	Unit heads	Teacher	-0.03	0.09	0.76	-0.21	0.16
		Principal	0.09	0.13	0.48	-0.16	0.35
	Principal	Teacher	-0.12	0.09	0.20	-0.31	0.07
		Unit heads	-0.09	0.13	0.48	-0.35	0.16
*. The mean difference is significant at the 0.05 level.							

4.2.3 Question 3: Is there any Statistically Significant Difference Between the Perceptions of the School Leaders [Principals, Unit heads], and STEM Teachers in Regard to the Actual and Preferred STEM Teaching Practices?

The below table shows the paired sample t-test of teachers' actual and preferred STEM implementation practices regarding the mean, value, purpose and implementation of STEM teaching practices.

Table 19: Paired Sample T-test of Teachers' Actual and Preferred STEM Implementation Practices Regarding [Meaning, Value, Purpose, and Implementation]

Teachers N (421)		Mean	Std. Deviation
Pair 1-Defnintion	Meaning Actual	3.91	.59
	Meaning Preferred	4.25	.53
Pair 2-Value	Value actual	4.06	.50
	Value Preferred	4.37	.48
Pair 3-Purpose	Purpose Actual	4.24	.56
	Purpose Preferred	4.47	.46
Pair 4-Implementation	Implementation Actual	3.91	.60
	Implementation Preferred	4.36	.43

Table 20: Paired Sample T-Test of Teachers' Actual and Preferred STEM Implementation Practices Regarding [Meaning, Value, Purpose, and Implementation]

Pair		Mean	SD	T	Df	Sig. (2-tailed)
Pair 1- Defeintion	Meaning Actual – Meaning Preferred	-.34	.67	-10.442	420	.000
Pair 2- Value	Value Actual – Value Preferred	-.31	.58	-11.00	420	.000
Pair 3-Purpose	Purpose actual – Purpose Preferred	-.24	.57	-8.50	420	.000
Pair 4- Implementation	Implementation Actual - Implementation Preferred	-.45	.64	-14.54	420	.000

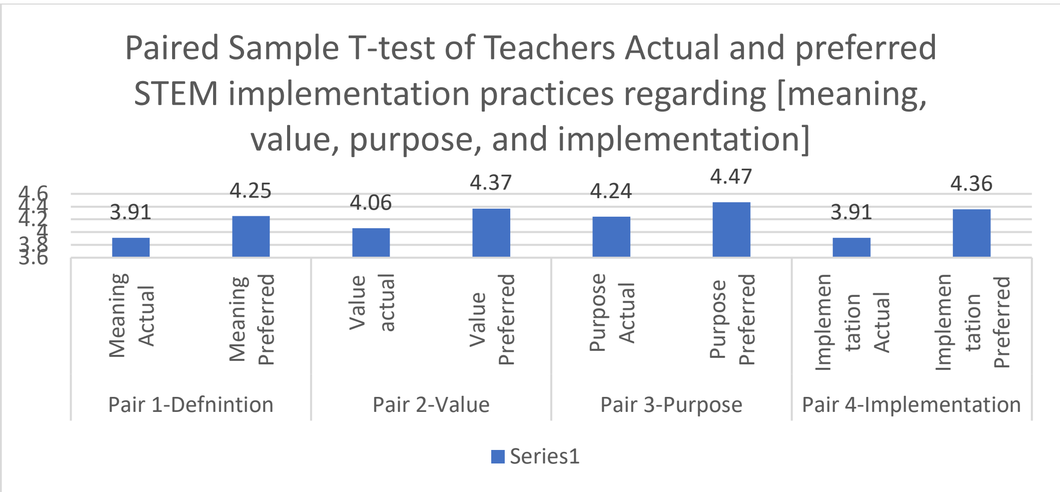

Figure 8: Paired Sample T-test of Teachers Actual and Preferred Practices Teachers of STEM

4.2.3.1 Meaning, Value, Purpose, and Implementation

As shown in Table 21, A paired-samples t-test was conducted to compare the teachers' STEM actual and preferred practices regarding STEM meaning, value, purpose, and implementation. There was a significant difference in the STEM definition actual practices M = 3.91, SD = 0.59 and STEM definition preferred practices M = 4.25, SD = 0.53 conditions; t (420) = -10.44, p = 0.00.

There was a significant difference in the STEM value actual practices M = 4.06, SD = 0.50 and STEM definition preferred practices M = 4.37, SD = 0.48 conditions; t (420) = -10.78, p = 0.00.

There was a significant difference in the STEM purpose actual practices M = 4.24, SD = 0.56 and STEM definition preferred practices M = 4.47, SD = 0.46, conditions; t (420) = -8.50, p = 0.00.

There was a significant difference in the STEM purpose actual practices (M = 3.91, SD = 0.60) and STEM definition preferred practices M = 4.36, SD = 0.43 conditions; t (420) = -14.55, p = 0.00.

Table 21: Descriptive of Paired Sample T-Test of Unit Heads Actual and Preferred STEM Implementation Practices Regarding [Meaning, Value, Purpose, and Implementation]

Unit heads N = 21		Mean	Std. Deviation
Pair 1-Definition	Meaning Actual	3.94	0.19
	Meaning Preferred	3.95	.22
Pair 2-Value	Value actual	4.03	.13
	Value Preferred	4.20	.44
Pair 3-Purpose	Purpose Actual	4.23	.16
	Purpose Preferred	4.43	.39
Pair 4-Implementation	Implementation Actual	4.00	.05
	Implementation Preferred	4.33	.17

Table 22: Paired Sample T-Test of Unit Heads Actual and Preferred STEM Implementation Practices Regarding [Meaning, Value, Purpose, and Implementation]

Unit Heads N = 21		Mean	Std. Deviation	T	df	Sig. (2-tailed)
Pair 1-Definition	Meaning Actual – Meaning Preferred	-.012	.12	-.434	20	.67
Pair 2-Value	Value Actual – Value Preferred	-.17	.51	-1.55	20	.14
Pair 2-Purpose	Purpose actual – Purpose Preferred	-.21	.339	-2.82	20	.011
Pair 4-implementation	Implementation Actual - Implementation Preferred	-.34	.16	-9.39	20	.000

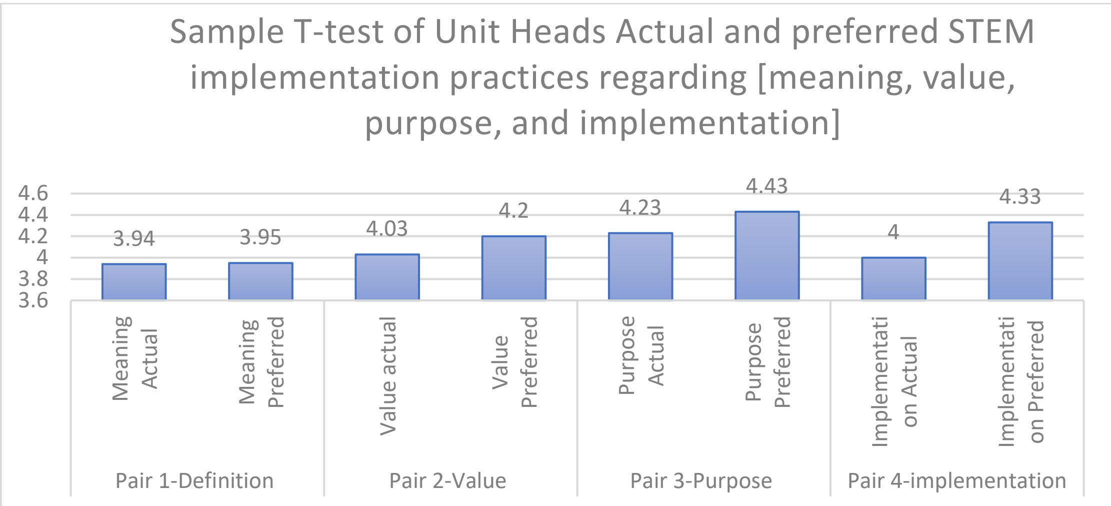

Figure 9: Paired Sample T-Test of Unit Heads Actual and Preferred Practices of STEM [Meaning, Value, Purpose, and Implementation]

As shown in Table 22, A paired-samples t-test was conducted to compare the unit heads' STEM actual and preferred practices regarding STEM meaning, value, purpose, and implementation. There was no significant difference in the STEM definition actual practices M = 3.94, SD = 0.19 and STEM definition preferred practices M = 3.95, SD = 0.22 conditions; t (20) = -.44, p = 0.67.

There was no significant difference in the STEM value actual practices M = 4.03, SD = 0.13 and STEM definition preferred practices M = 4.2, SD = 0.44conditions; t (20) = -1.55, p = 0.14.

There was a significant difference in the STEM purpose actual practices M = 4.23, SD = 0.16 and STEM definition preferred practices M = 4.43, SD = 0.39) conditions; t (20) = -2.82, p = 0.01.

There was a significant difference in the STEM implementation actual practices M = 4.00, SD = 0.05 and STEM definition preferred practices M = 4.33, SD = 0.17 conditions: t (20) = -9.39, p = 0.00".

Table 23: Descriptive of Paired Sample T-Test of Principals' Actual and Preferred Practices of STEM [Meaning, Value, Purpose, and Implementation]

Principals N = 21		Mean	Std. Deviation
Pair1-Definition	Meaning Actual	3.13	.19
	Meaning Preferred	3.89	.23
Pair 2-Value	Value actual	3.50	.29
	Value Preferred	3.98	.44
Pair 3-Purpose	Purpose Actual	3.32	.18
	Purpose Preferred	4.12	.33
Pair 4-Implementation	Implementation Actual	3.20	.32
	Implementation Preferred	4.24	.44

Table 24: Paired Sample T-test of Principals' Actual and preferred STEM implementation practices regarding [meaning, value, purpose, and implementation]

Principals N = 21		Mean	Std. Deviation	t	Df	Sig. (2-tailed)
Pair 1-Meaning	Meaning Actual – Meaning Preferred	-.76	.185	-18.87	20	.000
Pair 2-Value	Value Actual – Value Preferred	-.49	.241	-9.22	20	.000
Pair 3-Purpose	Purpose actual – Purpose Preferred	-.80	.17	-22.12	20	.000
Pair 4-Implementation	Implementation Actual - Implementation Preferred	-1.03	.34	-14.10	20	.000

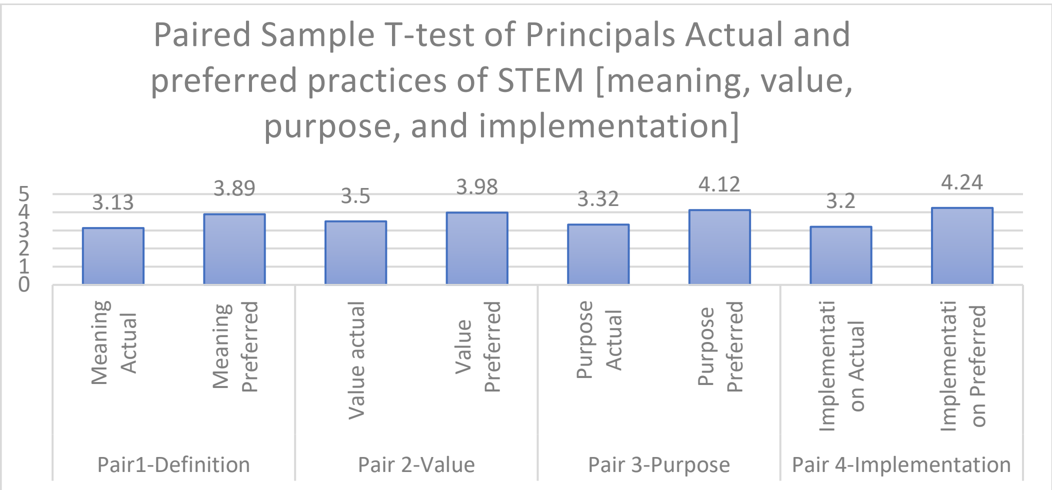

Figure 10: Paired Sample T-Test of Principals' Actual and Preferred STEM Implementation Practices Regarding [Meaning, Value, Purpose, and Implementation]

As shown in Table 23 and Table 24, A paired-samples t-test was conducted to compare the principals' STEM actual and preferred practices regarding STEM meaning, value, purpose, and implementation. There was a significant difference in the STEM definition actual practices M = 3.13, SD = 0.19 and STEM definition preferred practices M = 3.89, SD = 0.23) conditions; t (20) = -18.873, p = 0.00".

There was a significant difference in the STEM value actual practices M = 3.50, SD = 0.29 and STEM definition preferred practices M = 3.98, SD = 0.44 conditions; t (20) = -9.22, p = 0.00".

There was a significant difference in the STEM purpose actual practices M = 3.32, SD = 0.18 and STEM definition preferred practices M = 4.12, SD = 0.33 conditions; t (20) = -22.1, p = 0.00.

There was a significant difference in the STEM implementation actual practices M = 3.20, SD = 0.32

4.2.4 Question 4: Is There any Statistically Significant Difference in the Teacher's Perceptions about their Current and Preferred Competence Level in STEM Education Implementation?

The question aims to examine the teacher's actual and preferred competence levels to implement STEM education. Table 25 indicates the mean scores for the teachers' actual and preferred competence levels to implement STEM education. Results indicate that the mean score for actual competence is M = 3.9, SD = 0.6, whereas for preferred implementation is M = 4.4, SD = 0.4.

Table 25: Mean Values of Actual and Preferred Teacher's Competence Level

Position Title		Actual Implementation	Preferred Implementation
Teacher Competence level N = 421	Mean	3.9	4.4
	Std. Deviation	0.6	0.4

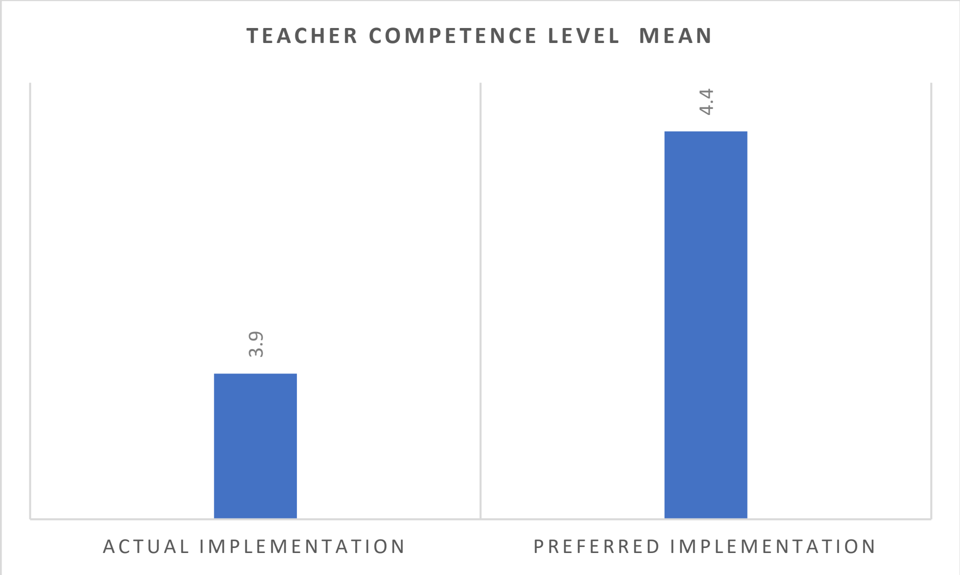

Figure 11: Mean Values of Actual and Preferred Implementation

As shown in Table 26, A paired t-test was further conducted to probe deep into significant differences between the actual and preferred competence of teachers in implementing STEM education. Table 26 below highlights the results from the t-test. There is a statistically significant difference in the mean scores for teachers' actual implementation M = 3.9, SD = 0.6 and their preferred implementation M = 4.4, SD = 0.4 conditions: t (354) = -0.105 p = 0.00.

Table 26: Mean Values of Teacher's Actual and Preferred Competence in Teaching STEM

		Mean	Std. Deviation	P. value
Teacher's Competence	Actual Implementation	3.9	0.6	0.000
	Preferred Implementation	4.4	0.4	

4.2.5 Question 5: What are the Factors may Impede STEM Implementation in UAE schools?

The question aims to examine the factors that may impede the successful implementation of STEM education. As shown in Table 27 below, In the contextual factors that may impede STEM implementation, the mean value of items ranged from

3.5 to 3.8, with the item “lack of time and heavy teaching loads” and “lack of STEM school culture that emphasizes shared beliefs, norms, and support needed to enact STEM” having the highest mean scores M = 3.8, SD = 1.2, M = 3.8, SD = 1.1 respectively. “Lack of strategical plan that emphasizes the implementation of STEM education” had the lowest mean score of M’s = 3.5, SD = 1.2. Among the teaching preparation and pedagogical issues, the mean value of items ranged from 3.5 to 3.8, with the items “Lack of instructional approach that has an emphasis on application to a real-world problem”, “Lack of confidence in handling hands-on activities,” and “Lack of time and heavy teaching load scored the highest means M = 3.8.

Table 27: Factors Impeding STEM Implementation

	Item Statistics	N	Mean	SD
Contextual factors	Lack of Clear institutional mission and vision that promote STEM education	463	3.6	1.2
	Lack of strategic plan that emphasizes the implementation of STEM education	463	3.5	1.2
	Lack of STEM school culture that emphasizes shared beliefs, norms, and support needed to enact STEM	463	3.8	1.1
	lack of STEM-oriented curricula	463	3.7	1.2
	lack of resources	463	3.6	1.2
	Lack of time and heavy teaching loads	463	3.8	1.2
Teacher preparation and Pedagogical issues	Insufficient preparation during teacher preparation program	463	3.7	1.1
	Lack of needed training to prepare teachers for STEM education	463	3.5	1.3
	Lack of collaborative learning community within STEM disciplines	463	3.6	1.3
	Lack of need-based professional development for successful STEM enactment they should have to be trained training resources	463	3.5	1.3
	Teachers lacking STEM subject matter	463	3.6	1.3
	Teachers lacking instructional skills to enact STEM in their classes	463	3.5	1.32
	Lack of Textbooks and other STEM-based Curricula	463	3.5	1.2
	Lack of design and engineering, and technology instructional skills	463	3.7	1.2
	Lack of confidence in handling hands-on activities	463	3.8	1.2
	Lack of instructional approach that has an emphasis on application to a real-world problem	463	3.8	1.27

As shown in Table 28, the contextual factors items range from a percentage of 32.8% to 15.8%, listing the factors as not or slightly important, whereas the percentage ranges from 65.9% to 56.4% when it comes to the respondents citing the factors as very important and important.

More than 50% perceived that the "Lack of Clear institutional mission and vision that promote STEM education" is an important and very important factor that can impede STEM implementation. On the other hand, 27% believed that a Clear institutional mission and vision that promote STEM education is a Not or slightly important factor that impedes STEM implementation.

Lack of a strategic plan that emphasizes the implementation of STEM education was perceived by 56% of the participants as an important and very important impeding factor for the STEM implementation. At the same time, 32.8% of the responses revealed that it is a Not or slightly important factor that impedes STEM implementation.

The lack of STEM school culture that emphasizes shared beliefs, norms, and support needed to enact STEM was perceived by 62.20% of the participants as an important and very important factor that can impede STEM implementation. Whereas 15.80% of the responses indicate, that this factor is a Not or slightly important factor that impedes STEM implementation.

About 56.8 % identified the lack of STEM-oriented curricula as an important and very important factor that can impede STEM implementation. However, 23.1%

considered this factor as Not or a slightly important factor that impedes STEM implementation.

More than 50% of the responses indicated that lack of resources, lack of time, and heavy teaching loads are important and very important impeding factors for STEM implementation. At the same time, 25.00 - 28.00 % believed that these factors are Not or are slightly important factors that impede STEM implementation.

Moreover, Table 28 shows the percentages of factors related to Teacher's preparation and Pedagogical issues that can impact STEM implementation.

Insufficient preparation during the teacher preparation program, Lack of needed training to prepare teachers for STEM education, Lack of collaborative learning community within STEM disciplines, Lack of need-based professional development for successful STEM enactment they should have to be trained training resources, Teachers lacking STEM subject matter, Teachers lacking instructional skills to enact STEM in their classes, Lack of Textbooks and other STEM-based Curricula, Lack of design and engineering, and technology instructional skills, Lack of confidence in handling hands-on activities, and Lack of an instructional approach that has an emphasis on application to a real- world problem are perceived by more than 50% as an important and very important impeding factor for STEM implementation. Whereas percentages of participants range between 18.00- 32.00 % considered the factor related to teacher's preparation and Pedagogical issues are Not or slightly important factors that impede STEM implementation.

Table 28: Percentages of the Important and not Important Factors Impeding STEM Implementation

Contextual Factors	Condition	Not or slightly important %	Important and very important %
	Lack of Clear institutional mission and vision that promote STEM education	27.4	57.9
	Lack of strategic plan that emphasizes the implementation of STEM education	32.8	56.4
	Lack of STEM school culture that emphasizes shared beliefs, norms, and support needed to enact STEM	15.8	62.2
	lack of STEM-oriented curricula	23.1	56.8
	lack of resources	26.3	60.2
	Lack of time and heavy teaching loads	19.8	65.9
Pedagogical issues	Insufficient preparation during the teacher preparation program	18.8	56.4
	Lack of needed training to prepare teachers for STEM education	28.5	53
	Lack of collaborative learning community within STEM disciplines	25.9	55.1
	Lack of need-based professional development for successful STEM enactment they should have to be trained training resources	31.5	53
	Teachers lacking STEM subject matter	29.1	54.7
	Teachers lacking instructional skills to enact STEM in their classes	32.4	57.3
	Lack of Textbooks and other STEM-based Curricula	30	54.7
	Lack of design and engineering, and technology instructional skills	23.1	61.1
	Lack of confidence in handling hands-on activities	19.9	66.8
	Lack of instructional approach that has an emphasis on application to a real-world problem	19.4	60.2

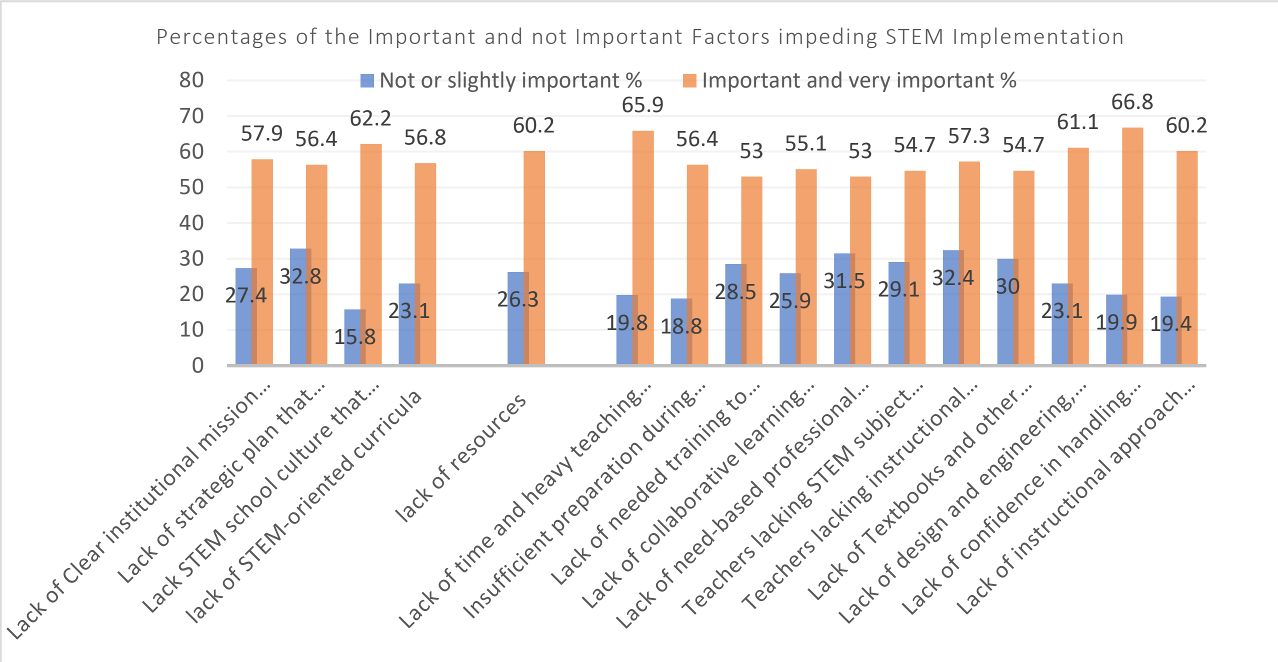

Figure 12: Percentages of the Important and not Important Factors impeding STEM Implementation

4.3 Qualitative Results

The following section presents the results of the data collected via semi-structured interviews and document analysis. The approach used for collecting qualitative data had three main domains as explained in Chapter 3; Sections 1 to 4 assessed the awareness of teachers, unit heads, and principals on STEM integration, and sections 5 to 6 examined their knowledge of the administration steps to implement STEM, whereas questions 7 to 9 measured the teachers', unit heads' and principals' readiness for implementing STEM. Finally, the last section of the interview assessed the challenges associated with STEM integration and factors promoting effective STEM integration in their schools. Overall, all themes that emerged were awareness of STEM integration, approaches for effective integration, teachers' readiness, and STEM implementation challenges.

4.3.1 Domain 1: Awareness of STEM Integration

A. STEM Implementation Definition and Experience

The purpose of the first part of the interview was to assess the meaning of STEM integration from the school leaders' and teachers' perspectives. Most the teachers [T1, T2] define STEM as a "multidisciplinary" teaching approach that can be integrated with any of the subjects taught; however, according to some [T3, T4], STEM education is one subject or unit that is "multidisciplinary" and contains main elements from each subject that help solve a real-world problem. As [T4] stated, "We combine all in one unit or lesson that helps connect between the subjects and the real-world problem". On the other hand, [T1, T2] all believe that STEM is a multidisciplinary teaching approach that, according to [T1], encourages the students' "growth mindset, not just having this fixed mindset". Similarly, [T2] states, "It's a teaching approach that relies on the collaboration between the different subjects for planning".

As for their experiences with STEM integration, the respondents seem to have varying experiences, seemingly based on their years of experience as teachers. [T1] with the most experience (25 years) was unaware of any strategy or planning done by the school. Any form of STEM integration was done internally through their sheer motivation as dedicated teachers. As [T1] states, "I was interested in STEM, and I worked with my students during many projects. Initially, I started with my motivation, and this also was supported by the Ministry of Education initiative". When asked about school plans and strategy, [T1] responded with a lack of awareness about what the school is implementing; rather, they were more aware of their teaching approaches, which is evident from their statement on how STEM is integrated. "It is just integrating these questions and my teaching and integrating that in my assessment for my students as a project. This is also included in my lesson plan for sure". There was also a lack of awareness on how the ministry measures the performance of the schools using indicators. "I don't have an idea about these indicators, but I know that there is an inspection coming to the school that is focusing on all the aspects of the story".

On the other hand, [T2], with (20 years of teaching experience), is well acquainted with the ministry's objectives and school's planning and strategy for STEM integration; listing3 phases of training delivered by the MOE: The first phase deals with informing teachers about the definition of STEM education, the second deals with planning for STEM lessons. They are currently undergoing the third phase. [T3] is aware of the school's involvement in the planning and strategy for implanting STEM. "At the beginning of integrating STEM, each school developed a STEM team. There is also a quality inspector from the ministry to follow up and evaluate the progress. The ministry provides us with plans to implement in our schools". [T2] also described the teachers' sentiments towards STEM integration initially; "At the beginning, the teachers were resisting the STEM approach, but when they started to get used to the activities, they became more interested". [T3] and [T4] seemed to have less information on STEM integration and attributed their experience as a "training" that was conducted to make teachers ready for STEM.

As for the unit heads, they share similar sentiments with the teachers, with [UH1] defining STEM as a "multidisciplinary" teaching approach that can be integrated with any of the subjects taught. Further, [UH1], with an experience of more than 20 years, is well aware of the ministry's objectives and the school's planning and strategy for STEM integration, much like [T2].

For the principals, most of them agree that STEM is an integrated multidisciplinary, cross-curricular teaching approach/method that prepares students with 21st Century skills that are needed". [P3] In the same vein, [P1] further adds that STEM enables more connectivity between the different subjects, allowing the student to improve in each subject by increasing their understanding scope. As a result, students' abilities in project-based activities are advanced and made them ready for additional future challenges". The school leaders' experiences with STEM integration were similar to the schoolteachers. [P2] explained the three phases of training that are delivered by MOE, similar to what the teachers explained above. [P1] reports the difficulty in implementing such a novel initiative in their school, citing, "At the beginning implementation was difficult because it's a new as method and as a concept as well. It was implemented by selecting specific sections of classrooms, and the teachers from different subjects plan the STEM activities and projects".

B. Principals' and Unit Heads' vision for STEM education

The principals' and unit heads' awareness of the STEM vision at their schools was assessed. There is no clear consensus on the level of awareness of the STEM vision among the two groups. [P1] and [P3] were well aware of the STEM vision that is firstly set by the MOE and then the school, with [P1] citing, "we have a vision that promotes the twenty-first-century skills such as creativity, problem-solving and critical thinking skills". [P2] [UH2] did not have the same opinions. [P2] clearly stated there was "no clear vision and no clear guiding framework", whereas [UH2] referred to the online brochure but was not sure of it when asked.

C. Purpose of STEM education

This section assessed the participants' awareness of the purpose and rationale for implementing STEM education. School teachers unanimously agreed on the purpose of STEM as a tool for improving the students' intellectual skills in the 21st century. These include critical thinking, problem-solving, and creativity [T1, T2, T3, T4]. Among other skills listed are innovation, real-life application, collaboration, and effective communication. [T2] summarized the above, stating, "STEM equips the students with 21st Century skills are: Critical thinking, Creativity, Collaboration, Communication. As These four skills are essential for modern students to succeed in school and the workplace".

Likewise, the unit heads and principals had similar sentiments; they believe STEM equips students with 21st-century critical thinking and problem-solving [P1, P2, P3]. [UH2] cites that STEM helps "growth, mindset, and connection to real-life" and that the purpose of STEM is to prepare students for their future in terms of finding their passions and gaining awareness about societal issues and the capability to solve them. In addition to improving intellectual skills, participants also cited that STEM helps students face real-life issues and equips them with tools to solve such issues. It essentially prepares them for the future by "enhancing their competencies when they move to the marketplace as professionals with high critical thinking and outstanding thinking pattern [UH1]".

D. Support for STEM education

Concerning the schools' support for STEM, STEM teachers unanimously agree that their school's culture supports STEM implementation by providing (a) resources, (b) infrastructure, and (c)finances. [T3] states that their school's "culture is supporting the STEM by providing all the materialistic resources and teacher capacity building to enhance STEM implementation", [T1] also agrees and adds, "We have a lot of resources, especially online simulation".

As for unit heads and principals, they all agree that the school's culture is conducive to effective STEM implementation. They point towards financial support, the inclusion of STEM in school plans, and professional development for teachers. [P1] and [P2] believe professional development training is an evident initiative proving the school's support for STEM. [P1] states, "We prepare professional development sessions for the teachers to enhance their teaching abilities; we have the needed resources to facilitate the teachers and student integration process". Unit Heads also nod toward finances akin to teachers and principals, as [UH1] spoke about the financial support "The school has a specific financial plan to support the STEM integration", further adding that "The school infrastructure is highly equipped to implement STEM".

4.3.2 Domain 2: Approaches for Effective STEM Integration

The following section examined the teachers', unit heads', and principals' insights into the approach and the resources necessary for effective STEM integration. Most schools have the basic resources to implement STEM in terms of resources needed. However, the teachers mentioned a few pointers to enhance the STEM implementation. [T4] mentions the need for a detailed framework and guidance plan that will help the school implement STEM. [T1] and [T4] both feel incentivization programs for both students and teachers will help engage them more and motivate them, with [T1] stating, "We have all the resources, but we need motivated teacher to teachers to use these resources we have" …... "the students need prizes, certificates, extra workshops". Increasing the parents' awareness of STEM integration is another sentiment [T3] and [T4] shared. "Increase the parents' awareness about STEM and incorporate them in the implementation process".

As for unit heads, they share varying thoughts and perceptions. Firstly, [UH2] believes in the presence of a clear and detailed plan for implementing STEM. [UH1] mentions that while the curriculum is STEM-based, the evaluation is still traditional; this has to be aligned to STEM for successful outcomes, stating "the assessment and evaluation tools need to be changed and aligned to STEM strategies."

In terms of staffing, the principals believe that the teachers have to be well prepared and, according to [P1], "believe in the importance of STEM and will support the process of STEM implementation" …. "Teachers must understand the mechanism of STEM implementation, understand the necessary skills, and how to apply them in their lessons". [P3] believes no significant staffing changes are required, and that lab technicians would be sufficient in supporting the teachers. Regarding professional development for teachers, [P3] also believes that the development sessions need to be more interactive. "Time made available to plan with other teachers from different schools is necessary". In terms of curriculum development, [P1] cited integrative practices to teach STEM would be the most valuable resources for STEM implementation and material resources to implement various STEM projects. [P3] also believes in the need for lab materials and resources to implement such projects, stating, "Printing of materials, community support, resources based on kid's needs and likes, proper lab materials for science subjects".

Principals and unit head also provided their insights for the administrational steps to be considered for effective STEM implementation. According to school leaders, planning and a solid implementation plan are essential [P1, P3 UH2]. MOE provides the guidelines for preparing the plans, and the schools create procedural plans for STEM implementation accordingly. As [UH2] mentions, "We had to come up with planning, but we had a guideline to do it". Additionally, school leaders also believe that among the administrational steps, spreading awareness of the importance of STEM among all related stakeholders is critical. As [SL1] mentioned, we need to "spread the awareness about STEM and the value behind it between our students and teachers as well". [UH2] has similar thoughts, stating, "we try to convince them that STEM will be better for students and teachers because it needs lots of effort and understanding at the beginning".

4.3.3 Domain 3: Teachers' Readiness

The following section assessed the teachers' readiness from the school leaders' and teachers' perspectives by examining their insight on their level of preparedness and their personal experiences with integrating STEM in a teaching and learning context. Teachers believe they need more training to enable them to teach STEM. Specifically, they need STEM disciplines knowledge and pedagogical knowledge for STEM teaching. Teachers also perceived that none-STEM teachers would require building their capacity and providing STEM discipline knowledge and instructional knowledge that promotes STEM teaching. Their views varied; some teachers believed they were ready to teach STEM [who attended the MOE training], while some indicated they need more training as they are new teachers or are not trained to teach STM.

Moreover, the teachers need to be exposed to teaching methods that are student-centered and engaging, and interactive. In terms of teaching methods and practices, teachers agreed that the following methods to teach STEM; Inquiry-based learning, problem-based, and conceptual approaches were listed by the teachers. Additionally, [T2] added that "participating in extracurricular activities in which students share their products and projects" is an effective teaching method used. Teachers' readiness to teach STEM was assessed as well. According to [T1], [T2], and [T3], teachers need more training. As [T1] states, "knowledge is there, but we still need more training for the future" and that "teachers that they are still behind using technology". This result supported the quantitative result as the participant believed that the teachers were not ready to teach STEM. Notably, [T5] states that teachers are ready as they have "got all training".

On the other hand, unit heads and principals are divided equally, with [P1] and [UH2] believing that teachers are fully ready due to the copious training session held to improve their skills. "We conducted different training sessions about STEM integration in the classroom, how to prepare the activities, and how to raise issues and to stimulate questions" [P1]. Conversely, [P2], [P3], and [UH1] believe the teachers are not ready to implement STEM, with [P3] and [UH1] mentioning that teachers from other disciplines will face issues in teaching STEM compared to science teachers who are much more familiar with STEM. According to [UH1], teachers need more training. Further, [UH1] elaborates that non-science teachers will face difficulty as compared to their science teachers' peers, stating "other discipline teachers will face difficulties in applying STEM".

4.3.4 Domain 4: STEM Implementation Challenges

The following section focuses on the main challenges in effective STEM implementation and the factors that may facilitate or hinder STEM.

A. Challenges in implementing STEM

A majority of the teachers cited the main challenge with STEM implementation as "time-consuming". [T3] mentions that the "existing curriculum is extensive and focuses great importance on math itself". [T3] believe that time is a challenge mainly due to the training aspect; it is "time-consuming especially if the teacher needs to be trained and teach and spread STEM within the students and the teachers". Similarly, Principals and unit heads also believe that time was a significant challenge in implementing STEM. [UH1] believe that time is a challenge mainly due to the training aspect if the teacher needs to be trained. As [P1] says, "time was a challenge for teaching as STEM is a time-consuming approach", and [UH2] elaborates, "the most critical thing is time" …. Good teachers feel guilty because they weren't able to finish the curriculum, or they didn't meet the outcome…and sometimes the shift is totally towards STEM. Further, [P2] states that the additional duties "overwhelm the teacher who already has major teaching loads". [P3] and [P3] believe that the lack of teacher training for all teachers is one of the biggest challenges in implementing STEM.

B. Factors impeding or facilitating effective STEM integration

School teachers' have many factors that impede effective STEM implementation. Lack of awareness is a factor, as raising awareness about STEM is one repeated sentiment expressed by teachers [T2], [T3]. Secondly, teachers agree that more planning and preparation are needed to help teachers with their STEM teaching. [T3] states, "But more preparation is needed in the teacher education program to prepare for STEM teaching". In addition, teachers also felt that motivation was an important factor, with [T1] adding that teachers' motivation through evaluation and appreciation is essential.

Lack of upgraded curriculum, lack of proper assessment strategies and tools for STEM, lack of teacher training, teachers' mode, and language of instruction were all factors that may impede adequate integration. Government support was identified among the factors facilitating effective STEM integration as [T3] highlights, "The government is providing the needed support like the plans, human and materialistic resources".

On the other hand, unit heads and principals have similar thoughts and opinions on these factors. In terms of awareness, school leaders also believe that there needs to be more awareness of the values of STEM and its role in education [P1], [UH2]. [UH2] further elaborates that raising awareness to highlight the importance of STEM to the parents is crucial as "Parents are wanting their kids to study and do a traditional way and they think it's a waste of time". Lack of planning, lack of enthusiastic teachers, and lack of training are factors that impede STEM integration. Further, [UH1] elaborates no "common consensus on STEM as a concept".

On the other hand, [P3] believes that a factor facilitating successful STEM integration is the "consistency between ministry initiatives and STEM initiatives", pointing toward the government support for STEM in the UAE.

C. Impact of COVID-19 on STEM Implementation in the UAE Schools

The participant considered is negatively influenced by STEM implementation due to the discontinuity of STEM pieces of training. The pandemic affected everyone differently, and teachers tried their best to deliver quality STEM education online. While some found it challenging, others found it more flexible and effective. Since there are only a few trained teachers, "During the pandemic, all the teachers flipped to teach from home, so we don't know if the delivered training is effective or not" [T1]. STEM training and integration were disconnected, and the use of virtual labs is high. [T2]

On the other hand, [T4] says that there was not enough time before the pandemic, but since moving online, she had a lot of time to plan out her STEM-related lessons.

The unit heads and principals all have the same concern for STEM during the pandemic. "Implementing STEM concepts has been a challenge due to distance learning" [P3]. "There is a gap" in achieving stream learning objectives [P2] since they are entirely dependent on virtual Laboratories.

Table 29 summarizes the factors either facilitating or impeding the successful implementation of STEM as indicated by the participants.

Table 29: Factor Impeding STEM Implementation

Impeding
Lack of awareness (about the value and role of STEM in education) No consensus on STEM as a concept Lack of parental awareness in understanding the importance of STEM.
Lack of Preparation and procedural planning
Lack of teacher Motivation and lack of enthusiastic working teams
Lack of guiding framework/planning
Lack of Upgraded Curriculum
Lack of Assessment tools for STEM
Lack of teacher training for all teachers
Lack of availability of resources.
Teachers' language of instruction

A. Best practices for integrating STEM

The following section focuses on the best practices for integrating STEM education within schools. Within the UAE context, STEM teachers believe that the government's unwavering support for STEM education is one of the best practices for successful STEM implementation. [T3] states the best practice as "The government support such as the financial, teacher training, and continuous follow up", with [T2] adding "the government motivation toward innovation and creativity" is a best practice in the UAE context. [T4] also added that the government supports by providing the needed training and the resources. Principals and unit heads had similar perceptions as [P3]'s response summarizes the best practices into the following:

- Training Provided.
- Willingness to participate in STEM.
- Cooperation of teachers.
- Support of admin and parents.

[P2] also cites government support as a best practice in the UAE context for successful STEM integration.

4.4 Question 6: What are the Best Implementation Practices for STEM in UAE Context?

Question 6 was assessed using qualitative data from the interviews to identify the best practices of STEM from the participant's perspectives.

4.4.1 Awareness of STEM Values and Stakeholder's Engagement

Awareness of STEM values and stakeholder engagement for fostering STEM was identified as the first best implementation practice by the participants. For Principals, [P3] mentions a "willingness to participate" as one of the best practices for STEM implementation that can be applied within the UAE context. The willingness can be supported by communicating the value of STEM and raising awareness of its importance, further building awareness by involving the stakeholders. [P2], [P3] stated that "stakeholder involvement" is essential in helping to understand the value of STEM and for better engagement. [UH2] resonated with the same idea. Students and parents are listed as the primary stakeholders whose involvement is necessary for effective STEM implementation. Like the principals and unit head [UH1], [T3] also believes the stakeholder involvement and engagement in understanding the value of STEM.

4.4.2 Government Support

Support for the government was listed as another best practice for effective STEM implementation. [P1] and [P3] also believe that "support and assistance from government" and administrators in school is vital as a best practice for effective STEM implementation. According to participants, there should be a unified STEM implementation framework and a clear guiding action plan based on alignment with the market demands globally and locally. [UH1] and [T2] also mention the government support and motivational drive to teach STEM as a best practice.

4.4.3 Training

Teachers have similar views on the best practices for STEM implementation in the UAE context; [T1], [T3], and [T4] list the “training for teachers” and build on their expertise to teach STEM subjects as a best practice. The teacher described several areas of the training required, such as discipline knowledge, integration mechanism, and instructional knowledge. Expressly, they indicated STEM topics planning, teaching, and assessment. Moreover, they needed additional training on collaborating with other teachers for effective STEM teaching.

4.4.4 Effective Leadership

The participants' responses revealed different managerial issues that can impact STEM implementation. They believed that the believed use of proper planning and established guiding plans would positively promote STEM implementation. Moreover, they believed that the availability supports a school culture that focuses on planning, implementation of STEM, and the incorporation of all stakeholders, especially parents. The administrational process was yet another focus of effective STEM implementation. Participants believed that effective leadership would focus on allocating the required resource. Especially there needs to focus on the time allocation for STEM to give teachers enough time to implement STEM effectively. Moreover, providing the needed resources such as the STEM-related Standards, STEM-oriented curriculum, professional development, and any resources required for STEM projects.

4.4.5 Building Effective Pedagogical Methods

According to the participants, building effective pedagogical methods are vital in ensuring effective implementation of STEM; having a clear STEM teaching road map through using STEM-based standards that help guide the teaching process was frequently cited by participants. The teachers listed the use of effective pedagogical methods that facilitate STEM teachings, such as Inquiry-based learning, problem-based, and conceptual approaches. Additionally, [T2] added that “participating in extracurricular activities in which students share their products and projects" is an effective teaching method. Furthermore, participants listed the use of a STEM-based curriculum that aligned with STEM-based standards as one of the best practices to be used in the UAE context.

4.5 Essence of the Quantitative and Qualitative Phases

The participants responses of both qualitative and quantitative phases revealed their perceptions on understanding of STEM meaning, purpose, value and implementation practices, and factors facilitating or impeding STEM implementation. Table 30 below summarizes the participants thoughts and views about STEM implementation practices within UAE context.

Table 30: Summarizes Responses from Both the Quantitative and Qualitative Phases

Question	Focus	Quantitative outcomes	Qualitative outcomes
Understanding of STEM (Meaning, Purpose, Implementation)	Meaning	Actual: Teachers believe STEM is taught as a science teaching approach (M = 4.03), whereas unit heads believe STEM is intradisciplinary (M = 4.05). Principals believe STEM is taught as a multidisciplinary approach (M = 3.23). Preferred: Teachers believe STEM should be taught as an Interdisciplinary approach (M = 4.39), whereas unit heads believe STEM should be taught as an instructional approach (M = 4.81). On the other hand, principals believe STEM should be taught as both an Interdisciplinary and intradisciplinary approach (M = 4.10)	• A majority of teachers' unit heads and principals agree that STEM is a multidisciplinary teaching approach focused on collaboration and prepares students with 21st Century skills.
Understanding of STEM (Meaning, Purpose, Implementation)	Value	Actual: The value of STEM lies in its ability to lead to quality education (M = 4.37), whereas unit heads believe STEM can expand the workforce, improve STEM literacy, and spread the innovation culture (M = 4.05). Principals also believe that STEM leads to expansion of the STEM capable workforce, improves STEM literacy, and leads to quality education (M = 3.71) Preferred: Teachers perceive STEM to lead to quality education (M = 4.43), whereas the preferred value for STEM according to unit heads to expand the number of students who ultimately pursue advanced degrees and careers in STEM fields (M = 4.33). Principals believe the preferred value of STEM lies in spreading an innovation culture as well as leading to high-quality education (M = 4.10)	• The participants all agreed that STEM will enhance students' academic achievement and increase their interest in STEM disciplines. • Will result in having more students enrolled in STEM related professions.

Table 30: Summarizes Responses from Both the Quantitative and Qualitative Phases (Continued)

Question	Focus	Quantitative outcomes	Qualitative outcomes
Understanding of STEM (Meaning, Purpose, Implementation)	Purpose	Actual: For teachers and principals, the purpose of STEM is to enhance students' ability to think critically (M = 4.37), whereas for unit heads, enhancing decision-making skills and long-life skills are the main purpose of STEM (M = 4.478. Principals believe That enhancing student's ability to think critically is the purpose of STEM (M = 3.86) Preferred: Teachers believe STEM should be taught to enhance students' ability to be innovative (M = 4.52). The principals agree with teachers and unit heads (M = 4.24), whereas unit heads believe STEM should be taught to enhance: • Problem-solving • Critical Thinking • Technological Literacy (M = 4.60).	School teachers, unit heads and principals unanimously agreed on the purpose of STEM as a tool for improving the students' intellectual skills in the 21st century, including: • Critical thinking • Problem-solving • Creativity
Understanding of STEM (Meaning, Purpose, Implementation)	Implementation	Actual: Teachers believe STEM is taught using a standardized-based curriculum aligned with STEM outcomes (M = 4.08), whereas unit heads believe STEM is taught using problem-based approaches. Similarly, principals believe that STEM is taught using problem-based approaches, but also STEM is incorporated using a Clear institutional mission and vision that promote STEM education and that STEM is taught using STEM education framework and guidelines (M = 3.17) Preferred: Teachers believe STEM should be taught through real-world problems that promote a richly engaging and motivating context. (M = 4.57). Notably, unit heads believe STEM should be taught during afterschool activities (M = 5.0). Principals believe STEM should be taught during extracurricular activities (M = 4.6). A one-way ANOVA test was conducted to compare the principals', teachers', and unit heads' actual and preferred implementation of STEM. There was a significant difference between these groups at the $p<0.05$ level for the three conditions [DF (2,1676), F (29.323), P = 0.000]	According to unit heads, principals, and teachers, planning and having a solid implementation plan is essential; there is a need for a detailed framework and guidance plan that will help the school in implementing STEM.

Table 30: Summarizes Responses from Both the Quantitative and Qualitative Phases (Continued)

Question	Focus	Quantitative outcomes	Qualitative outcomes
Teacher' s Competence to implement STEM	Competence Level	There is a significant difference in the mean scores for teachers' actual implementation (M = 3.9, SD = 0.6) and their preferred implementation (M = 3.9, SD = 0.4) conditions; t (354) = -0.105 p = 0.917 Actual: Teachers believed that they were prepared to teach STEM during their teacher education program (M = 3.35), whereas unit heads and Principals believed they could work collaboratively with the other subjects' teachers with means (M = 4.76), (M = 4.42), respectively. Preferred: Teachers believed that they would prefer to have the needed subject matter to teach STEM (M = 3.62). Unit heads prefer to receive the needed professional development to be ready to teach STEM and to work collaboratively with other subjects. (M = 3.95). Principals prefer to have all the skills to handle STEM teaching, have the instructional knowledge to enact STEM in my class and work collaboratively with the other subjects' teachers with a mean (M = 4.43).	A majority of teachers believe they have the knowledge but needs more training. As for unit heads and principals, half of them believe there is a lack of training and that non-STEM teachers will face difficulties, whereas half of them believe the teachers have ample training and knowledge. In terms of teaching methods and practices, there is a unanimous agreement for the following methods to teach STEM. • Inquiry-based learning • Problem-based • Conceptual approaches

Table 30: Summarizes Responses from Both the Quantitative and Qualitative Phases (Continued)

Question	Focus	Quantitative outcomes	Qualitative outcomes
Factors facilitating or impeding STEM implementation	Impeding Factors	Among contextual factors, • lack of time and heavy teaching loads • lack STEM school culture that emphasizes shared beliefs, norms, and support needed to enact STEM had the highest mean scores (M = 3.8, SD = 1.2), (M = 3.8, SD = 1.1) Among the teacher preparation and pedagogical issues, • lack of confidence in handling hands-on activities • lack of instructional approach that has an emphasis on application to a real-world problem had the highest mean scores (M = 3.8, SD = 1.2), (M = 3.8, SD = 1.27) respectively.	A majority of the teachers, unit heads and principals cite that the main challenge with STEM implementation is "time-consuming". • Lack of awareness (about value and role of STEM in education) • No consensus on STEM as a concept • Lack of parental awareness in understanding the importance of STEM. • Lack of Preparation and procedural planning • Lack of teacher Motivation and lack of enthusiastic working teams • Lack of guiding framework/planning • Lack of Upgraded Curriculum • Lack of Assessment tools for STEM • Lack of teacher training for all teachers • Lack of availability of resources. • Teachers' language of instruction
		Best STEM implementation Practices	• Awareness of STEM values • Stakeholders Engagement • Government Support • Teacher Training • Effective Administration Steps. • Effective Pedagogical Methods

Chapter 5: Discussion, Implications and Conclusion

5.1 Overview

This chapter discusses the findings presented in chapter 4 within the context of the reviewed literature. Specifically, the chapter presents a discussion related to these research questions and attempts to propose recommendations for policymakers and curriculum planners. Also, suggestions for future research studies related to the concepts and the context of this study will be presented. This chapter contains four sections, starting with an overview of the mixed-methods study, a discussion of the results from both the quantitative and qualitative phases, an introduction to the STEM implementation framework built based on the study findings, and the implications and recommendations with the conclusion of the research.

5.2 Research Implications

Research questions 1, 2, and 3 have employed quantitative methods such as descriptive statistics to determine the response rates, including percentages, means, and standard deviation. Question 4 was analyzed using an ANOVA test to go beyond the data and make predictions regarding the participant response to STEM implementation practices. The interpretive paradigm assesses the qualitative questions to explain participants' experiences and thoughts regarding STEM implementation practices. The structure of this section is guided by the themes of the findings from both strands of the study and the conclusions gleaned from the themes.

5.3 Quantitative Research Questions

1. What are the school leaders' [principals, unit heads], and teachers' perceptions regarding actual and preferred STEM implementation practices in terms of their definition, purpose, value, and implementation of STEM?

2. Are there any statistically significant differences between the school administrator, unit heads, and teachers in their perceptions regarding the actual and the preferred STEM implementation practices?

3. Is there any statistically significant difference between the perceptions of the school leaders [principals, unit heads] and teachers in regard to the actual and preferred STEM implementation practices?

4. Is there any statistically significant difference in the teacher's perceptions about their current and preferred competence level in STEM implementation?

5. What are the factors that may impede the successful STEM implementation in UAE schools?

5.4 Qualitative Research Questions

1. What are the best STEM implementation practices in the UAE context from the participant's perspectives?

5.5 Quantitative Discussion

5.5.1 Question 1: What are the School Leaders' [Principals, Unit heads, and Teachers' Perceptions Regarding Actual and Preferred STEM Implementation Practices in Terms of Its Definition, Purpose, Value, and Implementation of STEM?

Based on both the quantitative and the qualitative results, the participants demonstrated a good understanding of STEM education in many areas. In particular, they were able to define STEM, explain the rationale and the purpose of implementing STEM, and they were able to describe components of STEM implementation. Previous research also addressed those finding (Al Basha, 2018; Elayyan & Al-Shizawi, 2019; El-Deghaidy & Mansour, 2015; El-Deghaidy et al., 2017; Falloon, 2019; Johnson, 2013; Mahil, 2016; Al Murshidi, 2019; Sanders, 2009; Tsupros et al., 2009; Thibaut et al., 2018; Wang et al., 2011). This section discusses the finding of the participants' perceptions regarding the STEM implementation practices related to its definition, purpose, values, and implementation.

5.5.1.1 Discussion of the Participant's Perceptions of STEM Definitions

The quantitative findings in Table 13 revealed that the participants have positive perceptions in both their actual and preferred practices regarding STEM definition practices. The participants' perceptions of STEM definition showed a varied understanding of STEM definition. They believed that STEM is an instructional approach that can be taught as a science teaching approach that can be implemented either interdisciplinary or multidisciplinary.

They also defined STEM as an instructional approach that integrates the teaching of science and mathematics disciplines through the combination of the practices of scientific inquiry, technological and engineering design, mathematical analysis, and 21s century interdisciplinary skills. The participant's definition is aligned with the definition of other researchers who also defined STEM as an "approach", as evidenced in several studies (Johnson, 2013; Tsupros et al., 2009). Johnson (2013) similarly defines STEM as ''an instructional approach, which integrates the teaching of science and mathematics disciplines by using scientific inquiry, technological and engineering design, mathematical analysis, and 21st-century interdisciplinary themes and skills'' (pp. 367).

In line with the result, Tsupros et al. (2009) also defined STEM as an interdisciplinary approach that promotes the learning of academic concepts coupled within authentic contexts that make connections between school, community, work, and global enterprise. The qualitative result also confirmed the quantitative results and indicated that the participants had shown a good level of understanding of STEM implementation practices. The school leaders agreed to define STEM as an integrated multidisciplinary, cross-curricular teaching approach method that requires connections with different subjects [SL1, SL3]. The result is consistent with Falloon (2019), who described that effective STEM implementation employs application activities based on cross-curricular activities.

The interviews showed that the teachers [T1, T2, T3] define STEM as a "multidisciplinary" teaching approach that can be integrated with any subjects taught. However, according to [T4, T5], STEM education is one subject or unit that is "multidisciplinary" and contains elements from each STEM subject that help solve a real-world problem. As [T5] stated, "We combine all in one unit or lesson that helps connect between the STEM subjects and the real-world problem". Inconsistent with the result Al Basha (2018) reported that teachers held informed perceptions about STEM education. They defined STEM as a teaching approach that integrates science, math, engineering, and technology within an authentic context. This exemplary level of knowledge held by the participants can be explained by the continuous involvement in activities related to STEM education and its powerful impact on education.

Specifically, it can be due to the UAE government's drive; the UAE’s National Agenda 2021 determined science, technology, and innovation indicators and set ambitious targets for them (Science, Technology & Innovation Policy in the United Arab Emirates, 2021). Another reason anticipated the UAE government's initiatives to renew its whole education system, mainly its teaching of STEM subjects (Mahil, 2016). In UAE, science teachers were initially introduced to STEM education in 2010, starting to adopt the Next generation science standards (NGSS) within the science curriculum. This could reflect the newness of STEM education initiatives in the UAE and the Arabic region (Al Murshidi, 2019). Another reason for their positive perceptions about STEM is the teacher’s training provided by the ministry of education. Such as the Subject Forum titled "Future-ready," aimed to empower teachers with the experiences, knowledge, and skills to increase the scientific curiosity of learners by using STEM in all subjects (MOE, 2021). Another training opportunity was the fourth Arab Gulf Education Forum 2018 about STEM education in UAE schools which included 370 training workshops delivered by 90 trainers, targeting 8,800 teachers from various schools throughout the United Arab Emirates (MOE, 2021).

In 2020 three-tiered STREAM training was provided by the MOE as indicated by the MOE explain the participants' positive level of awareness about STEM education. Similarly, the findings of Al Basha (2018) revealed that teachers are receiving training about how to teach STEM. Moreover, their perceptions indicated that they prefer to define STEM teaching as a multidisciplinary approach through collaboration with other subjects’ teachers. Specifically, teachers [T4, T5] believed STEM implementation is one subject or unit that is “multidisciplinary” and contains main elements from each subject that help solve a real-world problem. In line with this result, Al Basha's (2018) study findings indicated teachers reported that schools’ curricula are developed to be taught in isolation as a multidisciplinary STEM activity through integration with other subject contexts. Sanders (2009) has contradicting view about STEM implementation that it never intended to be stand-alone subject-area teaching.

Thibaut et al. (2018) study findings also replied that they believed the implementation of STEM content focuses on making a connection between the different STEM disciplines. Furthermore, the teachers believe they have strong subject matter in their subjects, and they can easily implement STEM topics and relate them to the other subjects. The teachers also asserted that they were trained to implement STEM only within their teaching discipline. As mentioned by [T5] who states that teachers are ready as they have “got all training to teach STEM within our disciplines”. They also described interdisciplinary as a teaching model which requires specialized competencies and skills and the availability of a well-merged STEM- curriculum, and they lack both. Teachers also considered multidisciplinary STEM teaching as one subject content and skill that gives the students better chances of connections with the other subjects.

These findings are similar to Wang et al. (2011), who indicated multidisciplinary begins and ends with the subject-based content and skills. Students were expected to connect the content and skills in different subjects. Teachers believed shortage of time is another reason to consider STEM as multidisciplinary teaching; they explained that there is no time allocation for STEM teaching. They have their discipline's pace to finish. Elayyan and Al-Shizawi (2019), Al Basha (2018), and El-Deghaidy and Mansour (2015) study shared similar findings, which showed that teachers perceived STEM implementation as a multidisciplinary teaching approach as they considered it more relevant to their subject.

5.5.1.2 Discussion of the Participant’s Perceptions of STEM implementation Values

The study findings showed that participants had acknowledged actual and preferred perceptions about STEM integration values. The quantitative study findings Table 13, 16 that all the participants believed that STEM integration would positively contribute to education, leading to the expansion of STEM qualified professionals and a solid STEM-work force. Furthermore, they perceived that the value lies in improving STEM literacy in all citizens and spreading the innovation culture. Teachers thought that STEM could lead to quality education. From the above findings, school leaders and teachers agree that currently and preferably, the value of STEM now and preferably lies in its ability to lead to high-quality education and improve the STEM literate workforce.

As shown in Table 16, the qualitative findings also revealed that the leaders and teachers demonstrated a good understanding of STEM education value. [T2] reported that "STEM equips the students with 21st Century skills and critical thinking, Creativity, Collaboration, Communication. Likewise, the principals and unit heads had similar sentiments; they believe STEM equips students with 21^{st-}century critical thinking and problem-solving [P1, P2, P3,]. The interview results showed that [UH1] believed that STEM education prepares students for the future by "enhancing their competencies when they move to the marketplace as professionals with high critical thinking and outstanding thinking patterns". [UH2] cites that STEM helps "growth, mindset, connection to real-life, and prepare them for the future". Likewise, El-Deghaidy and Mansour's (2015) study findings proposed that teachers perceived that STEM education could inspire students to take future careers in STEM.

Similarly, El-Deghaidy et al. (2017) reported that teachers' views revealed they have a positive insight into the significance of STEM in increasing students' interest in STEM education and future STEM careers. In the same vein Elayyan and Al-Shizawi (2019) showed that science teachers have a high degree of perception that STEM prepares the student with the requirements skills of the 21st century. According to Al Basha (2018), study outcomes revealed that teachers in UAE had informed perceptions of STEM education and a good understanding of STEM's definition and its potential impacts on students and the community. In line with the above result, Kubat (2018) study findings indicated science teachers have a positive perception of STEM education and how it contributes to the production of qualified individuals in science, mathematics, and engineering fields. Consistently, Holmlund et al. (2018), in their study, found that STEM programs in the USA have three primary and inclusive goals for STEM education: (a) increase the number of STEM innovators and professionals, (b) strengthen the STEM-related workforce, and (c) improve STEM literacy in all citizens.

5.5.1.3Discussion of the Participant's Perceptions of STEM implementation Values

A. Purpose

The study findings showed that the participants had informed actual and preferred perceptions about the purposes of STEM education in UAE, as shown in Table 17. They perceived that STEM purposes are to enhance student's ability to solve problems; to enhance student's ability to think critically; to enhance student's ability to innovate; to enhance student's ability to be technology literate; to enhance student's academic achievement; to enhance students learning through the connection between subjects within an authentic context; to enhance decision-making skills; to enhance long life skills.

According to the qualitative strand, school leaders and teachers believed that the rationale behind STEM is to improve the students' intellectual skills by enhancing their critical thinking, problem-solving, and Creativity, thus verifying the above quantitative results. El-Deghaidy et al. (2017) findings were consistent with the current study findings as teachers perceived that STEM education could help in enhancing students thinking skills, collaboration, problem-solving, and research skills. According to Park et al., (2016), teachers believe that STEM education can positively impact students' learning outcomes. In general, teachers consider STEM implementation can result in better learning outcomes (Margot & Kettler, 2019). Similarly, Kubat (2018) indicated that science teachers perceive that STEM equips students with problem-solving, creativity, research-questioning, critical thinking, entrepreneurship, and communication skills.

5.5.1.4 Discussion of the Participant's Perceptions of STEM implementation Values

The quantitative and qualitative results indicated that the participant perceived STEM implementation needs to be incorporated using a clear institutional STEM mission and vision and a STEM implementation framework and guidelines. Moreover, they believed that STEM could be implemented during extracurricular activities and during afterschool activities.

The participants also believed that STEM implementation must employ a STEM curriculum and STEM-related standards. The findings also indicated that the participants believed that STEM instruction must emphasize student's centered approaches, such as problem-based, inquiry-based learning, and project-based learning. The use of STEM-oriented assessment tools, and time allocation, were also perceived as crucial in STEM implementation. Those findings indicated by the participants were also discussed in previous studies (Averill, 2018; Al Basha, 2018; Brown et al., 2011; Belbase et al., 2021; Davis, 2015; Elayyan & Al-Shizawi, 2019; Wang et al., 2011).

The principals and unit heads appeared to have different perceptions where some indicated the use of institutional vision that promote STEM teaching. However, some leaders clearly stated the absence of a school vision or even a guiding implementation framework. The interviews revealed that school leaders [P1] and [P3] were aware of STEM. This can be seen in the high level of perceptions reported in Table 18. Similarly, the school leader [P1] claimed that “we have a vision that promotes the twenty-first-century skills such as creativity, problem-solving and critical thinking skills”. However, the school leader [P2] clearly stated, “no clear vision and no clear guiding framework”. As [UH2] confirmed the lack of visionary planning when he mentioned, “We had to come up with planning, but we had a guideline to do it”. The teachers agree that more planning is needed to help teachers with their STEM teaching. In line with the study findings, Davis (2015) study results reported that STEM educators held strong perceptions about the need for a detailed framework and guidance plan to foster STEM implementing STEM. Similarly, Averill (2018) indicated that school administrators believed its essential to have a school-wide vision and effective leadership in promoting STEM implementation within schools.

Table 18 shows that the participants held positive views about the current STEM implementation practices, and they believed STEM-oriented curriculum and STEM-related Standards are used for STEM implementation. However, the qualitative finding was generally contradictory as the participants' perceptions indicated the lack of STEM curriculum or even standards and how they prefer to have a STEM-based curriculum. As confirmed by [T3], who mentioned that there is “no STEM-oriented curriculum” and that they “incorporate using the science learning objectives”. In line with the result, [T4] explained that the department coordinator provided the STEM outcomes—similarly, Elayyan and Al-Shizawi (2019) study findings point out that teachers believe that effective STEM integration requires using STEM-related curricula and standards such as engineering design steps and educational technology.

Furthermore, the participants perceived that STEM integration requires specific teaching methods and practices. They all agreed that Inquiry-based learning, problem-based, project-based, and student-centered approaches within a realistic context could facilitate STEM teaching, in line with Brown et al. (2011), who claimed that teachers believed that STEM teaching and learning could be implemented through authentic teaching content, problems, and using hands-on activities. Al Basha (2018) study findings were also aligned with the current study findings as they found that teachers perceived that STEM implementation should rely on real-world applications. The findings are similar to the study outcomes of Wang et al. (2011), who reported that teachers believe that STEM implementation starts with real-world problems. STEM implementation elements perceived by the participant are consistent with the finding of Belbase et al. (2021), who indicated that STEM is a teaching approach to teaching and learning math, science, engineering, and technology-based through employing instruction that engages students in authentic learning, experiential learning. Belbase et al. (2021) also indicated that the interdisciplinary approach is based on engaging activities that involve doing things, project-based learning related to the real world, and inquiry learning that entails problem identification and solutions findings.

The participants also viewed STEM integration as a method that can be implemented via extracurricular activities. The interview outcome validated that [T2], who claimed "participating in extracurricular activities in which students share their products and projects," is an effective teaching method. This finding aligns with Park et al. (2017) study results that revealed that teachers perceive that STEM education can be implemented through extracurricular activities. Averill (2018) study results are consistent with importance of implementing STEM by involving students in extracurricular STEM activities.

Time allocation and the use of STEM specialized labs, and resources are actually and preferably perceived as components required for STEM implementation. El-Deghaidy et al., (2017); Averill (2018), and Margot and Kettler (2019) considered the availability of resources and time allocation for planning and teaching are essential in STEM implementation. The interview outcomes reported that principals, unit heads, and teachers consider the shortage of time a challenging factor that hinders STEM teaching.

As claimed by [UH1] and [T3], "STEM teaching is time-consuming, especially if the teacher needs to be trained, teach, and spread STEM within the students and the teachers". The participants believed that STEM implementation demands equipping the schools with a STEM lab and assures the availability of resources. As stated by [P3], "Printing of materials, community support, resources based on kid's needs and likes, proper lab materials for science subjects". The participants' perceptions matched the finding of Thibaut et al. (2018), who indicated that to facilitate the STEM integration process, there is a need for restructuring of interdisciplinary curriculum and lessons; materials, and resources for to facilitate STEM implementation; creating a supportive school culture that promotes STEM implementation.

5.5.2 Question 2: Is There any Statistically Significant Differences Between the School Administrator [Principals, Unit Heads] and Teachers in Their Perceptions Regarding the Actual and Preferred STEM Implementation Practices?

The overall quantitative and the qualitative results revealed that the unit heads held higher perceptions regarding preferred practices of STEM education in favor of the teachers and the administrators. The result was explained during the interview as the MOE trained the unit heads, and they were the channel of communication between the MOE and their schools. Moreover, the finding indicated that teachers have higher perceptions about the preferred STEM practices than those held by the administrators. The interviews revealed that the novelty of STEM and the lack of guidelines for STEM integration could be correlated to the low perceptions held by the school principals. While The teachers' perceptions are based on their direct involvement in STEM integration in their classroom, which results in a better understanding. The study findings were also identified in previous studies (Averill, 2018; Al Basha, 2018; Brown et al., 2011; Davis, 2015; El-Deghaidy & Mansour, 2015; El-Deghaidy et al., 2017; Margot & Kettler, 2019; Munje et al., 2020; Al Murshidi, 2019; Natarajan et al., 2021; Owens, 2014; Park et al., 2016; Patel, 2020; Sandall, 2016).

The question aimed to understand the differences between actual and perceived levels of STEM implementation between the three groups: principals, unit heads, and teachers. A one-way ANOVA test in Table 19 suggested that the unit heads held higher perceptions than the principals and the teachers. This was explained during the interviews by the school leaders and teachers. As it was reported that unit heads attended the ministry training, and they were the first communication channel between the district and the schools' leaders and teachers. The teachers and leaders indicated that the unit heads were coordinating the STEM integration process through conducting the required professional development for the teachers, creating the STEM learning plans, following up the implementation process in the classroom, and managing the collaboration with other STEM schools. According to [T1] and [UH1], the academic unit heads and some teachers attended the ministry training about STEM, and then they trained the schoolteachers. Therefore, their good understanding and level of knowledge about STEM integration are possible explanations for their informed perceptions. This finding is aligned with Natarajan et al. (2021), who described that knowledge and awareness could help shape people's perceptions. The interviews also revealed that school principals selected the unit heads and some teachers to participate in the MOE STEM training. The interviewee [P2] explained that the chosen principals, unit heads and one teacher from each department based on their qualifications and enthusiasm. Natarajan et al. (2021) supported this finding by claiming that school principals authorize the head of departments to implement STEM in most schools to lead STEM initiatives. This Result is similar to those of Munje et al. (2020), who claimed that heads of departments are considered specialists in the subject areas in which they play leadership roles and are expected to direct and monitor instruction, which includes providing relevant support and guidance to teachers. This Result is also supported by Patel (2020), who described that successful administrators hire and develop highly professionalized teachers who share a commitment to strong STEM content teaching and the school's mission. It was correlated that unit heads are more likely to come with a higher educational background, which was linked to experience, level of education, and better perception of the implementation of STEM education. This possibly could explain highly informed perceptions about STEM integration. The teachers were found to have a lower perception of STEM education than unit heads, perhaps as they didn't attend the MOE training and were indirectly trained by the school representatives who attended the MOE training. Therefore, this could lead to some gaps in delivering STEM conceptualization as perceived by the newly trained school representative members. Another explanation is that due to the pandemic, all STEM training was discontinued. All the time and effort were focused on preparing the teachers for implementing the virtual learning process that was relatively new and required a lot of training. The interviews revealed that the pandemic affected the training for STEM integration. According to [T2], during the pandemic, all the teachers shifted to online teaching, and STEM integration training was disconnected. Thus, another possible gap is discounted stem training and implementation, which limited opportunities to experience STEM integration in their classrooms. Averill (2018) study finding similarity revealed that teachers need more training opportunities to know more about STEM and be ready to STEM implementation.

The qualitative result also supported the teachers' need for more training to enact STEM inside their classroom; as stated by [T1] states, "knowledge is there, but we still need more training for the future". This Result was supported by Al Basha (2018), who reported how the teachers perceived concerns about the need for continuous professional development in STEM education. Inconsistent with this result Al Murshidi (2019) study findings recommended the need to escalate teachers' development efforts at both personal and professional development handle STEM implementation.

The lack of an established STEM curriculum made it difficult for the teachers to integrate STEM into their classes as they had to make their STEM topics. Moreover, the teaching loads and schedules and their administrative duties are other contributing factors as they didn't have adequate time to improve their perceptions. Most of the teachers believe in their experience that there is a severe misalignment with the current curriculum. [T3] mentioned that there is "no STEM-oriented curriculum", and [T3], who is a math teacher, mentions that the "existing curriculum is extensive, and he focuses great importance on math itself". This Result was also confirmed by the school leader who, as [P1] says, "time was a challenge for teaching as STEM is a time-consuming approach", and [UH2] elaborates, "the most critical thing is time" …. Good teachers feel guilty because they couldn't finish the curriculum, or they didn't meet the outcome…, and sometimes the shift is totally towards STEM.

Further, [P2] stated that the additional duties "overwhelm the teacher who already has major teaching loads". Park et al, (2016) study findings indicated that they are likely to consider the focus on the school curriculum as a legitimate reason not to implement STEM as it's not part of the school curriculum. This finding is in line with El-Deghaidy et al. (2017) findings that revealed how teachers perceived lack of time and lack of curricula focus on STEM activities as factors that directly impacted their experiences with STEM. Correspondingly, Owens (2014) study outcomes asserted that time restraints, inadequate preparation, and a misunderstanding of expectations associated with STEM could affect STEM conceptualization.

Science teachers found STEM teaching relative to their teaching subject is based on inquiry-based and experiential learning. In contrast, the teachers of other subjects consider STEM application challenging and require more preparation and changes in their teaching style. This Result was validated by [P3], who mentioned that teachers from other disciplines would face issues in teaching STEM compared to science teachers who are much more familiar with STEM. Thus, teachers are not at the same level of knowledge about STEM implementation, impacting their perceptions about STEM implementation. In contradiction to the current study findings, El-Deghaidy and Mansour (2015) research findings indicate that teachers don't possess the pedagogical knowledge required for STEM education. However, Davis (2015) results revealed that not all teachers are ready to teach STEM, and they don't have enough knowledge about it. Their understanding of STEM can impact how they perceive STEM implementation. This result was supported by Mousa (2016) study findings which reported that teachers don't have an adequate level of STEM disciplines knowledge which impacted their conceptualization of STEM implementation. Al Basha (2018) also indicated that not all the teachers received STEM training which affected their perceptions. Furthermore, El-Deghaidy and Mansour (2015) described that the inadequate preparation of teachers could be a possible reason for their interdisciplinary teaching and learning across STEM subjects.

The novelty of STEM and the lack of guidelines for STEM integration could be correlated to the low perceptions held by the school principals. The school leader viewed STEM integration as a novel initiative in their school, as claimed by [P1] "At the beginning integration was difficult because it's a new as method and as a concept as well". This finding is consistent with Al Murshidi (2019), who described that STEM integration in UAE is novel and still in its early stages. The result is confirmed as "the nature of STEM education and its "newness" as a combined field; if you ask STEM practitioners, you will likely get a wide range of key components of an integrated STEM definition and factors that influence the implementation of an integrated STEM curriculum" (Sandall, 2016, p. 30).

A one-way ANOVA test in Table 19 suggested that the teachers held more informed perceptions regarding actual STEM implementation practices than the principals and unit heads. However, the qualitative result indicated that the principals had informed perceptions of the managerial aspects of STEM implementation. While the teachers had strong perceptions regarding the STEM implementation aspects inside the classroom. As mentioned by [P1], who reported that "we have a vision that promotes the twenty-first-century skills such as creativity, problem-solving and critical thinking skills". However, [P2] and [UH2] claimed did not have the same opinions. [P2] clearly stated there was "no clear vision and no clear guiding framework", whereas [UH2] referred to the online brochure but was not sure of it when asked. The result is consistent with Davis (2015), who reported that administrators' views depicted that they are not ready to address STEM education programs. Brown et al. (2011) reported the administrators perceived the unavailability of evidence of STEM education vision to facilitate managing STEM implementation. Another possible justification is that administrators are not directly involved in STEM implementation. They perform their administration part by empowering unit heads and teachers in the direct STEM implementation. While The teachers' perceptions are based on their direct involvement in STEM integration in their classroom, which results in a better understanding. Hence, their perceptions highlighted different areas related to STEM current practices, such as the need to raise awareness about STEM, missing STEM-oriented curricula, the gap between the STEM teaching nature, and the use of irrelevant traditional assessments. In line with the result, Margot and Kettler (2019) study findings suggested that teachers perceive a lack of quality assessment tools, and the impact can influence STEM implementation. Similarly, Park et al. (2016) study findings suggest a need to reform the curriculum and the assessment system that promotes STEM education.

Furthermore, the result revealed no statistically significant difference between the leaders' and the teachers' preferred practices. The lack of significant difference in the preferred perceptions among the school leaders and teachers can be comprehended by the common impression of the novelty of STEM integration and the lack of clear guidelines and curriculum for its application, as described by Al Murshidi (2019), who described that STEM integration in UAE is a novel and still in its early stages. Moreover, it reflects that they are willing to improve their STEM implementation practices. The result is aligned with the findings of Al Quraan (2017), who described STEM implementation in the UAE as still in the early stage in UAE.

Results are similar to Brown et al. (2011), who reported that the administrators believed that there are no clear guiding visions to facilitate managing STEM implementation. Al Murshidi (2019) recommended intensifying efforts on personal and professional development for teachers of STEM to enhance STEM implementation and increase student interest in STEM. From the qualitative findings, it was revealed that the teachers prefer using a detailed STEM framework that will facilitate their STEM implementation. Moreover, they prefer to use STEM-based assessment tools rather than traditional assessment modes.

While school leaders have only spoken about how the MOE provided STEM guidelines and samples for teacher development in STEM education, there seems to be a gap in awareness of the STEM guidelines as teachers voiced the lack of clear guidelines for implementation, in contrast to the leaders who spoke about the presence of the framework handed to them by MOE, which they use for planning. This is indicated in the literature, wherein leadership is essential in providing teachers with the necessary guidance and vision to implement STEM effectively. Owens (2014) recommended the need for skilled STEM leadership that can drive curriculum development and teacher preparation that supports STEM programs. Leaders must involve various stakeholders to develop and carry out a common vision and mission. While these requirements are true for all K-12 administrators, there is evidence that visionary leadership is particularly important for those in STEM-focused schools (Davis, 2015). Scott (2012) found STEM schools' missions must be aligned with STEM implementation goals. Scott also reported that STEM-focused schools require visionary principals who are committed to positively affecting the lives of their students.

5.5.3 Question 3: Is there any Statistically Significant Difference Between the Perceptions of the School Leaders [Principals, Unit heads] and Teachers in Regard to the Actual and Preferred STEM Implementation Practices?

The findings of the study revealed that the principal, unit head, and teachers have promising preferred practices compared to their actual practices in regard to STEM meaning, value, purpose, and implementation practices. These can be considered expected findings due to their rich environment, which is based on the national calls for the importance of STEM in education and the steps taken to prepare the teachers for STEM implementation as the participant's responses. In particular, this can explain their good understanding of how to have an effective STEM implementation. The study findings in Table 23 revealed a significant difference in the category of school leaders. The overall result showed that they held a higher perception regarding their preferred SEM teaching practices related to STEM definition, value, and purpose, as reported in Table 27. The qualitative findings also suggested that the principals strongly perceived the preferred STEM teaching practice. The school principals preferred to have a unified STEM implementation conceptualization as they perceived that STEM is a new method, and there were no clear guiding plans to implement it. As reported by [P1], who claimed, "At the beginning, integration was difficult because it's a new method and concept. The result aligns with the findings of Alumbaugh (2015) study, which indicated that school leaders held positive perceptions about STEM implementation; however, they acknowledge the ambiguity around the meaning of STEM and successful implementation procedures, the school principals and unit heads also explained they had to come up with their plans and to collaborate with the other STEM schools to validate their implementation process. This was also indicated clearly by [P2] "no clear vision and no clear guiding framework". The interview pointed out that the school principals preferred practices about better managerial issues that may positively impact STEM implementation. As claimed by the school principals that planning and having a solid implementation plan is essential [P1, P3] as well as [UH2] for STEM implementation. They also stressed the provision of the MOE guidelines to help the schools plan and create their procedural plans for STEM implementation. As [UH4] mentions, “We had to come up with planning, but we had a guideline to do it”. The result is in line with the findings of Davis (2015), who asserted the unavailability of a clear vision for STEM education, even by individuals who deem it to be necessary.

Additionally, school principals and unit heads also believed that among the administrational steps, spreading awareness about STEM among all related stakeholders is critical. Owens (2014) study outcomes asserted inadequate preparation and a misunderstanding of expectations associated with STEM are the challenges and obstacles that impede the essential STEM implication. The result is also supported by Averill (2018), who described the success of any educational initiative as dependent on the quality and support of those in leadership roles (Rogers, 2007; Scott, 2012). Similarly, Sanders (2009) and Scott (2012) believed that practical managerial steps taken by educational leaders play an essential role in implementing STEM by focusing on program implementation and maintenance. The school principals also preferred to raise awareness about STEM and involve all the stakeholders as it promotes and fosters STEM implementation. The STEM school culture requires collaboration among stakeholders and building a collaborative and supportive STEM community in school; as [P1] mentioned, we need to “spread the awareness about STEM and the value behind it between our students and teachers as well”. Moreover, [UH2] elaborated that raising awareness to highlight the importance of STEM to the parents is crucial as “Parents are wanting their kids to study and do a traditional way and they think it's a waste of time”. Similarly, El-Deghaidy and Mansour (2015) reported that more collaboration among stakeholders is required within the school culture to support STEM implementation.

The school principals preferred perceptions indicated that their teachers are not yet ready to implement STEM, and the teacher requires more professional development opportunities. According to [P2] and [P3] believe, the teachers are not prepared to implement STEM; this may be due to the novelty of STEM education in the region. Consistently, Wang et al. (2011) study findings revealed that professional development is needed if STEM implementation is sustainable. In the same vein, Owens (2014) study findings indicated that teachers are not ready and require more professional development to prepare them for STEM teaching.

The school leaders preferred more time allocation to facilitate STEM teaching and provide more space for collaboration with other subject teachers. As [P1] says, “time was a challenge for teaching as STEM is a time-consuming approach”. Therefore, the school leaders stressed the need for a STEM-oriented curriculum and all the resources required for STEM projects.”. Park et al. (2016) study findings also indicated that teachers consider time as an essential factor in STEM implementations as they must carry out their lesson and their administrative duties. Likewise, El-Deghaidy et al. (2017) discussed that the allocation for more planning periods is essential for better STEM experiences.

The school principals’ perceptions revealed that they favor using STEM-based curricula to enhance STEM teaching. As [P1] indicated, integrative practices to teach STEM would be the most valuable resource for STEM implementation. Additionally, [P3] also believes in the need for lab materials and resources to implement such projects. A similar result shared by Thibaut et al. (2018) indicated that to facilitate the STEM integration process, there is a need to restructure the interdisciplinary curriculum and lessons, numerous materials, and resources for students, such as construction tools.

Furthermore, the category of the teachers’ findings showed statistically significant differences between the teachers’ perceptions regarding actual and preferred practices in favor of the preferred practices, as shown in Table 23. Teachers’ perceptions indicated that they preferred to define STEM as a multidisciplinary teaching approach through integration with the other STEM subjects. Their definition matches the definition of Wang et al. (2011), who described a multidisciplinary as one subject approach where concepts and skills are independently learned in each discipline, and students must connect the content taught in the other disciplines on their own. Moreover, their perception indicated that they value STEM as it positively impacts students’ intellectual skills and enhances their critical thinking, problem-solving, and creativity, as indicated by [T1, T2, T3, T4]. Correspondingly, Belbase et al. (2021) study findings suggested that the STEM approach has several advantages, such as: equipping students with essential skills, including problem-solving, creativity, critical analysis, teamwork, independent thinking, taking the initiative, communication, and digital literacy. Also, Falloon (2019) believed that integrated STEM education could be considered a platform for developing important personal and professional competencies, including research inquiry, problem-solving, critical and creative thinking, entrepreneurship, collaboration, teamwork, and communication. Likewise, El-Deghaidy et al. (2017) revealed that teachers believed that STEM education could promote 21st-century skills involving thinking skills, collaboration, problem-solving, and research skills that could be useful for selecting careers in science.

The teachers held positive perceptions that acknowledge teaching methods that foster STEM teaching, such as inquiry-based learning, problem-based, and experiential. They also emphasized the use of extracurriculars for more STEM experiences. Additionally, [T3] added that “participating in extracurricular activities in which students share their products and projects” is an effective teaching method. The result is in line with the findings of Falloon (2019), who illustrated that perspectives on STEM pedagogy favored student-centered approaches, possibly reflecting the predominance of studies that advocated project-based, multi or interdisciplinary designs.

Furthermore, teachers’ perceptions asserted that they prefer to use established detailed frameworks and guiding plans, as stated by [T4], to use the precise framework and guidance plan that will help the school implement STEM. The finding also revealed that teachers prefer to use a STEM-oriented curriculum as it will facilitate STEM teaching and make it easier to handle. The findings are similar to El-Deghaidy et al. (2017) study findings that showed how teachers perceived the need for more administration to implement STEM in their classroom.

Moreover, the teacher believes that a severe misalignment with the current curriculum influences STEM teaching. [T3] mentioned that there is “no STEM-oriented curriculum” and that they “incorporate using the science learning objectives”. Although [T4] further adds that the department coordinator provides the STEM outcomes. Wang et al. (2011) and Thibaut et al. (2018) agreed with the teachers’ perceptions and reported that STEM implementation in the classroom relies on the availability of an integrative curriculum. Additionally, Thibaut et al. (2018) also indicated that to facilitate the STEM integration process, there is a need to restructure the interdisciplinary curriculum and lessons. Teachers and unit heads also showed that they favor having more time allocation as they consider STEM implementation is “time-consuming,” as a report by [UH1], [T3].

Moreover, [T3], a math teacher, mentions that the “existing curriculum is extensive and focuses great importance on math itself”. Similarly, [UH1] and [T2] believe that time is a challenge as STEM teaching is “time-consuming especially if the teacher needs to be trained and teach and spread STEM within the students and the teachers”. Margot and Kettler (2019) suggested that teachers perceive that a lack of planning time is crucial for STEM implementation.

Another justification for the participant's optimistic vision of STEM is STEM education's global attention (Holmlund et al., 2018). Moreover, as claimed by Stanley (2017), who described STEM as a significant component of human culture; all humans need a level of STEM literacy to cope with the engineering world we live in, make informed decisions, or be informed consumers of science, technology, engineering, and mathematics. Alumbaugh (2015) studied administrators’ and teachers’ perceptions of STEM schools; his findings indicated that leaders in professional STEM organizations have positive perceptions regarding STEM education. Principles' answers reflected their belief in STEM education to increase students' engagement and academic achievement. In line with the results, various research studies pointed out the positive impact of STEM integration on student outcomes (Boe et al., 2011; Bybee, 2013; Choi & Hong, 2013; Honey et al., 2014; Roberts, 2012; Morrison, 2006; Stohlmann et al., 2012; Yildrim & Selvi, 2017). Similarly, the other studies discussed the favorable impact of the interdisciplinary approach to teaching STEM disciplines and how it enables students to explain many situations in everyday life and solve problems critically (Bybee, 2010; Roberts, 2012).

Likewise, Stohlmann et al., (2012) and Thibaut et al. (2018) indicated that using a STEM teaching approach provides opportunities for more relevant, less fragmented, and more stimulating experiences for learners. The results also aligned with Stohlmann et al. (2012) who indicated the positive impact of STEM implementation practices on students' attitude and interest in school, improved motivation to learn, and increased achievement (Stohlmann et al., 2012). Honey et al. (2014) similarly asserted that STEM education positively impacts the student's achievement. In line with the above views, Kang (2019), in his study, also indicated that STEM has a positive effect on student learning where students are effective in both cognitive and affective learning.

5.5.4 Question 4: Is There any Statistically Significant Difference in the STEM Teachers' Perceptions about their Actual Current and Preferred Competence Levels in STEM Implementation?

The overall result indicated that the teachers held positive perceptions of their preferred competence level compared to their current status. Their views reflected the need for more professional development to prepare them to teach STEM in their classes. They believed that they needed more instructional knowledge about STEM disciplines, more understanding of engineering concepts, and how to integrate technology. They also indicated that they need more preparation to use student-centered teaching methods within an authentic context, especially for those who are not science teachers. Finally, teachers perceived that they needed more training and preparation for STEM teaching and collaboration with other STEM disciplines.

Those findings were identified in previous studies (Berlin & White, 2012; Brown, et al., 2012; Epstein & Miller, 2011; Honey et al., 2014; Makhmasi et al., 2012; Mousa, 2016; Al Murshidi, 2019; Margot & Kettler, 2019; Moore et al., 2014; Pinnell et al., 2013; Sanders, 2009; Shaer et al., 2019; Wang et al., 2011).

Table 26 suggested a statistically significant difference between the actual competence level and the preferred competence level of teachers during STEM implementation. This can be due to their openness and motivation to be prepared to handle their role as STEM-qualified teachers. Teachers hold positive preferred insights like having the required subject matter to teach STEM, acquiring skills to handle STEM teaching, having instructional knowledge to enact STEM inside the classroom, receiving the needed professional development to be ready to teach STEM, and being prepared to work collaboratively with the other subjects' teachers. The qualitative results suggest that teachers state they require more training; [T1] states, “knowledge is there, but we still need more training for the future” and that “teachers that they are still behind using technology”.

Working collaboratively is affirmed as most teachers and unit head state they prefer to work collaboratively with other discipline teachers to prepare a STEM lesson; however, the needed subject matter is a challenge highlighted by both qualitative and quantitative strands as many teachers’ state that non-science teachers will face difficulty as compared to their science teachers’ peers, stating “other discipline teachers will face difficulties in applying STEM. Moreover, [UH1] mentions, “As a teacher, I must prepare the lesson to integrate STEM objective…I can also work collaboratively with other discipline teachers to prepare a STEM lesson”.

Similarly, Margot and Kettler (2019) described that authentic STEM education entails the availability of qualified teachers who have confidence in the student-centered pedagogy. Honey et al. (2014) also reported that the actual skills needed for STEM education depend on the expertise of teachers and their strong content knowledge of various STEM subjects being taught. This challenge seems to be the case worldwide; traditional models of teaching and teacher development have been slow to change to fit the needs of teachers in STEM classrooms (Epstein & Miller, 2011). In addition, Epstein and Miller (2011) also reported that those models are deficient in producing teachers ready for the rigorous challenges of STEM learning environments, especially at elementary levels. The NCLB legislation indicated the shortage of highly qualified science and math teachers. It has still been challenging to find elementary teachers capable of teaching science, math, engineering, and technology with integrity (Sanders, 2009).

Moreover, many K-12 teachers do not have a strong enough understanding of engineering concepts and their applications that enable them to enact STEM effectively and encourage them to engage in STEM careers (Davis, 2015). The qualitative findings indicated that STEM teachers prefer to have more specialized knowledge on implementing STEM. The results are like Berlin and White (2012), who suggested STEM teacher education programs need to include: (a) more exposure to concepts, processes, and skills in STEM that are similar, analogous, complementary, or synergistic; (b) familiarity with instructional strategies and access to resources; (c) a deeper understanding of content across STEM; and (d) strategies for collaboration and teamwork to make integrated instruction time. Therefore, more structured and STEM-aligned professional development is required to equip the teachers with the required STEM teaching and STEM pedagogical competencies to handle STEM teaching. However, previous studies showed a lack of specialized training in the teaching methods and tools of STEM education has continued to hamper their deliverables (Al Murshidi, 2019).

Moreover, teachers prefer to have the required pedagogical considerations that guide effective STEM implementation using integrative teaching content, implying a student-centered teaching approach and incorporation of engineering design (Moore et al., 2014). Concurrently, Wang et al. (2011) study findings revealed that professional development is needed if STEM integration is sustainable. Margot and Kettler (2019) Supported the current study finding. They indicated that teachers believed that several factors impede STEM implementation, and they are: inadequate assessment tools, planning time, and lack of STEM teaching content. Mousa (2016) study findings showed that participants perceived that teachers' understanding, training, enthusiasm, and school settings were considered substantial obstacles that challenged the implementation of integrated STEM education.

5.5.5 Question 5: What are the Factors that May Impede the Successful STEM Implementation in UAE Schools?

The quantitative and qualitative strands both indicated that participants believed that several factors might hinder the STEM implementation process. Specifically, they showed a lack of clear institutional mission and vision that promotes STEM education, supportive school culture, time and heavy teaching loads, lack of STEM pedagogical knowledge, lack of STEM-oriented curriculum, and lack of resources.

Those factors were also addressed in previous studies (Austin, 2019; Averill 2018; Al Basha, 2018; Brown et al., 2012; El-Deghaidy et al., 2017; Kubat, 2018; Makhmasi et al., 2012; Margot & Kettler 2019; Mousa, 2016; Al Murshidi, 2019;

Owens, 2014; Park et al., 2016; Pinnell et al., 2013; Al Quraan, 2017; Rogers, 2007; Scott, 2012; Thibaut et al., 2018; Wang et al., 2011).

As shown in Table 32, 65.9% of the participants believed that lack of time and heavy teaching loads impeding factors that challenge STEM implementation. The qualitative outcomes also supported the result as time is a factor that has been repeatedly mentioned by the interviewees as a challenging factor that impacts STEM implementation. The teachers and school leaders cite that the main challenge with STEM implementation is "time-consuming". [T3] mentions that the "existing curriculum is extensive and focuses great importance on math itself". [T2] believe that time is a challenge mainly due to the training aspect; it is "time-consuming especially if the teacher needs to be trained and teach and spread STEM within the students and the teachers". School leaders also believe that time was a significant challenge in implementing STEM. As [P1] says, "time was a challenge for teaching as STEM is a time-consuming approach", and [UH2] elaborates, "the most critical thing is time". [UH1] also affirms that time is a challenge in terms of the training that needs to be provided, much like [T3].

Furthermore, [P2] states that the additional duties "overwhelm the teacher who already has major teaching loads". [P3] and [P2] believe that the lack of teacher training for all teachers is one of the biggest challenges for implementing STEM. These findings are in line with the results of Al Murshidi (2019), which indicated that a shortage of time is a challenge for the teachers as they have an enormous workload to handle. They must spend time preparing for classes and draft lesson plans, grade tests and other assessment exercises, and carry out other administrative duties. Likewise, Owens (2014) asserted that time restraints, inadequate preparation, and a misunderstanding of expectations associated with STEM are the challenges and obstacles that impede the successful STEM implication. Al Basha (2018) similarly reported several factors that challenge STEM implementation and the lack of time, resources, and collaboration between STEM disciplines. Other studies also supported the result as they asserted that K-12 teachers do not have a strong enough understanding of STEM implementation practices (Brown et al., 2012; Pinnell et al., 2013). Al Basha (2018) shared the same results, as they found a lack of resources and a shortage of time for collaboration and instructional design.

Moreover, 62.2% of the participants believed that the Lack of STEM school culture that emphasizes beliefs, norms, and support needed to enact STEM is a contextual factor that can hinder STEM implementation. The result is similar to the Al Quraan (2017) study result that indicated that school culture supporting STEM learning is an essential factor in promoting STEM implementation. Similarly, El-Deghaidy et al. (2017) shared that school culture plays a crucial role in implementing STEM education in schools, as it facilitates the success of STEM implementation.

As shown in Table 32, 66% of the participants considered a lack of confidence in handling hand-on activities as an impending factor under the teacher's preparation and pedagogical factors. The result also aligns with the findings of Margot and Kettler (2019), who asserted the need for skilled STEM teachers to handle authentic experiences using student-centered pedagogy. Teachers' readiness and STEM subject matter knowledge are essential factors that may negatively influence STEM implementation if it has to lack (Brown et al., 2012; Pinnell et al., 2013). Similarly, Kubat (2018), in his study, also reported teacher barriers that prevent the successful implementation of STEM integration in science classrooms, including class size, broad curriculum: and teachers' lack of the needed knowledge to teach using the STEM approach consistent with this study result.

Moreover, the results indicated the importance of proper guidance and leadership. Table 32 revealed that more than 50% perceived that the lack of a clear institutional mission and vision that promotes STEM education impedes STEM implementation. The result was confirmed by the qualitative result as indicated by the school principals, and unit heads s; planning and having a solid implementation plan is essential [P1, P3. UH2]. Teachers also confirmed the need for guiding plans [T4], who mentioned the need for a detailed framework and guidance plan that will help the school implement STEM. The result aligns with the findings of Park et al. (2016), who reported the lack of administrative support is one of the challenges of STEM implementation.

Similarly, Averill (2018), Rogers (2007), and Scott (2012) study results also indicated that the success of STEM initiatives is dependent on the quality and support of those in leadership roles. Furthermore, Scott (2012) also reported that STEM-focused schools require confident, visionary principals committed to positively affecting the lives of their students. Wang et al. (2011) shared a similar result regarding the factors that challenged STEM implementation education and indicated that few general guidelines or models exist for teachers to follow regarding implementing STEM in their classes. The result indicated that more than 50% of the participants, as shown in Table 32, considered the lack of STEM-oriented curricula to hinder the STEM implementation process. The qualitative result also confirmed the result as claimed by (T3), who confirmed that there is “no STEM-oriented curriculum”.

El-Deghaidy et al. (2017) also supported this result by indicating that the lack of a STEM curriculum is a factor that can negatively influence teachers’ enthusiasm for STEM Teaching. The result is also consistent with Austin (2019), who indicated that STEM implementation is challenged by a lack of STEM-focused standards, ready-to-teach teachers, and student materials. The results presented in Table 32 can be related to external and internal factors similar to those found by El-Deghaidy et al. (2017) that directly affected teachers’ STEM practices and performances. Results of Park et al. (2017) and Floreal (2019) research on teachers’ readiness to teach STEM asserted seven challenges associated with STEM implementation: 1) time allocation to teach STEM; 2) unavailability of resources; 3) training inadequate; 4) Poor administrative support; 5) inadequate STEM disciplines knowledge, particularly engineering; 6) lack of parental participation; and 7) reluctance of teachers to collaborate.

Factors 1-6, indicated by Park et al. (2017), are like the factors shared by the participants in this study. In particular, lack of time, lack of STEM-focused curriculum or standards, lack of solid administration support, lack of STEM subject matter, and the need for more professional training.

As mentioned by Mousa (2016), the results of this study showed similar views related to STEM knowledge, STEM preparation and training, and teachers’ enthusiasm, which were the biggest challenges that confronted the implementation of integrated

STEM education. The results are aligned with the results of Makhmasi et al. (2012), who indicated obstacles to STEM implementation and the need to address them by improving the curricula, lack of resources, and providing professional guidance via development courses and seminars is necessary if teachers are to be more effective in the classroom.

5.5.6 Question 6: What are the Factors that May Impede the Successful STEM Implementation in UAE Schools?

The overall findings of the quantitative and the qualitative phase revealed the existence of specific factors that can facilitate and promote the STEM implementation process. The results were also addressed in previous studies (Averill, 2018; Al Basha, 2018; Brown et al., 2012; Davis, 2015; El-Deghaidy & Mansour, 2015; Fong, 2019; Kubat, 2018; Makhmasi et al., 2012; Margot & Kettler, 2019; Moore et al., 2014; Al Murshidi, 2019; Natarajan et al., 2021; Park et al., 2016; Pinnell et al., 2013; Al Quraan, 2017; Scott, 2012; Thibaut et al., 2018; Wang et al., 2011)

5.5.6.1 Government Support, Involvement, and Resources

The interviews reported that the participants held informed perceptions about the role of effective leadership and the government drives that push STEM implementation. [P1] and [P2] also believe that "support and assistance from government" and administrators in school is vital as a best practice for effective STEM implementation. Participants believed that there should be a unified STEM implementation framework and a clear guiding action plan that is based on alignment with the market demands globally and locally, which is ultimately set by the ministry of education (MOE). [T2] and [UH1] mention the government support and motivational drive to teach STEM as a best practice. The government in UAE continuously placed a considered effort to promote STEM education, as reported. Al Murshidi (2019) reported that the government of the UAE had derived STEM through an initiative of education reforms. After introducing the UAE National Innovation Strategy in 2015, the government started the Fourth Industrial Revolution in September 2017.

Moreover, Al Murshidi (2019) indicated that UAE prioritizes STEM in the education sector, as reported by the strategic plan for 2017-2021 to raise the post-secondary graduation rate. Therefore, Vision 2021for education calls for improving UAE students' performance to be one of the best in reading, mathematics, science, and Arabic skills. Allying with Vision 2021, the ministry of education created the Strategy 2017-2021 to support the vision of supporting the fields of science, innovation, and technology in the UAE (Al Murshidi, 2019). The present study results are in line with Park et al. (2016) study results that suggest that sufficient support from the government, the reform of the curriculum, and the assessment system are needed to promote STEAM education better. Consistently the success of any initiative in education at the district or school level requires quality and support of the individuals in leadership roles (Davis, 2015).

Moreover, Davis (2015) asserted that schools and districts that want to provide students with quality STEM opportunities to prepare them for higher education and employment in STEM fields; require highly functional leaders. The results are also related to those reported by Brown et al. (2011). Brown and colleagues showed evidence of a lack of clear vision for STEM education, even by individuals who deem it essential. Brown et al. (2011) also claimed that visionary leaders must work with the various stakeholders of their organizations to develop and carry out a shared vision and mission.

In line with the above results, Al Murshidi (2019) indicated that the government in UAE had supported STEM through different education reforms and by using strategic measures such as launching the UAE National Innovation Strategy in 2015, lunching the Fourth Industrial Revolution in September 2017, UAE prioritizes STEM the education sector as reported by a strategic plan for 2017-2021 that seeks to raise the of post-secondary graduation rate, and in UAE Vision 2021 that focuses on improving UAE students education ”to be one of the best in reading, mathematics, science, and Arabic skills. Aligning with Vision 2021, the ministry of education came up with Strategy 2017-2021 to support the vision of promoting the fields of science, innovation, and technology in the UAE” (Al Murshidi, 2019, p.322).

5.5.6.2 Strong Leadership

The participants believed that successful STEM implementation requires highly qualified STEM leaders who can manage and support STEM implementation using well-established implementation plans. Scott's (2012) study result also indicated that the success of STEM initiatives is dependent on the quality and support of those in leadership roles. In line with this result, Brown et al. (2011) reported a lack of clear vision for STEM education. Even individuals who deem it to be important will negatively impact STEM implementation. Furthermore, Scott (2012) also reported that STEM-focused schools require confident, visionary principals committed to positively affecting the lives of their students. Wang et al. (2011) shared a similar result regarding the factors that challenged STEM implementation education and indicated that few general guidelines or models exist for teachers to follow regarding implementing STEM in their classes. Participant shared that leadership role make a strong emphasis on the stakeholders involved in the STEM implementation process through raising their awareness and providing tailored professional development that respond to their needs.

El-Deghaidy and Mansour (2015) study also addressed the stakeholder's awareness, which indicated that STEM implementation requires a different school culture that emphasizes collaboration among stakeholders and building a collaborative and supportive STEM community in the school. In a similar line, Al Quraan (2017) findings asserted the importance of bringing more awareness of STEM in UAE society and recommended that the Ministry of Education, Education Administration, and educators need to start an awareness campaign to educate people, businesses, community, and politicians about STEM literacy and its importance for the country's future. Averill, (2018) study findings revealed that teachers and leaders considered developing awareness and understanding of the importance of STEM skills and ways to implement STEM in their as important factors that can promote STEM implementation success. This finding is aligned with Natarajan et al. (2021), who described that knowledge and awareness could help shape people's perceptions. Thus, participants believe that raising the awareness will make them value STEM and make them willing to apply it. Principals [P3] mention a "willingness to participate" as one of the best practices for STEM implementation that can be applied within the UAE context. Similarly, Fong (2019) findings indicated that raising the teacher's awareness results in how teachers value STEM career discussion in the classroom as it offers a channel through which knowledge can be transferred, and teachers build rapport with students when they draw upon their own experience with STEM careers. Consistently, Al Murshidi (2019) recommended that awareness about STEM implementation should be raised to pique the interest of students. Nationals should also understand that it is not a field for the elites but rather a field that will determine the quality of life of every citizen (Al Murshidi, 2019).

5.5.6.3 Resources

The participants' perceptions indicated the need for specific resources that can promote the STEM implementation process. They clearly mentioned the need for financial resources integrated curriculum and a STEM-oriented curriculum that will facilitate STEM teaching. Moreover, they perceived the preparation of STEM labs as equipped with all the needed tools to develop STEM projects. Furthermore, they perceived time to be allocated as they consider it as a challenging factor that hinders the STEM implementation process. Moreover, the participant also asserted that providing the required resources that can facilitate STEM implementation, such as STEM-based standards, STEM-oriented curricula, and the necessary materialistic resources for STEM projects.

Similarly, Kubat (2018) and Al Basha (2018) findings aligned with the study findings and reported that successful STEM implementation requires the availability of time, resources, and STEM-related curriculum. The assurance of time availability and allocation for STEM implementation processes such as teaching, training, and planning. The use of STEM-based assessment tools reflects student performance in the STEM outcomes. El-Deghaidy et al. (2017) and Thibaut et al. (2018), in their findings, indicated the availability of the resource is an important factor that can foster STEM implementation. The result was aligned with Park et al. (2017), who indicated the several factors that influence STEM integration, including the lack of time faced by those on the frontlines: "1) lack of time to teach STEM; 2) lack of instructional resources; 3) lack of professional development; 4) lack of administrative support; 5) lack of knowledge about STEM topics, particularly engineering; 6) lack of parental participation; and 7) reluctance of teachers to collaborate" (p. 284). Likewise, Thibaut et al. (2018) shared that teacher-reported lack of time and needed resources can influence their STEM teaching and learning process.

Another critical factor, as indicated by the participants, was the availability of STEM-oriented curricula. Most of the teachers believe in their experience that there is a severe misalignment with the current curriculum. [T3] mentioned that there is "no STEM-oriented curriculum" and that they "incorporate using the science learning objectives". Several studies supported this result and indicated that integrative content and a STEM-oriented curriculum would enhance STEM implementation (Brown et al., 2011; Pinnell et al., 2013).

5.5.6.4 Teacher Training and Professional Development

STEM Teachers have similar views on the best practices for STEM implementation in the UAE context; [T1], [T3], and [T4] list the "training for teachers" and build on their expertise to teach STEM subjects as a best practice. The above results and findings are in line with the studies based on a UAE context. Thus, teacher development professionals need to be structured to equip teachers with the required competencies and skills to handle STEM teaching (Al Basha, 2018; Makhmasi et al., 2012; Al Murshidi, 2019). Al Basha (2018) asserted that professional development should be structured to prepare the teachers to

"*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".*

Similarly, Makhmasi et al. (2012) results indicated Teachers and School leaders had recommended the need for "continuous training" and "interactive workshop" to foster teachers' professional STEM development. In line with the result, Al Murshidi (2019) also recommended intensifying efforts on personal and professional development for STEM teachers to enhance STEM implementation and increase student interest in STEM. Inconsistent with El-Deghaidy et al. (2017) study recommended developing a professional development model to facilitate the implementation of STEM education in schools, with the participation of partners from universities and industries as a necessary step for enacting a STEM integrated model. Furthermore addition, providing professional guidance via development courses and seminars is essential if teachers are to be more effective in the classroom is recommended.

5.5.6.5 Building Effective Pedagogical Methods

The participants' perceptions indicated the need for effective pedagogical teaching methods that facilitate STEM teaching, such as Inquiry-based learning, problem-based, and conceptual approaches were all listed as the teachers. Additionally, [T2] added that "participating in extracurricular activities in which students share their products and projects" is an effective teaching method. Furthermore, participants listed the use of effective Student-centered teaching methods such as inquiry -base, problem-based, and project-based. Similarly, Moore et al. (2014) described that STEM teaching practices need to focus on math and science; rely on student-centered pedagogy; use engaging activities and incorporate engineering design. The result indicated is like Moore's findings as the participant believed that they need to implement STEM using engaging student-centered activities.

In line with the result, Rockland et al. (2010) indicated that discovery, problem-solving, and inquiry-based learning all play substantial roles in STEM integration. Therefore, they emphasized the teacher's use of STEM instructional strategies that promote student-centered problem-based learning strategies (Rockland et al., 2010). Likewise, Wang et al. (2011) indicated that teachers must emphasize problem-solving skills and inquiry-based learning within STEM implementation content. Furthermore, school leaders and teachers listed the need for appropriate evaluation and assessment tools to measure STEM progress in students compared to the traditional assessment tools used to evaluate student performance. The result is similar to Margot and Kettler (2019) findings which suggested that using quality assessment tools, planning time, and knowledge of STEM disciplines can promote STEM implementation.

5.5.6.5 STEM Implementation Drives in the UAE Context From the Participant's Perspective

Based on the synthesis of the quantitative, qualitative, and literature review outcomes STEM implementation framework is suggested to contribute to the successful transformation of STEM education in the UAE, as described in Figure 13. By providing a comprehensive conceptualization of the STEM implementation process that highlighted the process at different levels involved the national, school level, and classroom levels. The suggested framework provides a clear road map for STEM implementation through the involvement of three primary levels: the government level, the school, and the classroom level. Those levels spot the light on the different factors that may promote the efficiency of the STEM implementation process by addressing the gaps emphasized in the reviewed literature review.

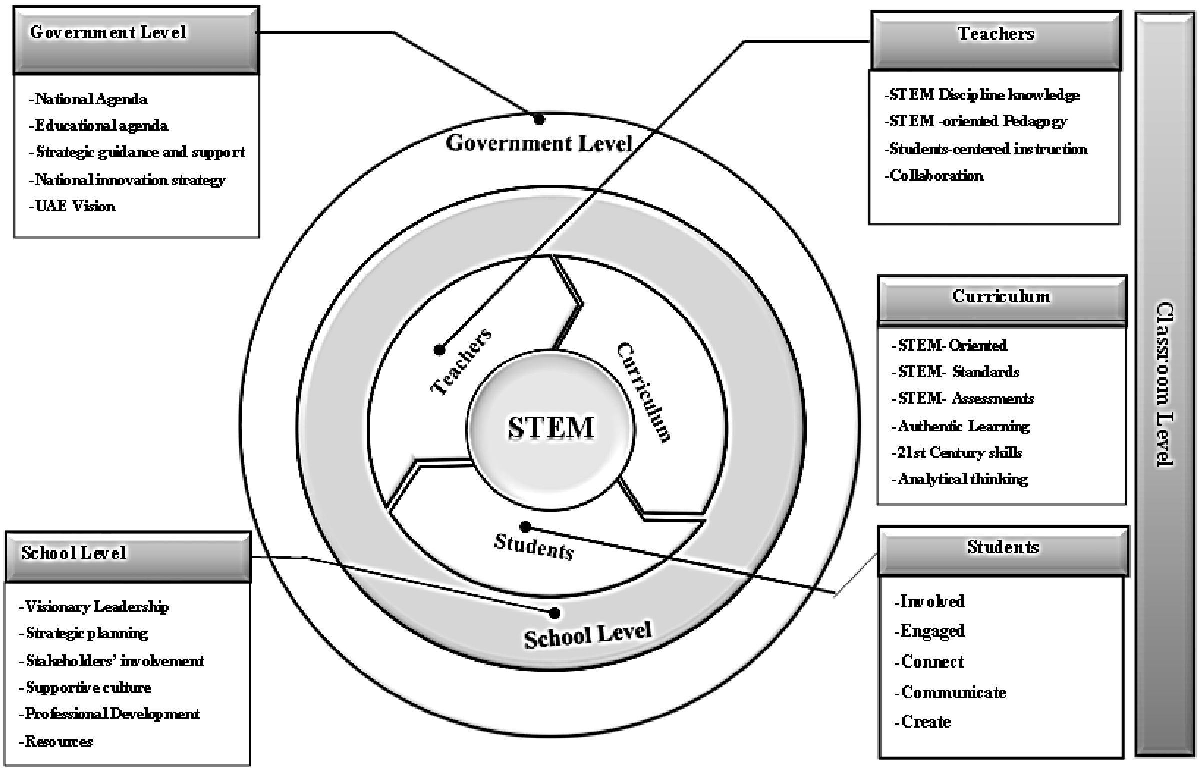

Figure 13: STEM Implementation Drives Framework within UAE Context

The government-level encompasses the national vision that identifies priorities associated with STEM education, such as health, energy, and aerospace and education, which reflect the need for a highly qualified science-driven scholar. This level also involved important elements such as educational agenda, national innovation initiative, and providing guidance and support. In general, this level shapes the STEM implementation planning by projecting the features of the future students and the required outcomes that align with the global and national requirements. The result asserted that any innovations or transformations in education would not be successful without big support from the government and schools.

Moreover, the school level includes essential drives that can foster STEM implementation within any STEM school, such as visionary leaders, stakeholders' involvement, supportive culture, and availability of resources. The school-level control and management STEM implementation process and the adequacy of this level can accelerate and enhance the STEM implementation process. As the success of STEM implementation requires visionary leadership who can strategically manage the planning and maintain STEM implementation, assert the stakeholders' involvement and spread awareness about STEM, and promote a supportive school culture that ensures the availability of required resources in a similar line.

Davis (2015) findings asserted that for schools and districts to promote quality STEM requires highly functional leaders. The results are also related to those reported by Brown et al. (2011), which indicated successful STEM implementation needs visionary leaders who are capable of working with the various stakeholders of their organizations to develop and carry out a common vision and mission. In line with the result, Davis (2015) findings described that effective school administrators must provide "visionary, instructional, organizational, collaborative, ethical, and advocacy led to the schools they serve" p (43).

Moreover, Davis's findings reported that leadership requires the management f procedures and resources to create a safe and effective environment that promotes learning for all students. The school level is made of three basic levels involving teachers, curriculum, and the student level. In line with this Davis (2015) also described that STEM implementation requires administrators to foster a positive culture and promote an instructional program that ensures learning for all students and supports professional growth for the faculty members. The classroom level incorporates fundamental aspects that can contribute to improving STEM teaching and learning procedures. Specifically, it describes that successful STEM enactment requires highly qualified STEM teachers who know the skills of STEM teachings. Teachers equipped with appropriate STEM-teaching methods implement student-centered, problem-based, inquiry-based, and interactive teaching methods.

The result is aligned with Margot and Kettler (2019), which indicated that STEM teachers are to be skilled and able to handle authentic experiences using student-directed pedagogy. Teachers' readiness and STEM subject matter knowledge are important factors that may foster STEM implementation (Brown et al., 2012; Pinnell et al., 2013). The utilization of a STEM-oriented curriculum, which is developed based on STEM-based standards, and relay on authentic, engaging students centered activities, is an important drive that will foster STEM implementation in line with the result El-

Deghaidy et al. (2017) result by indicating that the utilization of STEM-oriented curriculum will positively influence the STEM implementation process.

5.6 Major Findings and Conclusions

A summary of the main conclusions described from the study data is articulated here. Firstly, the principals, unit heads, and teachers showed a good understanding of STEM definition, rationale, purpose, and STEM implementation practices. However, it was evident that teachers held higher informed perceptions compared to the principals and the unit heads' perceptions about STEM, and this can be explained due to the fact that most of the participants were science and math teachers who are more familiar with the STEM teaching nature. Secondly, the study participants have promising preferred practices compared to their actual practices in regard to STEM meaning, value, purpose, and implementation practices. Evidently, that was obvious from the participants' responses as they were able to describe the important elements that may facilitate STEM implementation practices, such as the need to have supportive school culture and more STEM-related professional development. Thirdly, the study result indicated that the teachers held positive perceptions of their preferred competence level compared to their current status, and it was perceptible from their answers that they need more preparation to have STEM disciplines subject matters and STEM- pedagogical knowledge. Fourthly, the participants highlighted several factors that may impede the successful STEM implementation. Particularly, they believed that there is a lack of clear institutional mission and vision that promotes STEM education, guiding implementation framework, supportive school culture, time, and heavy teaching loads. Lack of STEM pedagogical knowledge, lack of STEM-oriented curriculum, and lack of resources are crucial factors that may hinder the STEM implementation process. Finally, Government Support, involvement of stakeholders, and availability of Resources are perceived by the participants as vital elements that can foster STEM implementation.

5.7 Implications

STEM is considered an international and national prioritized goal in today's education; thus, students are expected to have a basic understanding of critical skills associated with STEM. However, Al Basha (2019) indicated that STEM implementation is still in its early phases. Consequently, the current study findings will offer educational implications that will contribute to increasing the efficiency of the STEM implementation process. The decision-makers, curriculum developers, teachers, students, parents, and international context will benefit from the promoted STEM educational implications. There are several educational implications, including Political, pedagogical, and educational capacity-building consequences.

The Policy implication emphasized the need for more partnership between K-12 and higher education to increase the quality of pre-service teacher STEM education outcomes. Specifically, the policy implications involve focusing on the education programs and a teacher employment system to ensure the availability of well-prepared STEM Teachers. The study suggested the need for proper STEM leadership capable of promoting the need for appropriate conceptual, procedural, and strategic plans aligned to a well-structured framework for STEM implementation and evaluation process (Averill, 2018; Davis, 2015; Al Murshidi, 2019). Moreover, the study pointed out implications related to STEM teachers' preparation as they need to have STEM disciplines knowledge and STEM teaching knowledge and skills. Therefore, the study draws attention to the importance of STEM specialized professional development to equip the teachers with the pedagogical content and integrated teaching knowledge required to facilitate quality STEM teaching.

Furthermore, the study places importance on developing STEM-related curricula that incorporate 21st-century skills within an authentic context. The study also outlined the importance of students and their parents being involved in STEM implementation by increasing their awareness of STEM implementation and its value. Finally, the study has implications on the global context as it will enrich the available literature with the findings of this study and the framework suggested for STEM implementation drives.

5.8 Recommendations

Based on the findings reported in the present study, more research studies are needed to explore further the difficulties surrounding STEM integration.

- Research that replicates this study with a larger population, involvement of additional stakeholders such as district-level leaders, students, and parents, and involvement of the private and public schools within all the educational regions.

- Research to examine teachers' and leaders' perceptions of the provided STEM professional development.
- The research examines STEM professional development content, delivery, and evaluation methods within the UAE context.
- Research to examine STEM literacy competencies in the available curricula and how it develops those skills.
- Research to examine STEM implementation inside the classroom.
- Studies to explore actions needed for better STEM- assessment
- Studies to measure the impact of STEM implementation on students' cognitive abilities and academic attainment.

5.9 Conclusion

In essence, the study focused on examining the participants' perceptions of the status of the STEM implementation process in the UAE context, highlighted their views on the current and preferred implementation practices, identified factors that may promote STEM implementation, and provided a recommendation to improve STEM implementation in the UAE. The UAE has facilitated STEM implementation in schools to create a knowledge-based economy and globally competitive society; however, STEM education is not yet received proper attention. It is neither actively nor effectively implemented (Makhmasi et al., 2012). The research was carried out using a mixed-methods research design. Research findings of the quantitative and qualitative phases indicated that school leaders and teachers had positive perceptions of STEM implementation and a good understanding of STEM definition (Al Basha,2018). In particular, they were able to define STEM, explain the rationale and the purpose of implementing STEM, and they were able to describe components of STEM implementation (Al Basha, 2018, Elayyan & Al-Shizawi, 2019; El-Deghaidy & Mansour, 2015; El-Deghaidy et al., 2017; Falloon, 2019; Johnson, 2013; Mahil, 2016;

Al Murshidi, 2019; Sanders, 2009; Tsupros et al., 2009; Thibaut et al., 2018; Wang et al., 2011).

Moreover, the present study's findings revealed that the principal, unit head, and teachers have promising preferred practices compared to their actual STEM meaning, value, purpose, and implementation practices. They indicated the need for a solid leadership that can effectively manage STEM implementation (Averill, 2018; Davis, 2015). The participants believed that more preparation is required for the stakeholders involved in STEM implementations, such as the teachers, students, and parents (El-Deghaidy et al., 2017). They asserted the need for more specialized STEM professional development to prepare teachers for STEM teaching. Furthermore, the participants also believed that using a STEM-oriented curriculum aligned to STEM standards would facilitate STEM implementation (Falloon, 2019; Thibaut et al., 2018; Wang et al., 2011). Also, the study findings revealed that teachers believed that they needed professional development to prepare them to teach STEM in their classes. They believed that they needed more instructional knowledge about STEM disciplines, more understanding of engineering concepts, and how to integrate technology (Makhmasi et al., 2012; Mousa, 2016; Al Murshidi, 2019). The participants also believed that several factors might hinder the STEM implementation process. Specifically, they indicated a lack of clear institutional mission and vision that promote STEM education, lack of supportive school culture, lack of time and heavy teaching loads, lack of STEM pedagogical knowledge, lack of STEM-oriented curriculum, and lack of resources (Austin, 2019; Averill, 2018; Al Basha, 2018; Brown et al., 2012; El-Deghaidy et al., 2017; Kubat, 2018; Makhmasi et al., 2012; Margot & Kettler 2019; Mousa, 2016; Al Murshidi, 2019; Owens, 2014; Park et al., 2016; Pinnell et al., 2013; Al Quraan, 2017; Rogers, 2007; Scott, 2012; Thibaut et al., 2018; Wang et al., 2011).

Finally, the synthesis of the quantitative, qualitative, and literature review outcomes STEM implementation drives framework is suggested to contribute to the successful transformation of STEM education in the UAE, as described in Figure 13. In particular, the framework provides a comprehensive conceptualization of the STEM implementation process that highlights the process at different levels involving the national, school level, and classroom levels.

Their views showed they perceived that the primary value of STEM lies in improving the STEM literacy of citizens and ensuring a better quality of education (Kubat, 2018). Furthermore, they perceived that the primary purpose of STEM is to enhance students' critical thinking skills and competency development. Regarding STEM implementation, school leaders and STEM teachers believe that STEM teaching entails engaging students in student-centered activities that focus on problem-based, inquiry-based, or project-based applications within an authentic context (Thibaut et al., 2018). The factors that impeded successful STEM implementation involve lack of time, lack of resources, lack of sufficient teachers' training and professional development, lack of a unified vision for leading STEM initiatives, lack of STEM-based curriculum, and lack of guided frameworks were all identified by the school leaders and STEM teachers.

To overcome the challenges of STEM implementation, more emphasis should be taken to raise stakeholders' awareness about STEM significance and have strong STEM leadership and teacher development, which are considered best practices for implementing STEM in the UAE context (Davis, 2015).

Finally, the study suggested that STEM implementation drives promote effective STEM implementation. The framework encompasses two levels: government and school, which self-included the teachers, curricula, and student levels. The government-level encompasses the national vision that identifies priorities associated with STEM education, such as health, energy, and aerospace and education, which reflect the need for a highly qualified science-driven scholar. Moreover, the school level includes essential drives that can foster STEM implementation within any STEM school, such as visionary leaders, stakeholders' involvement, supportive culture, and availability of resources. The current research highlighted the status quo of STEM implementation in the UAE schools, emphasizing the factors impeding successful STEM integration and implementation. For future research, it is recommended to delve deep into the pedagogical context of STEM curricula, examining its efficacy and exploring the assessment tools to evaluate students' STEM performance.

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Appendices

Appendix A	Ethical Approval for Conducting Research
Appendix B	Informed Consent and Questionnaire (English)
Appendix C	Informed Consent and Questionnaire (Arabic)
Appendix D	Interview Guide
Appendix E	Informed Consent and Interview Guide
Appendix F	Results from Document Analysis

Appendix A

Ethical Approval for Conducting Research

UAEU Faculty of Humanities and Social Sciences

جامعة الإمارات العربية المتحدة
United Arab Emirates University

Social Sciences Ethics Sub-Committee
Approval Letter

Nov 11, 2020

This is to certify that research proposal N: *ERS_2020_7208*, titled: *STEM education: Analysis of factors facilitating or impeding effective implementation in UAE*, submitted by Dr *Mohammed Yousif* has been reviewed and approved by the UAEU sub-committee for research ethics in social sciences.

The committee must be informed if there are any deviations from the protocol approved herewith.

Sincerely

Professor Sami Boudelaa
Chair of the UAEU Research Ethics Sub-Committee for Social Sciences
Department of Cognitive Sciences
United Arab Emirates University
UAE
Email: s.boudelaa@uaeu.ac.ae
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Appendix B

Informed Consent and Questionnaire (English)

Questionnaire on Science Technology Engineering and Mathematics Education in UAE

This survey consists of items designed to provide an understanding of the perceptions of schools' administrators and teachers on the meanings, rationales, risks, implementation, challenges, and opportunities pertaining to STEM education in UAE schools. The procedure involves filling out an online survey that will take approximately 15 minutes. Please select your responses through the checkbox or drop-down menu provided. Your responses will be confidential, and we do not collect any personal identifying information such as your name, email address, or IP address. The survey questions will be about your perceptions regarding various facets of STEM education. Your participation in this research study is voluntary. You may choose not to participate. If you decide to participate in this research survey, you may withdraw at any time. If you choose not to participate in this study or if you withdraw from participating at any point in time, you will not be penalized. We keep your information confidential. All data is stored and protected. To help protect your confidentiality, the surveys will not contain information that will personally identify you. The results of this study will be used for scholarly purposes only. This research has been reviewed according to UAE University procedures for research involving human subjects.

Clicking on the "agree" button below indicates that:

• you have read the above information
• you voluntarily agree to participate

If you do not wish to participate in the research study, please decline participation by clicking on the "disagree" button.

Agree ☐

Disagree ☐

Section 1: Demographic data		
School type: ☐ Private ☐ Public	**School Cycle:** ☐ Primary ☐ Preparatory ☐ High school	**Position Title** ☐ Administrator ☐ Teacher **If the teacher ticks, your specialization** ☐ Science ☐Technology [IT] ☐ Math ☐ Engineering ☐ Others
Gender: ☐ Male ☐ Female	**Years of Experience:** ☐ <5 ☐ 5-10 ☐ >10	
	Educational level: ☐ Bachelor ☐ Graduate / Master ☐ Graduate / PhD	

Section 1: Actual STEM Teaching Practices							
Scale	NO.	**This questionnaire contains statements about your STEM teaching practices. Please select the answer that describes how actually you practice the STEM Teaching approach** **Remember that you are rating your <u>actual</u> STEM Practices**	**5** **Very often**	**4** **Often**	**3** **Sometimes**	**2** **Seldom**	**1** **Almost never**
Meaning	1.	STEM is taught as a science teaching approach					
	2.	STEM is taught as an interdisciplinary approach					
	3.	STEM is taught as an intradisciplinary (separated subject for STEM) teaching approach					
	4.	STEM is taught as an instructional approach, which integrates the teaching of science and mathematics disciplines through the infusion of the practices of scientific inquiry, technological and engineering design, mathematical analysis, and 21s century interdisciplinary themes and skills.''					
Value	5.	STEM is implemented to expand the number of students who ultimately pursue advanced degrees and careers in STEM fields					
	6.	STEM is implemented to expand the STEM-capable workforce					
	7.	STEM is implemented to improve STEM literacy in all citizens					
	8.	STEM is implemented to spread the innovation culture					
	9.	STEM is implemented to lead to quality education					
Purpose	10	STEM is taught to enhance students' ability to solve problems.					
	11	STEM is taught to enhance students' ability to think critically.					
	12	STEM is taught to enhance students' ability to be innovative.					
	13	STEM is taught to enhance students' ability to be technology literate.					
	14	STEM is taught to enhance student's academic achievement					
	15	STEM is taught through the connection between subjects within an authentic context to enhance students learning.					
	16	STEM is taught to enhance decision-making skills.					
	17	STEM is taught to enhance long life skills.					

Implementation	18	STEM is incorporated using a Clear institutional mission and vision that promote STEM education					
	19	STEM is taught using a STEM education framework and guidelines.					
	20	STEM is implemented during extracurricular activities					
	21	STEM is taught during afterschool activities					
	22	STEM is taught using an integrated STEM curriculum					
	23	STEM is taught using my subject matter curriculum					
	24	STEM is taught using a standardized-based curriculum aligned with STEM outcomes.					
	25	STEM is taught using student's centered approaches					
	26	STEM is taught through real-world problems that promote a richly engaging and motivating context.					
	27	STEM is taught using inquiry-based learning					
	28	STEM is taught using problem-based					
	29	STEM is taught using project-based learning					
	30	STEM is taught using concepts that cut across disciplines.					
	31	STEM is assessed using STEM-oriented assessment tools to evaluate STEM learning					
	32	STEM is taught using STEM allocated period					
	33	STEM is taught using STEM-specialized Lab					

Section 2: STEM Teaching Preferred Practices					
This questionnaire contains statements about your preferred STEM teaching practices. Please select the answer that describes your preferred STEM Teaching practices. **Remember that you are rating your <u>preferred</u> STEM Practices**	**5** **Strongly agree**	**4** **Agree**	**3** **Neutral**	**2** **Disagree**	**1** **Strongly disagree**
STEM should be taught as a science teaching approach					
STEM should be taught as an Interdisciplinary approach					
STEM should be taught as a Multidisciplinary approach					
STEM should be taught as an intradisciplinary (separated subject for STEM) teaching approach					
STEM should be taught as an instructional approach, which integrates the teaching of science and mathematics disciplines through the infusion of the practices of scientific inquiry, technological and engineering design, mathematical analysis, and 21s century interdisciplinary themes and skills.''					
STEM should be taught to expand the number of students who ultimately pursue advanced degrees and careers in STEM fields					
STEM should be taught to improve STEM literacy in all citizens					
STEM should be taught to spread the innovation culture					
STEM should be taught to lead to quality education					
STEM should be taught to enhance students' ability to solve problems.					
STEM should be taught to enhance students' ability to think critically.					
STEM should be taught to enhance students' ability to be innovative.					
STEM should be taught to enhance students' ability to be technology literate.					
STEM should be taught to enhance student's academic achievement					
STEM should be taught through the connection between subjects within an authentic context to enhance students learning.					
STEM should be taught to enhance decision-making skills.					
STEM should be taught to enhance long life skills.					
STEM should be taught using a Clear institutional mission and vision that promote STEM education					
STEM should be taught using the STEM education framework and guidelines.					
STEM should be taught during extracurricular activities					
STEM should be taught during afterschool activities					
STEM should be taught using an integrated STEM curriculum					

STEM should be taught using my subject matter curriculum					
STEM should be taught using a standardized-based curriculum aligned with STEM outcomes.					
STEM should be taught using student-centered approaches					
STEM should be taught through real-world problems that promote a richly engaging and motivating context.					
STEM should be taught using inquiry-based learning					
STEM should be taught using problem-based					
STEM should be taught using project-based learning					
STEM should be taught using concepts that cut across disciplines.					
STEM should be taught using STEM-oriented assessment tools to evaluate STEM learning					
STEM should be taught using STEM allocated period					
STEM should be taught using STEM specialized lab					

Section 3: Teacher's STEM competence level										
Actual						**Preferred**				
5 **Strongly agree**	**4** **Agree**	**3** **Neutral**	**2** **Disagree**	**1** **Strongly disagree**	**Remember that you are rating your *actual and preferred* STEM competence level**	**5** **Strongly agree**	**4** **Agree**	**3** **Neutral**	**2** **Disagree**	**1** **Strongly disagree**
					I was prepared to teach STEM during my teacher education program					
					I have the needed subject matter to teach STEM					
					I have all the skills to handle STEM teaching					
					I have all the instructional knowledge to enact STEM in my class					
					I receive the needed professional development to be ready to teach STEM					
					I can work collaboratively with the other subjects' teachers					

Section 4: Please indicate to what extent the following statements are considered as impeding or facilitating factors for STEM implementation Indicate your opinion based on this scale of 1 (not serious) to 5(very serious)						
Scale	**Items**	**1 Not serious**	**2**	**3**	**4**	**5 Very Serious**
Contextual factors	1. Lack of Clear institutional mission and vision that promote STEM education					
	2. Lack of strategic plan that emphasizes the implementation of STEM education					
	3. Lack of STEM school culture that emphasizes shared beliefs, norms, and support needed to enact STEM					
	4. lack of STEM-oriented curricula					
	5. lack of resources					
	6. Lack of time and heavy teaching loads					
Teacher preparation and Pedagogical issues	7. Insufficient preparation during the teacher preparation program					
	8. Lack of needed training to prepare teachers for STEM education					
	9. Lack of collaborative learning community within STEM disciplines					
	10. Lack of need-based professional development for successful STEM enactment they should have to be trained training resources					
	11. Teachers lacking STEM subject matter					
	12. Teachers lacking instructional skills to enact STEM in their classes					
	13. Lack of Textbooks and other STEM-based Curricula					
	14. Lack of design and engineering, and technology instructional skills					
	15. Lack of confidence in handling hand-on activities					
	16. Lack of instructional approach that has an emphasis on application to a real-world problem					
	17. curricular and instructional methods that rely on student-centered activities					

استبيان حول تعليم العلوم والتكنولوجيا والهندسة والرياضيات في الإمارات العربية المتحدة
الفئة المستهدفة [الإداريون والمعلمون]

يتكون هذا الاستبيان من عناصر مصممة لمعرفة أراء الإداريين والمعلمين حول المعاني والأسباب والمخاطر والتحديات والفرص المتعلقة بتدريس العلوم والتكنولوجيا والهندسة والرياضيات في مدارس الإمارات العربية المتحدة. يتطلب ملء استبيان عبر الإنترنت يستغرق حوالي 15 دقيقة. يرجى اختيار اجابتك من خلال مربع الاختيار أو القائمة المنسدلة المتوفرة. ستكون اجاباتك سرية، ولا نقوم بجمع أي معلومات شخصية مثل الاسم أو عنوان بريدك الإلكتروني أو عنوان الجهاز. أسئلة الاستبيان حول أرائك فيما يتعلق بالجوانب المختلفة لتدريس العلوم والتكنولوجيا والهندسة والرياضيات. مشاركتك في هذه الدراسة البحثية تطوعية. يمكنك اختيار عدم المشاركة. وإذا قررت المشاركة في هذا الاستبيان، فيمكنك الانسحاب في أي وقت. إذا اخترت عدم المشاركة في هذه الدراسة أو إذا انسحبت من المشاركة في أي وقت، فلن يترتب عليك أي التزام. نحافظ على سرية معلوماتك. يتم تخزين جميع البيانات وحمايتها. للمساعدة في حماية خصوصيتك، لا يحتوي الاستبيان على معلومات من شأنها كشف هويتك الشخصية. يتم استخدام نتائج هذه الدراسة للأغراض العلمية فقط. تمت مراجعة هذا البحث وفقًا لإجراءات جامعة الإمارات العربية المتحدة الخاصة بالبحوث التي تشمل البشر.

النقر فوق الزر "موافق" أدناه يشير إلى أنك:
•لقد قرأت المعلومات الواردة أعلاه
•أنت توافق طواعية على المشاركة

إذا كنت لا ترغب في المشاركة في الدراسة البحثية، يرجى رفض المشاركة بالنقر فوق الزر "غير موافق"

القسم 1: البيانات السكانية		
نوع المدرسة ☐خاص ☐ عام	**الحلقة الدراسية** ☐أساسي ☐ إعدادي ☐ ثانوي	**المسمى الوظيفي** ☐إداري ☐ معلم
الجنس ☐ذكر ☐ أنثى	**سنوات الخبرة** ☐ >10 ☐ 5-10 ☐ <5	**إذا كنت معلم يرجى اختيار التخصص** ☐العلوم ☐ التكنولوجيا ☐الرياضيات ☐ الهندسة ☐غير ذلك
	المستوى التعليمي ☐بكالوريوس ☐ ماجستير ☐ دكتورا	

القسم 1: ممارسات تدريس العلوم والتكنولوجيا والهندسة والرياضيات الفعلية							
المقياس	**الرقم**	**يحتوي هذا الاستبيان على عبارات حول ممارسات تدريس العلوم والتكنولوجيا والهندسة والرياضيات الخاصة بك. الرجاء اختيار الإجابة التي تصف ممارستك الفعلية لتدريس العلوم والتكنولوجيا والهندسة والرياضيات** **تذكر أنك تقوم بتقييم ممارساتك الفعلية لتدريس العلوم والتكنولوجيا والهندسة والرياضيات**	**5** **غالبا جدا**	**4** **غالبا**	**3** **أحيانا**	**2** **نادرا**	**1** **نادرا جدا**
المعنى	34	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات كنهج لتدريس العلوم					
	35	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات كنهج بيني التخصصات " الدمج بين التخصصات)					
	36	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات كنهج تدريس داخلي التخصصات (مواد منفصلة)					
	37	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات كنهج تعليمي يدمج تدريس تخصصات العلوم والرياضيات من خلال إدخال ممارسات البحث العلمي والتصميم التكنولوجي والهندسي والتحليل الرياضي والموضوعات والمهارات بينية التخصصات للقرن الحادي والعشرين"					

	38	يتم تقديم العلوم والتكنولوجيا والهندسة والرياضيات لزيادة عدد الطلاب الذين يسعون إلى الحصول على شهادات علمية ووظائف متقدمة في مجالات العلوم والتكنولوجيا والهندسة والرياضيات					
	39	يتم تقديم العلوم والتكنولوجيا والهندسة والرياضيات لزيادة القوى العاملة القادرة المتخصصة في مجال العلوم والتكنولوجيا والهندسة والرياضيات					
	40	يتم تقديم العلوم والتكنولوجيا والهندسة والرياضيات لتحسين المعرفة في مجالات العلوم والتكنولوجيا والهندسة والرياضيات لدى جميع المواطنين					
	41	يتم تقديم العلوم والتكنولوجيا والهندسة والرياضيات لنشر ثقافة الابتكار					
القيمة	42	يتم تقديم العلوم والتكنولوجيا والهندسة والرياضيات لتسحين جودة التعلم					
	43	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات لتعزيز قدرة الطالب على حل المشكلات.					
	44	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات لتعزيز قدرة الطالب على التفكير النقدي.					
	45	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات لتعزيز قدرة الطالب على الابتكار.					
	46	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات لتعزيز قدرة الطلاب على الالمام بالتكنولوجيا.					
	47	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات لتعزيز التحصيل الأكاديمي للطالب					
	48	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات من خلال ربط المواد في سياق حقيقي لتعزيز تعلم الطلاب.					
	49	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات لتعزيز مهارات صنع القرار.					
الهدف	50	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات لتعزيز مهارات الدائمة.					
	51	يتم دمج العلوم والتكنولوجيا والهندسة والرياضيات باستخدام رسالة ورؤية مؤسسية واضحة تعزز تعليم العلوم والتكنولوجيا والهندسة والرياضيات					
	52	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام إطار وإرشادات تعليم العلوم والتكنولوجيا والهندسة والرياضيات.					
	53	يتم تقديم العلوم والتكنولوجيا والهندسة والرياضيات خلال الأنشطة اللامنهجية					
	54	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات خلال أنشطة ما بعد المدرسة					
	55	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام منهج متكامل (منهج يدمج التخصصات الاربعة)					
	56	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام منهج المادة الخاص بي					
	57	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام منهج قائم على المعايير القياسية يتوافق مع نتائج العلوم والتكنولوجيا والهندسة والرياضيات.					
	58	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام مناهج تتمحور حول الطالب					
	59	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات من خلال المسائل الواقعية التي تعزز سياقًا غنيًا ومحفزًا.					
التقديم	60	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام التعلم القائم على التقصي					

	61	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام حل المشكلات					
	62	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام التعلم القائم على المشاريع					
	63	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام مفاهيم تتقاطع مع التخصصات.					
	64	يتم تقييم العلوم والتكنولوجيا والهندسة والرياضيات باستخدام أدوات التقييم الموجهة نحو العلوم والتكنولوجيا والهندسة والرياضيات لتقييم عملية التعلم					
	65	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام الفترة المخصصة لها					
	66	يتم تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام مختبر متخصص في العلوم والتكنولوجيا والهندسة والرياضيات					

					القسم 2: الممارسات المفضلة لتدريس العلوم والتكنولوجيا والهندسة والرياضيات	
1 لا أوافق بشدة	2 لا أوافق	3 محايد	4 أوافق	5 أوافق بشدة	يحتوي هذا الاستبيان على عبارات حول ممارسات تدريس العلوم والتكنولوجيا والهندسة والرياضيات المفضلة لديك. يرجى تحديد الإجابة التي تصف ممارسات تدريس العلوم والتكنولوجيا والهندسة والرياضيات المفضلة لديك. تذكر أنك تقوم بتقييم ممارسات العلوم والتكنولوجيا والهندسة والرياضيات المفضلة لديك	
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات كنهج لتدريس العلوم	34
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات كنهج بيني التخصصات (يدمج بين التخصصات)	35
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات كنهج تدريس داخلي التخصصات (مواد منفصلة)	36
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات كنهج تعليمي يدمج تدريس تخصصات العلوم والرياضيات من خلال إدخال ممارسات البحث العلمي والتصميم التكنولوجي والهندسي والتحليل الرياضي والموضوعات والمهارات متعددة التخصصات للقرن الحادي والعشرين"	37
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات لتوسيع عدد الطلاب الذين يسعون إلى الحصول على الشهادات العلمية ووظائف متقدمة في مجالات العلوم والتكنولوجيا والهندسة والرياضيات	38
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات لتوسيع القوى العاملة القادرة في مجالات العلوم والتكنولوجيا والهندسة والرياضيات	39
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات لتحسين المعرفة في العلوم والتكنولوجيا والهندسة والرياضيات لدى جميع المواطنين	40
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات لنشر ثقافة الابتكار	41
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات ليؤدي إلى تعليم جيد	42
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات لتعزيز قدرة الطالب على حل المشكلات.	43
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات لتعزيز قدرة الطالب على التفكير النقدي.	44
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات لتعزيز قدرة الطالب على الابتكار.	45
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات لتعزيز قدرة الطلاب على الالمام بالتكنولوجيا.	46
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات لتعزيز التحصيل الأكاديمي للطالب	47
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات من خلال ربط المواد في سياق حقيقي لتعزيز تعلم الطلاب.	48
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات لتعزيز مهارات صنع القرار.	49
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات لتعزيز المهارات الدائمة.	50
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام رسالة ورؤية مؤسسية واضحة تعزز تعليم العلوم والتكنولوجيا والهندسة والرياضيات	51
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام إطار وإرشادات تعليم العلوم والتكنولوجيا والهندسة والرياضيات.	52
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات خلال الأنشطة اللامنهجية	53
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات خلال أنشطة ما بعد المدرسة	54
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام منهج متكامل	55
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام منهج المادة الخاص بي	56
					أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام منهج قائم على المعايير القياسية يتوافق مع النتائج.	57

58	أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام مناهج تتمحور حول الطالب					
59	أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات من خلال المسائل الواقعية التي تعزز سياقا غنيا ومحفزا.					
60	أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام التعلم القائم على التقصي					
61	أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام حل المشكلات					
62	أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام التعلم القائم على المشاريع					
63	أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام مفاهيم تتقاطع مع التخصصات.					
64	أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام أدوات التقييم الموجهة نحو العلوم والتكنولوجيا والهندسة والرياضيات لتقييم التعلم					
65	أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام الفترة المخصصة لها					
66	أفضل تدريس العلوم والتكنولوجيا والهندسة والرياضيات باستخدام مختبر متخصص					

القسم 3: مستوى كفاءة معلم العلوم والتكنولوجيا والهندسة والرياضيات

الفعلي						المفضل				
5 أوافق بشدة	4 أوافق	3 محايد	2 لا أوافق	1 لا أوافق بشدة	تذكر أنك تقوم بتقييم مستوى الكفاءة الفعلي والمفضل لديك	5 أوافق بشدة	4 أوافق	3 محايد	2 لا أوافق	1 لا أوافق بشدة
					كنت على استعداد لتدريس العلوم والتكنولوجيا والهندسة والرياضيات بعد إتمام برنامج تعليم المعلمين					
					لدي المعرفة المطلوبة لتدريس العلوم والتكنولوجيا والهندسة والرياضيات					
					لدي كل المهارات اللازمة للقيام بتدريس العلوم والتكنولوجيا والهندسة والرياضيات					
					لدي كل المعرفة التدريسية لتقديم العلوم والتكنولوجيا والهندسة والرياضيات في صفي					
					أتلقى التطوير المهني اللازم لأكون مواكبا لتدريس العلوم والتكنولوجيا والهندسة والرياضيات					
					يمكنني العمل بشكل تعاوني مع معلمي المواد الأخرى					

القسم 4: يرجى توضيح إلى أي مدى تعتبر العبارات التالية عوامل معوقة أو ميسرة لتقديم العلوم والتكنولوجيا والهندسة والرياضيات
اذكر رأيك بناءً على هذا المقياس من 1 (غير هام) إلى 5 (هام جدًا)

المقيا س	العبارات	1 غير هام	2	3	4	5 هام جدا
العوامل السياقية	1- عدم وجود رسالة ورؤية مؤسسية واضحة تعزز تعليم العلوم والتكنولوجيا والهندسة والرياضيات					
	2- عدم وجود خطة استراتيجية تؤكد على تدريس العلوم والتكنولوجيا والهندسة والرياضيات					
	3- عدم وجود بيئة مدرسية داعمة لثقافة تدريس العلوم والتكنولوجيا والهندسة والرياضيات و تؤكد على المعتقدات المشتركة والمعايير والدعم اللازم لتقديم العلوم والتكنولوجيا والهندسة والرياضيات					
	4- عدم وجود مناهج معدة و موجهة للتدريس العلوم والتكنولوجيا والهندسة والرياضيات					
	5- نقص الموارد و المصادر التعليمية					
	6- ضيق الوقت وكثرة الأعباء التدريسية					
إعداد المعلم و قضايا تربوية	7- الإعداد غير الكافي أثناء برنامج إعداد المعلم					
	8- نقص التدريب اللازم لإعداد المعلمين لتدريس العلوم والتكنولوجيا والهندسة والرياضيات					
	9- عدم وجود مجتمع التعلم التعاوني مع تخصصات العلوم والتكنولوجيا والهندسة والرياضيات					
	10- عدم وجود تطوير مهني قائم على الحاجة من أجل تقديم ناجح للعلوم والتكنولوجيا والهندسة والرياضيات، بحيث يجب أن يكونوا موارد تدريبية مدربة					
	11- يفتقر المعلمون إلى ال المعرفة و المهارات لتدريس مادة العلوم والتكنولوجيا والهندسة والرياضيات					
	12- يفتقر المعلم إلى المهارات التعليمية لتفعيل العلوم والتكنولوجيا والهندسة والرياضيات في فصولهم الدراسية					
	13- نقص الكتب المدرسية والمناهج الدراسية الأخرى القائمة على العلوم والتكنولوجيا والهندسة والرياضيات					
	14- الافتقار إلى مهارات التصميم والهندسة والتكنولوجيا التعليمية					
	15- عدم الثقة في التعامل مع الأنشطة العملية					
	16- عدم وجود نهج تعليمي يركز على تطبيق المسائل الواقعية					
	17- الأنشطة الصفية و اللاصفية التي تعتمد على الأنشطة المتمحورة حول الطالب					

Appendix D

Interview Guide

Teachers Interview protocol

Dear Participant,

We request you to provide your views and perception about best practices associated with the success of STEM integration. This information is required for research purposes only. Your identity and opinions will be confidential.

Demographic part

Subject:	School cycle:	Education background:
Gender:	years of experience:	Zone:

Interview questions

1. Tell us about STEM integration in education experience?

    a. ---

2. How would you define integrated STEM? Multidisciplinary or interdisciplinary?
3. --
4. What do you think is the rationale or the purpose of STEM education?
   ----
5. To what extent do you consider your school culture is supporting STEM implementation?

   ----

6. What does it take to create integrated STEM education? a) What resources will it take to implement integrated STEM education? b) What changes in staffing do you see are needed to implement integrated STEM education? c) Any thoughts on teacher certification considerations? d) What about facilities, equipment, software, etc. e) Are

there teacher preparation/professional development needs to be addressed to implement integrated STEM education? If so, what are they?

----

7. What is your experience in integrating STEM in the teaching and learning context?
    a. Do you have a clear institutional vision, mission, and STEM standards?
    b. Curriculum planning, time allocation STEM period, assessment, and measurement?
    c. Teaching within your subject matter or STEM is taught using a standard-based curriculum aligned with STEM outcomes.
    d. --
8. What teaching method are you using to integrate STEM in your class?
    a. Student-centered, inquiry-based, problem-based, or others? Or outside the class
    b. --
9. Do you think that the teacher is ready to teach using the STEM teaching approach?
    a. --
10. In your opinion, what are the challenges that impede STEM implementation?
    a. Do you think it time related or curriculum-related, or does it have to do with the teacher's preparation level?
    b. ---
11. In your opinion, what are the factors impeding or facilitating STEM education in UAE?
    a. --
12. What elements contribute to the best STEM practice in the UAE context from the participant's perspective?
    a. ---
13. Any additional comments on this topic?

- Can you share any STEM-related documents such as framework, lesson plan, curriculum plan, professional development schedule, initiatives, meetings, school mission, or vision?

School Leaders Interview protocol

Dear Participant,

We request you to provide your views and perception about best practices associated with the success of STEM integration. This information is required for research purposes only. Your identity and opinions will be confidential.

Demographic part

Position:	School cycle:	Education background:
Gender:	years of experience:	Zone:

Interview questions

- What does STEM integration in education mean to you? How would you define integrated STEM?
- Is there a vision at your organization for STEM education? Is your vision for STEM?
- What do you think is the rationale and purpose of embedding STEM in education locally, academically, and organizational-wise?
- What are the administrational steps taken to implement STEM effectively? In terms of plans, procedural framework, and evaluation measures?
- Are there any National/District STEM implementation or curriculum frameworks for STEM/ level of integration at your organization?
- To what extent do you consider your school culture supports STEM implementation? in terms of funding, resources, and teacher preparation?
- What does it take to create integrated STEM education? a) What resources will it take to implement integrated STEM education? b) What changes in staffing do you see are needed to implement integrated STEM education? c) Any thoughts on teacher certification considerations? d) What about facilities, equipment, software, etc. e) Are there teacher preparation/professional development needs to be addressed to implement integrated STEM education? If so, what are they? (as a decision-maker)
- To what extent do you believe teachers are ready to integrate STEM in their classrooms.
- What is your experience in integrating STEM in the teaching and learning context?

- In your opinion, what are the challenges that impede STEM implementation?

- In your opinion, what are the main factors impeding or facilitating STEM education?

- What elements contribute to the best STEM practice in the UAE context from the participant's perspective?
- Any additional comments on this topic?

Appendix E

Ministry of Education (MOE) Approvals

6/22/22, 7:42 PM Mail - Sara El Hassan Hamad - Outlook

Fwd: Fw: تسهيل مهمة الباحثة ثريا السالمي
Sara El Hassan Hamad
Sat 21/11/2020 13:12
To:

- Mohammed Madi Ahmed <m.yousif@uaeu.ac.ae>

1 attachments (15 KB)
قائمة مدارس الاستدامة والفريق المشرف.xlsx;
---------- Forwarded message ----------
From: Reem Hareth Saif Alquwaitaei <reem.alquwaitaei@moe.gov.ae>
Date: 21 Nov 2020 10:04 am
Subject: Fw: تسهيل مهمة الباحثة ثريا السالمي
To: Sara El Hassan Hamad <201180807@uaeu.ac.ae>
Cc:

The list of schools implemented STREAM.

Good luck my dear

From: Amal Shaikh Alawi Shehab
Sent: Saturday, November 21, 2020 6:55 PM
To: Reem Hareth Saif Alquwaitaei
Subject: إعادة توجيه: تسهيل مهمة الباحثة ثريا السالمي

مع جزيل الشكر
kindest Regards,

Amal Shehab
Acting Principal
Al Ertiqa'a School for Girls C2&3
Tel:02 4119230

رؤيتنا :تعليم ابتكاري لمجتمع معرفي ريادي عالمي
Our vision is innovative education for a knowledge, pioneering, and global society

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From: Moza Rashed Sultan Almuhiri
Sent: 24 يونيو, 2020 19:37
To: Shawqeya Khalil Sabt Al Hosani; Amal Shaikh Alawi Shehab; فاطمة حسين زيداني البلوشي; Ayesha Belal Obaid Alzaabi

https://outlook.office.com/mail/id/AAMkAGZiZDQzNzg4LTNlNTktNDQ0Ni1iNDAyLTUxOTNmOTQ4NWUwMwBGAAAAAACC%2BQkOjFcaRISq%2BH... 1/3

Cc: Fatima Hamad Obaid Al Kaabi
Subject: Fw: تسهيل مهمة الباحثة ثريا السالمي

مديرات الثانويات الكرام

كل الشكر علي جهودكم المبذولة نرجو منكن دعم مديرة مجلس 5 الاستاذة ثريا في مهام بحثها في حل الاستبانه المرفقة وتفاصيلها في الايميل ادناه وهي خاصة معلمي الثانوية (حلقة 3

ارجو تعميمها ونشرها في التواصل الاجتماعي ليتسني لها الحصول علي العدد الكافي من حل الاستبانات

مع الشكر الجزيل
موزة المهيري
مدير أول نطاق 1 مجلس 5

From: Operation Center Abu Dhabi
Sent: Wednesday, June 24, 2020 9:59:35 AM
To: AL GHAZALI MODEL; AL QARM; AL MAHA; AL REEF; AL WATHBAH; AL BAHEYAH; MOZA BINT BUTI; AL BAHEYAH; AL BAWADI MODEL; AL SAMHA; AL FALAHIYYA; Al Khatem; AL ZALLAQAH; MARYAM BINT OMRAN; Al Reyadah School; Umm Al Arab; AL MARWA; Hamdan Bin Zayed School; AL REEM MODEL; AL MAALI MODEL; SALAMAH BINT BUTI; AL DANAT; AL HAYAR; AL REFAAH; AL AIN MODEL; Al Hosson; AL BADIYAH; AL ATAA; Muraijib; AL SHIYAM 2; AL SALAMAT; Al Nebras School; NAHEL; AL FOAA; HESSA BINT MOHAMMAD; AL HEMMAH; Al Tomooh School; AL FAROOQ; AL Shomookh; UM AL FADHEL BINT AL HARETH; Al Huiteen School; BAYAH SCHOOL; Amra Bint Abdel Rahman
Cc: Lubna Alshamsi; Humaid Abdulla :ADEK- HQ; Khaled Al Abri; Khaled Al Ansari; Rahma Al Rubaei; Thuraya Al Salemi :ADEK- HQ; Fatima Murad Ali Al Mazam; ClusterLeadsAD; LeadPrincipalsAD; Muna Mohammad Janahi; Muna Alsuwaidi; Rashed Mohammed Salem Saeed
Subject: تسهيل مهمة الباحثة ثريا السالمي

Facilitating a researcher's study Thuraya Al Salemi	تسهيل مهمة الباحثة ثريا السالمي
Dear Public-school Directors, The researcher Thuraya Al Salemi is pursuing her postgraduate PHD degree from Aberystwyth University in the United Kingdoms. She has designed her final dissertation topic entitled, "An Investigation of Teachers' Perceptions on Integration of STREAM Education in Secondary Schools' Curricula and the Overall Strategic Futuristic Educational Vision 2021 of the UAE". The objective of the study is to identify teachers' perceptions about the integration of STREAM subjects and how students' achievement is assessed along the line. We would like to invite High school teachers in the Emirate of Abu Dhabi to share their experiences and points of view regarding STREAM by completing the following survey: https://e.moe.gov.ae/ords/f?p=SV:Q::F06Q:::: Your corporation in facilitating the researcher study is highly appreciated.	**السادة / مدراء المدارس المعنية المحترمين** تقوم الباحثة ثريا السالمي باستكمال الدراسات العليا للحصول على شهادة الدكتوراه من جامعة ابريستووث بالمملكة المتحدة، وحالياً تقوم بإجراء بحث التخرج بعنوان: " الاطلاع على ممارسات المعلمين لدمج تعليم ستريم في المدارس الإماراتية للمرحلة الثانوية بإمارة أبوظبي." حيث إن الهدف من الاستبانة هو جمع المعلومات لفهم كيفية تنفيذ المعلمين لبرنامج ستريم (العلوم، التكنولوجيا، القراءة، الفن، الهندسة والرياضيات) في المدارس الثانوية مع دعم وتوفير التطوير المهني والوسائل التقنية لتطبيق المواد المتكاملة وكيفية تقييم تحصيل الطلبة، وعليه ندعو جميع معلمي المرحلة الثانوية بإمارة أبو ظبي بالمشاركة وتزويدنا بإجاباتكم، وذلك من خلال الإجابة على الاستبانة على الرابط التالي: https://e.moe.gov.ae/ords/f?p=SV:Q::F07A:::: وعليه نرجو الإيعاز لما يلزم بتسهيل مهمة الباحثة المذكورة،

جامعة الإمارات العربية المتحدة
United Arab Emirates University

UAE UNIVERSITY DOCTORATE DISSERTATION NO. 2022: 17

STEM education in the UAE is currently receiving growing attention due to the massive economic growth, which created a need for STEM-qualified graduates. Therefore, this research emphasized that STEM education positively affects students' ability to solve problems, be innovative, think critically, and be technology literate. The study aims to examine school leaders' and STEM teachers' perceptions of STEM implementation practices in the UAE context.

Sara Elkeir Elhassan Hamad received her PhD from the Department of Curriculum and Instruction, College of Education at UAE University, UAE. She received her ME from Curriculum and Instruction, College of Education at UAE University, UAE