

**Investigating Teachers' and Students' Perceptions of STEM
Education in Private Elementary Schools in Abu Dhabi**

تقصّي تصوّرات المعلّمين والتلامذة في مجال تعليم العلوم والتكنولوجيا والهندسة
والرياضيات (STEM) في المدارس الابتدائية الخاصة في
أبو ظبي

by

HEBA CHAYA

**A thesis submitted in partial fulfilment
of the requirements for the degree of**

DOCTOR OF PHILOSOPHY IN EDUCATION

at

The British University in Dubai

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June 2022

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ABSTRACT

One of the furthestmost essential reforms in education is STEM education. It comes as a priority in the well-industrially and economically national agendas of the developed nations, as it is acknowledged for preparing scholars for the technological revolution that the world is experiencing.

In the UAE, many initiatives were taken by the STEM promoters to implement effective STEM education as the UAE economy is moving from being oil-based to knowledge-based and that requires more students to graduate as scientists and engineers. STEM education must be implemented starting from the early years as this period is critical for the children's cognitive, social, and academic development. For STEM to be implemented effectively at the elementary level, the teachers must be well equipped to face the complicated and entangled web that enshrouds the STEM education field. Additionally, identifying teachers' perceptions of STEM education is considered as one of the ultimate significant processes that need to be considered by the STEM education stakeholders as the teachers' STEM practices are highly influenced by their perceptions of STEM. Similarly, the students' perceptions and practices of STEM education and the student's motivation to pursue careers in STEM fields are highly affected by teachers' perceptions of STEM education.

The purpose of this study was to explore the current provisions that are on offer in relation to STEM education and to investigate the teachers' and the students' perceptions of STEM education in Abu Dhabi private elementary schools. No studies had been conducted in the UAE context on this topic.

The researcher conducted an empirical study with an exploratory sequential mixed methods design to meet the purpose of the study. The mixed research methods included both qualitative and quantitative methods including document analysis, teacher questionnaire, and student questionnaire.

The document analysis reported eight themes related to the STEM status and implementation in private elementary schools in Abu Dhabi: (1) Integrated STEM-based curriculum, (2) Project-based learning, (3) Technology and Engineering Integration, (4) Teacher willingness to implement STEM, (5) 21st century skills and STEM, (6) Authentic STEM

classroom environment, (7) Authentic STEM Assessment, and (8) School Administration support of STEM integration. Results from the teacher and student questionnaires revealed that most of the elementary teachers and students in STEM private schools in Abu Dhabi have positive perceptions of STEM education. Also, elementary students were interested in STEM careers. Furthermore, quantitative findings related to the teacher questionnaire revealed that the majority of the elementary teachers in STEM private schools in Abu Dhabi strongly understand what STEM education is and they strongly agree that STEM competencies are extremely important. Yet, half of the teachers agree that they find difficulties in implementing STEM education. Qualitative data related to the teacher questionnaire revealed that these difficulties were related specifically to the lack of STEM resources, the constraint of time, and the need for professional development.

The study ends by discussing the findings of the study, highlighting the researcher's recommendations, and by outlining the limitations of this study.

Key Words: STEM Education, STEM Perception, Elementary Level, Abu Dhabi, STEM Private Schools

ملخص

يشكل تعليم العلوم والتكنولوجيا والهندسة والرياضيات (STEM) أحد أهم مجالات الإصلاح وأبرزها في قطاع التعليم. وهو يندرج كأولوية ضمن البرامج الوطنية للدول المتقدمة صناعياً واقتصادياً نظراً للاعتراف السائد بمساهمته في تحضير التلامذة للثورة التكنولوجية التي يمرّ بها العالم.

أطلق مروجو STEM في الإمارات العربية المتحدة باقةً من المبادرات الآيلة إلى تطبيق تعليم العلوم والتكنولوجيا والهندسة والرياضيات بشكل فعّال على ضوء تحوّل الاقتصاد في دولة الإمارات من النفط إلى المعرفة، الأمر الذي يستدعي المزيد من حملة شهادات العلوم والهندسة.

لا بدّ من اعتماد تعليم STEM منذ مراحل التعليم الأولى لأنها تعدّ أساسيةً للنمو المعرفي والاجتماعي والأكاديمي لدى الأطفال. ولكي يطبّق تعليم STEM بشكل فعّال عند مستوى التعليم الابتدائي، يجب أن يكون المعلمون محصّنين لتذليل العقبات والتعقيدات التي تكتنف تعليم STEM. علاوةً على ذلك، لا بدّ من تحديد تصوّرات المعلمين بشأن تعليم STEM وهي إحدى أهم العمليات التي يجدر بالجهات المعنية بتعليم STEM الأخذ بها نظراً لتأثير ممارسات المعلمين في مجال STEM إلى حدّ كبير بتصوّراتهم في هذا السياق. على نحوٍ مماثل، تتأثّر تصوّرات التلامذة وممارساتهم المتعلقة بتعليم STEM وشعورهم بالاندفاع لاختيار مهنة في مجالات مرتبطة بـSTEM بشكل كبير بتصوّرات المعلمين في هذا المضمار.

ترمي هذه الدراسة إلى نقصيّ تصوّرات المعلمين والتلامذة في مجال تعليم العلوم والتكنولوجيا والهندسة والرياضيات (STEM) في المدارس الابتدائية الخاصة التي تعتمد هذا التعليم في أبو ظبي. لم تتفدّ أيّ دراسة حول هذا الموضوع في الإمارات العربية المتحدة إلى تاريخه.

أجرت الباحثة دراسةً تجريبية واعتمدت تصميمًا يقوم على أساليب استكشافية تسلسلية مختلطة لتحقيق الهدف من الدراسة. تضمّنت أساليب البحث المختلطة وسائل نوعية وكمية على حدّ سواء تقوم على تحليل للمستندات، الاستبيانات الخاصة بالمعلمين، والاستبيانات الخاصة بالتلامذة.

اشتمل تحليل المستندات على ثمانية مواضيع متعلّقة بوضع STEM وتطبيقه في المدارس الابتدائية الخاصة في أبو ظبي، ألا وهي: (1) المناهج الدراسية المدمجة المرتكزة على STEM، (2) التعليم المستند إلى مشروع، (3) إدماج التكنولوجيا والهندسة، (4) استعداد المعلم لتنفيذ STEM، (5) مهارات القرن الحادي والعشرين وSTEM، (6) البيئة الحقيقية التي يجب أن تسود صفّ STEM، (7) التقييم الحقيقي لـSTEM، و(8) دعم إدارة المدرسة لإدماج STEM.

عكست النتائج المنبثقة من استبيانات المدرّسين والتلامذة تصوّرات إيجابية لتعليم STEM لدى غالبية المعلمين والتلامذة في المدارس الخاصة التي تعتمد STEM في أبو ظبي. كما أبدى تلامذة المرحلة الابتدائية اهتماماً في المهن المتصلة بـSTEM. على صعيد آخر، أظهرت الاستنتاجات الكمية الناشئة عن استبيانات المدرّسين أنّ غالبية المدرّسين في المدارس الابتدائية الخاصة التي تعتمد STEM في أبو ظبي يحسنون فهم معنى تعليم STEM ويوافقون بشدّة على الأهمية القصوى التي تكتسبها مهارات STEM. غير أنّ نصف المعلمين أجمعوا على أنّهم يواجهون الصعوبات في تطبيق تعليم STEM. وقد

أظهرت البيانات النوعية المستمدة من استبيانات المعلمين أنّ هذه المشاكل ناشئة بشكل خاصّ عن غياب الموارد والقيود الزمنية والحاجة إلى التطوير المهني.

تختتم الدراسة بمناقشة الاستنتاجات التي خلّصت إليها وبسرد توصيات الباحثة وبذكر القيود التي تعترضها.

الكلمات المفتاحية: تعليم العلوم والتكنولوجيا والهندسة والرياضيات (STEM)، التصوّرات المرتبطة بـ STEM ، المرحلة الابتدائية، أبو ظبي، المدارس الخاصة التي تعتمد تعليم STEM.

DEDICATION

I dedicate this thesis to my Lord.

The strength that I gain from my faith in you has enabled me to overcome all difficulties in my educational journey.

Thank you.

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I wish to express my sincere gratitude to Prof. Sufian Forawi, my Director of Studies at the British University in Dubai (BUiD), for his tremendous support and guidance in completing this dissertation. It was a great honor to accomplish my highest postgraduate achievement under his supervision.

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To my children, Bahaa and Noor Hassanieh, learning has no limits. I hope that I am able to be a role model in showing you that nothing is impossible and success is achieved with extraordinary determination, resilience, and commitment. Aim to the stars my darlings.

Most importantly, to my husband, Nazih Hassanieh, thank you for the amazing support and care you offered me throughout this challenging period of my life. The faith you put in me and the sacrifices you made on my behalf have eased and sparkled my journey in different ways. You are my backbone and the rock I lean on whenever I feel lost, fatigued, or challenged. I owe you the utmost degree of gratitude.

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CHAPTER 1: INTRODUCTION

Education is vital in leading the vision for a flourishing and sustainable development in a nation (Agbedahin, 2019). The United Nations (UN) in its seventieth general assembly agreed on seventeen sustainable development goals which were renowned as the global goals or the 2030 agenda for sustainable development. Kahle and Gurel-Atay (2013) defined sustainable development as “the practice of maintaining the productivity by replacing resources used with resources of equal or greater value without degrading or endangering natural biotic systems”. Magee et al. (2013) added that sustainable development has to be endeavoured via “the lens of four interconnected domains: ecology, economics, politics, and culture”.

The fourth sustainable development goal (SDG 4) elucidates the agenda for global education (Organization for Economic Cooperation and Development, 2017). Warranting that all learners attain knowledge and skills to endorse sustainable development is one of the agenda’s ten targets (Uvalic-Trumbic & Daniel, 2016).

Education for sustainable development is described as a method of learning of how to take decisions that ponder the long-term future of the economy, ecology, and equity of all communities (UNESCO, 2016). Moreover, education for sustainable development grants education to improve sustainable development by incorporating practices, values, and principles of sustainable development into all parts of education (Uitto et al., 2011). Besides, as it comprises environment, economy, and society, the apprentices must gain “basic knowledge from the natural sciences, humanities, and social sciences before they can comprehend the values of education for sustainable development” (McKeown et al., 2002, p.6).

Fundamentally, STEM education befits a favorable place for the achievement of the agenda of the fourth sustainable development goal (SDG 4) as it doesn’t only improve the learners’ learning achievement, but it also expands their problem-solving skills (Mathis et al., 2018) and nurtures them to fulfill STEM sub-subjects and pursue STEM careers (Vennix, den Brok & Taconis, 2018).

1.1 Context of the Research Study

Science, Technology, Engineering, and Mathematics fields or subjects are referred to in education by the acronym STEM (Hacioglu & Gulhan, 2021; Permanasari, Rubini & Nugroho, 2021). STEM has no definitive definition (Dare, Ring-Whalen & Roehrig, 2019; Gao et al., 2020). In fact, in some places, it substitutes the terms of mathematics and science (Breiner et al., 2012); however, in other places, it denotes a farther integrated approach to teaching and learning that imposes explicit affiliations among disciplinary content and practices (Delahunty, Prendergast & Ní Ríordáin, 2021; Kelley & Knowles, 2016; Permanasari, Rubini & Nugroho, 2021), where students are expected to “work in the context of complex phenomena or situations on tasks that require them to use knowledge and skills from multiple disciplines” (Honey et al., 2014, p.52). Still, with several definitions of STEM education that aim to establish a paradigm shift from the individual subject approach to teaching real-life skills in order to solve real-life problems (El Sayary, Forawi & Mansour, 2015), the literature related to integrated STEM approaches reveals common features. These features are; for instance, the inclusion of an engaging real-world context (Dare, Ring-Whalen & Roehrig, 2019; Delahunty, Prendergast & Ní Ríordáin, 2021; Permanasari, Rubini & Nugroho, 2021), the premeditated and explicit liaisons between the four domains: science, mathematics, engineering, and technology (Gao et al., 2020; Honey et al., 2014; Sirajudin & Suratno, 2021), the modeling of the four domains as they will potentially be utilised in STEM careers (Kelley & Knowles, 2016), the intended insertion of the 21st-century skills such as collaboration, communication, creativity, and critical thinking (Bryan et al., 2015; El Sayary, Forawi & Mansour, 2015; Hacioglu & Gulhan, 2021; Honey et al., 2014), the use of technology to create and communicate innovative solutions (Sirajudin & Suratno, 2021), and lastly an accent on the student-centered academic strategy to support apprentices developing problem- solving and critical thinking skills (Bryan et al., 2015; Hacioglu & Gulhan, 2021; Permanasari, Rubini & Nugroho, 2021; Rinke et al., 2016; Sirajudin & Suratno, 2021).

STEM education has been considered as a foremost concentration in the system of education to achieve global competitiveness. It has been adopted in several programs in order to positively impact the levels of students’ achievement by improving and reforming their educational structures (English, 2016). Moreover, McKinney de Royston and Sengupta-Irving

(2019) stated that the world is moving towards a knowledge-based economy where the outsized mass of jobs will be allied to vocations focused on Science, Technology, Engineering, and Mathematics (STEM); in other words, STEM education should be the focus of schools and students should be involved with STEM education in their early years in order for their interest to be stimulated and to be exposed to a realm on the rim of a technological revolution.

The STEM conception fluctuates among the STEM's educational stakeholders. For instance, some of them view STEM as an innovative approach to teach its subjects or as an advantageous combination of the science, technology, engineering, and mathematics disciplines. Thus, others view it as a novel curriculum that connects the four academic disciplines. Hence, there is a consensus that this curriculum has to be applied through an active way of teaching and learning and should depend on problem-based learning to solve real-world problems (STEM Task Force, 2014).

STEM education originated in the United States (US) as SMET (Science, Mathematics, Engineering, and Technology) at the beginning of the 1990s (Martín-Páez et al., 2019) with the National Science Foundation (Kelley & Knowles, 2016) where the US Government created a learning program to prepare the high school alumni to be capable to compete internationally (Breiner et al., 2012). In the last decade, numerous researches have appraised the movement of STEM education especially in the secondary school level (Hudson et al., 2015) such as, in Australia (English, 2016; Timms et al., 2018), in India (Bhagat & Vijayaraghavan, 2019), Finland (Su, Ledbetter & Ferguson, 2017), the United Kingdom (Smith & White, 2019), Africa (Barakabitze et al., 2019), Asia (Lee, Chai & Hong, 2019; Shahali et al., 2016), Spain (Castellanos, Haya & Urquiza-Fuentes, 2016; Toma & Greca, 2018), the United States (Beckett et al., 2016; Suter & Camilli, 2019; Toth, 2016), and in the middle east such as in Saudi Arabia (Madani, 2017), Lebanon (Makarem, 2019), and Jordan (Al-Haj Bedar & Al-Shboul, 2020; Al-Muhaisin & Khaja, 2015).

To be implemented in an effective way, the STEM's four disciplines have to be addressed via the principles of Vygotsky's social development theory (Vygotsky, 1978). For instance, in

STEM classes, students should socially interact and actively collaborate to solve real-world problems, develop their critical thinking, and build their own learning experience. Moreover, STEM education has to be approached through a learner-centered approach where students have to be at the center of the learning process by actively participating and contributing to all hands-on STEM activities held in class, as per the Dewey's theory of integration principles (Dewey, 1938; Hassan et al., 2019).

Although STEM education requires the students to be the main and active participants in class, yet, STEM teachers play a vital role in the students' learning process. They are the mentors who facilitate the students' learning process by providing a suitable learning environment in order to scaffold their cognitive skills, and attain their learning goals (Hassan et al., 2019; Vygotsky, 1978).

The United Arab Emirates (UAE) considers education as a keystone for sustainable development (Assaf, 2020) and a basis for its 2021 vision which was initiated by his Excellency Sheikh Mohammed bin Rashid Al Maktoum, Vice-President and Prime Minister of the UAE and Ruler of Dubai, at the closing of a Cabinet meeting in 2010 (Patent, 2017; Vision UAE, 2021) and which aimed at providing a world-class education by stipulating innovative educational standards, developing scholars' critical thinking, and generating intellectual autonomy (Ministry of Education, 2016). Hence, H.H. Sheikh Mohammed bin Rashid Al Maktoum approved a set of national indicators known by the UAE national agenda. These long-term indicators which were established by more than three hundred officials from ninety federal and local government entities are periodically monitored and they lead to the UAE 2021 vision. These indicators are used to evaluate the performance outcomes of different sectors such as the sectors of education and healthcare and they compare the UAE against global benchmarks (Vision UAE, 2021). Furthermore, the Ministry of Education (MoE), along with its strategic partners, placed a resilient plan to employ its ample potential to foster the national human capital by expanding participation in high-quality education, emboldening entrepreneurship, and encouraging the leaders of both public and private sectors. Moreover, through the collaboration of the MoE and the Higher Education, the UAE was able to emphasize both, the equity and the quality from nursery to

higher education in order to fulfill the gap between the needs of the labor markets and the academic requirements (Ministry of Education, 2016). The UAE also installed a smart learning program in order to accelerate the progress towards the sustainable development goals (The UAE portal for the sustainable development goals, 2020). Additionally, the MoE, within the context of the annual meetings of the government of the UAE, launched the National Strategy for Higher Education 2030 where his Excellency Hussain Al Hammadi, Minister of Education, asserted that education is a priority for the leadership and announced that the UAE is developing an educational model which is intended to be one of the world's top models depending on the Higher Education Strategy 2030 (Ministry of Education, 2020). By doing so, the UAE is working on establishing a strong and high-quality educational vocational as well as an academic system to promote successful research outputs that are conducive to driving the helm of the knowledge-based economy (Ministry of Education, 2020).

STEM education is considered new in the UAE (Al Murshidi, 2019). In fact, it was implemented in the UAE in 2010 when several schools adopted the Next Generation Science Standards (NGSS) in their science curricula (Ahmed, 2016). Many initiatives were taken by the STEM promoters in the UAE to implement effective STEM education as the UAE economy is moving from being oil-based to knowledge-based and that requires more students to graduate as scientists and engineers (National Academies of Sciences, 2018). Sheikh Mohammed bin Zayed, Crown Prince of Abu Dhabi and Deputy Supreme Commander of the UAE Armed Forces stated that the UAE students' practises of engineering, technology, and finance are imperative to the information-economic revolution in UAE and he encouraged them to join scientific fields and careers. Furthermore, in order to match the UAE's government's vision 2021, the MoE executed the educational development program for mathematics and science in an attempt to mend the integrated STEM education (Bahrum, Wahid & Ibrahim, 2017; Warner & Burton, 2017). For instance, supporting scientific literacy and developing mathematics and science curricula were within the initiatives of this program. In fact, the latest curricula in the UAE are founded on McGraw Hill Education's textbooks which were Arabized (Al Quraan, 2017). However, studies in the UAE reveal that few students are joining the STEM fields (Alyammahi et al., 2016).

Additionally, several studies were conducted in the UAE in the last decade to create awareness for STEM-based education, to specify its needs, to suggest implementation frameworks and effective instructional policies and practices of STEM education, and to explore the females' representation in STEM areas (Abdallah, 2017; Al Basha, 2018; Al Quraan & Forawi, 2019; Alblooshi & May, 2018; Assaf, 2020; Cairns & Dickson, 2021; Hathcock et al., 2015; Houjeir et al., 2019; John & Manoj Mechankara, 2018; Soomro, 2019). Yet, very few studies were conducted to explore the STEM teachers' perceptions of STEM education in the UAE regarding the challenges and barriers that they encounter to execute integrated STEM education in a successful way in their classrooms (Abdallah, 2017; Al Basha, 2018; Al Quraan, 2017) although they are considered as critical elements to guarantee the fundamental structure of the SDG 4 targets (Organization for Economic Cooperation and Development, 2017) and the vanguard of STEM implementation in academic establishments around the world (Aslam, Adefila & Bagiya, 2018; Watermeyer & Montgomery, 2018).

Limited instruments were developed to measure teachers' perception of STEM education and fewer instruments were developed to study the STEM students' perception. For instance, Thi To Khuyen et al. (2020) developed a survey with an aim to investigate the Vietnamese teachers' perceptions in order to sustain the STEM education development in Vietnam. The valid and reliable survey consists of three components: STEM education, value of STEM competencies, and STEM difficulties. This study investigates the teachers' perceptions of STEM education in private elementary schools in Abu Dhabi. In order to examine the students' perceptions of STEM scientific disciplines (science, mathematics, engineering, technology) and STEM careers in STEM schools in Abu Dhabi, the researcher developed a questionnaire based on the quantitative, valid, and reliable cross-sectional STEM semantic survey (Tyler-Wood, Knezek & Christensen, 2010) which was adapted from Knezek and Christensen (1998) Teacher's attitudes Toward information Technology Questionnaire (TaT) and which is available online.

1.2 Statement of the Problem

One of the furthestmost essential reforms in education is STEM education (Al Basha, 2018; Yoh et al., 2021). It comes as a priority in the industrially and economically developed

nations' national agendas (Guzey, Harwell & Moore, 2014; Hacioglu & Gulhan, 2021; Permanasari, Rubini & Nugroho, 2021) as it is known as an approach for preparing learners for the technological revolution that the world is experiencing, for increasing job opportunities in STEM (Li et al., 2019; McClure et al., 2017) and for an economic boost, technological innovations, and national prosperity and security to a country as a whole (Li et al., 2019).

STEM education has to be implemented from the early years as this period is critical for the children's cognitive development where they come into contact with stimuli that grant the growth of a conscious perception of how the world works (Baltsavias & Kyridis, 2020; Schmidt & Fulton, 2016). Fostering STEM starting from the early years is considered significant in the development of the students' motor and social skills. More, learners can develop fine motor skills, acquire visualization skills and develop communication skills, scientific literacy, and vocabulary use more effectively than when STEM is introduced in higher schooling years (Holter, 2017). Moreover, early STEM learning experiences enhance the students' interests and attitudes towards STEM and contribute to positive academic trajectories in STEM fields (Ricks, 2012). STEM education helps students become highly skilled and better logical thinkers and achievers, problem solvers, innovators, inventors, and technology literate by developing their technological dexterities (Delahunty, Prendergast & Ní Ríordáin, 2021; Morrison, 2006). Wheelock College Aspire Institute (2010) stated that by fostering STEM education starting from the early years, teachers help boost the students' overall learning by stimulating their curiosity and interest in engineering and hands-on experimentation. Additionally, Chesloff (2013) and Toma and Greca (2018) asserted that although investing in STEM education in early childhood is considered an issue for educational stakeholders, it is mandatory to foster STEM education at elementary levels and to focus on Mathematics discipline from the age of one to four, where the brain is remarkably alert to acquire mathematics. Thus, Alumbaugh (2015) affirmed that an introductory-level STEM within a high-quality learning environment provides the elementary students with a structure that can help them explore, build, and question in a natural way. Alumbaugh's (2015) findings revealed that young students who practice STEM education at elementary levels via hands-on learning acquire and sustain a superior understanding of STEM disciplines when they progress to middle and high school. While Pfeiffer, Overstreet and Park

(2009) confirmed that STEM education enhances the elementary students' creativity, understanding, and learning especially when problem-based learning is used. Bilgin, Karakuyu and Ay (2015) added that the executed creativity in STEM pushes the students to be more adventurous and to search for solutions for the current challenges in a nation and consequently, to achieve national goals in the future. Therefore, since interest in STEM subjects and STEM careers are mainly bent while youngsters attain the upper elementary school level, it turns out to be increasingly and significantly critical that the youngsters' interest in these areas be caught, promoted, and supported during the early elementary grades, way earlier than the moment they register in courses driving to ultimate career paths during high school and college (Daugherty, Carter & Swagerty, 2014). In addition, extra studies related to students' needs in STEM education in elementary levels are in need especially that Bentley (2021) affirmed that research and interest in STEM at the elementary level has unquestionably had the least focus among all educational levels in the last decade.

Besides, STEM teachers are considered the vanguard of STEM implementation in academic establishments around the world; the leaders with an aim to train scientists and technologists who partake in the foundation of a sustainable and prospering economy, and the front-runners and drivers of the learning process who are needed for the development of nations, research, and innovation (Aslam, Adefila & Bagiya, 2018; Flogie, Dolenc & Aberšek, 2015; Lazarides & Warner, 2020; Wahono & Chang, 2019; Watermeyer & Montgomery, 2018). Yet, to implement and enhance STEM curricular activities in an effective way, the pre-service and in-service teachers have to be well equipped to face the complicated and entangled web that enshrouds the STEM education field (Assefa & Rorissa, 2013). Identifying teachers' perceptions of STEM education is considered one of the ultimate significant processes that need to be considered by the STEM education stakeholders (Srikoom, Hanuscin & Faikhamta, 2017) as the teachers' STEM practices are highly influenced by their perceptions of STEM (Thibaut et al., 2018).

Various studies were conducted to investigate the in-service and pre-service teachers' perceptions towards teaching STEM as well as to explore the STEM implementation in classrooms (Srikoom, Hanuscin & Faikhamta, 2017). Bell (2016) stated that the teacher's perception of STEM education affects his/her way of delivering it in his/her class and it is

considered an aspect that offers a wealth of information related to STEM subjects, to STEM teachers, and to the STEM educational system (Wahono & Chang, 2019). However, there is ambiguity around the STEM teachers' perceptions. The STEM perception and good practices along with the criteria of a successful STEM education are still unclear and confusing in the United States and the other countries implementing STEM education (Bruce-Davis et al., 2014; Margot & Kettler, 2019). Furthermore, studies indicate that STEM teachers, in general, lack pedagogical knowledge and efficacy especially when it comes to science and mathematics and that can influence their motivation in planning and implementing STEM activities negatively and consequently affect the STEM education development, the students' perceptions and practices of STEM education, and the students' achievement and motivation to pursue careers in STEM fields (Al Quraan, 2017; Brown et al., 2016; Delahunty, Prendergast & Ní Ríordáin, 2021; Gülhan & Şahin, 2016; Hacıoglu & Gulhan, 2021; Lazarides & Warner, 2020; Permanasari, Rubini & Nugroho, 2021; Sirajudin & Suratno, 2021).

Additionally, the teachers' perceptions of STEM education affect the students' perceptions and practices of STEM education (Bell, 2016). Goldston and Downey (2012) suggested numerous tips for the teachers to follow to engage students in STEM education. For instance, teachers are encouraged to utilize the students' interests and input in STEM education to facilitate their learning. Teachers are also requested to encourage students to ask questions and address their concerns in STEM education. And, they need to offer non-compulsory challenging STEM activities once students have accomplished their initial work. Marzano (2013) encouraged the teachers to reflect on few questions in order to engage the students in STEM learning. For instance, teachers need to ask themselves if they are providing a safe, caring, and stimulating STEM learning environment for their students, if they are making STEM education interesting, if they are demonstrating why the STEM content is significant, and if they are helping the students realizing that their efforts in STEM are key to their success.

In order to attract students to the STEM fields and to increase academic rigor in its educational system, the UAE encouraged the establishment of private schools which are open to all nationalities. The majority of the private schools in Abu Dhabi follow British or American curricula and recruit Western, English native speaking teachers who offer high quality education

and learning and help the students in building strong skill sets to be able to enter top universities in Emirates or abroad (McKinnon, Barza & Moussa-Inaty, 2013). Besides, one of the four pillars of the UAE centennial, which aims to prepare the students with the skills needed to face the rapid changes and to place the UAE between the best countries in the world by 2071, is the “Excellent Education” that focuses on STEM subjects such as engineering, technology and science (Pillars of UAE Centennial 2071, 2021) and the main priority of the MoE along with Abu Dhabi Department of Education and Knowledge (ADEK) in Abu Dhabi and the Knowledge and Human Development Authority (KHDA) in Dubai is to implement the STEM subjects in the UAE schools and to foster them with three main elements, which are the students’ critical thinking, the problem-solving skills, and the use of technology (Al Basha, 2018; Al Quraan, 2017; Ibrahim & Mahmoud, 2017; Knowledge and Human Development Authority (KHDA), 2017; Lazarides & Warner, 2020). Yet, few studies were conducted to tackle teachers’ perceptions of STEM education in the last decade. The research studies in the UAE disclosed that STEM implementation in the UAE necessitates further support for teachers’ knowledge and practices via professional training and workshops, adequate time for teacher collaboration, availability of the necessary STEM resources and environments such as STEM labs, campuses, and funding, adequate time to implement STEM activities. strong leadership for better guidance, and strong coordination among the UAE government with the energy authorities and the educational institutions, which contribute to a sturdy STEM reform and an effective STEM implementation (Abdallah, 2017; Al Basha, 2018; Al Quraan, 2017; Assaf, 2020; Eltanahy, 2019; Fouad, 2018; Jarrar, 2020; Malaka, 2018).

Several initiatives were taken in the UAE to meet the students’ and the teachers’ needs in STEM education in a way to enable teachers to implement STEM education with effective methods and students to be motivated to enroll and embrace STEM areas which are keys to economic and technological development in the UAE (Malaka, 2018; Zahran, Pettaway & Waller, 2016). However, despite the remarkable initiatives toward STEM education in the UAE, few students are joining the STEM fields. Studies revealed that there are many reasons behind the student's lack of interest in selecting careers in STEM subjects. For instance, Alyammahi et al. (2016) stated that the deficiency of STEM capable teachers, the lack of STEM role models, and

the difficulty of the English language of instruction are a few of the many reasons affecting the students' choices in STEM education.

One of the essential reforms in education is STEM education (Al Basha, 2018) and the appeal of integrative policy of education calls for constructivist-based approaches that are deemed highly effective within STEM curricula because of the integrative nature of its concepts that include a myriad of constructivist practices to help build 21st -century skills within students.

STEM education has to be fostered starting from the early years to provide the students with an authentic development and means to improve their problem-solving skills while exploring the real-world problems in the global sphere (Hollingshead et al., 2016). In the UAE, every school has its own approach in STEM education, especially the private schools which have different curricula (Al Basha, 2018). Hence, it is not definite that these approaches are effective or successful in STEM education, neither it is certain that they can accomplish the MoE targets and the goals of the national agenda 2021 or the Pillars of UAE Centennial 2071. Thus, Gallagher (2019) noted that several attempts had been undertaken to increase the quality of STEM education and implementation in the UAE. For instance, STEM leaders are providing teachers with professional development such as training and workshops to support them, motivate them, to clarify their misunderstanding of STEM content and core concepts, and to enhance their STEM skills and practices. Nevertheless, these efforts necessitate a comprehensive and proper examination that guarantee that the implementation is running seamlessly, steadily, and successfully (Wahono & Chang, 2019). Besides, examination plays a vital role in improving the education system in general, and the curricula, the quality of teaching, and in specific student learning (Coy et al., 2019).

Therefore, the researcher finds it significant to conduct an in-depth study in order to explore the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools and to investigate the teachers' and the students' perceptions of STEM education in private elementary schools in Abu Dhabi in order to reveal more findings about the provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools and how STEM education is perceived in the UAE. The findings of this study

will be an added value to the literature of STEM education in the UAE by constraining the literature gap generated by the dearth of studies around STEM in the UAE (Jarrar, 2020; Malaka, 2018) and they will as well inform the STEM educational stakeholders and STEM scholars with enough knowledge about the obstacles and the necessary needs to implement STEM in an effective way to sustain its development, especially in elementary schools. This study will be unique especially that no studies, upon to the best of the researcher's knowledge, had been conducted to tackle the teachers' and the students' perceptions of STEM education in private elementary levels in Abu Dhabi.

1.3 Purpose and Objectives of the Study

The purpose of this study is to explore the current provisions that are on offer in relation to STEM education and to investigate the teachers' and the students' perceptions of STEM education in Abu Dhabi private elementary schools.

STEM education has been drawing the researchers' attention, internationally, in the last decades as it is considered as an effective means utilized to enhance the STEM learners' scientific knowledge and literacy. Besides, it fosters the students' aspirations and attainment by encompassing them in a comprehensive curriculum with related and connected instructions from the four STEM disciplines which are science, technology, engineering, and mathematics (Kelley & Knowles, 2016; Walker, 2017).

Identifying teachers' perceptions of STEM education is considered as one of the ultimate significant processes that need to be considered by the STEM education stakeholders and researchers (Srikoom, Hanuscin & Faikhamta, 2017) since first, teachers are considered the cornerstone for the advancement of education and its sustainability, and second, their perceptions of STEM education affect their practices in classrooms (Thi To Khuyen et al., 2020). Recently, the UAE started focusing on developing and improving STEM education. Several studies were conducted to shed the light on STEM policies and their implementation in order to elucidate information and reform curricula to empower students with enough knowledge and practices in STEM areas (Forawi, 2020). Thus, limited studies were conducted to elucidate the teachers' and students' perceptions of STEM education.

Al Basha (2018)'s study was among these studies that looked into the teachers' perceptions and implementation of STEM education in the UAE. Although the author used a mixed method approach by utilizing a questionnaire and interviews to collect data and to reveal the teachers' perceptions of STEM education, her scale was limited on collecting data from only teachers who teach in private American system schools in the UAE. Hence, the current mixed method study presents a more robust snapshot of STEM perceptions in private schools by revealing data and information coming from both, teachers and students from STEM private schools, from different schools' systems in Abu Dhabi, and with an emphasis on elementary levels.

The aim of this study is to shed the light on elementary teachers' and students' perceptions of STEM education in private elementary schools in Abu Dhabi due to its significance and its effect on students' education and careers in the future.

The researcher will conduct an empirical study with an exploratory sequential mixed methods design (Creswell & Clark, 2017) to meet the purpose of the study. First, the researcher will be analyzing valuable and related documents to STEM education in private elementary schools in Abu Dhabi such as elementary STEM evidence-based curricula, STEM study plans, ADEK schools' inspection reports, and elementary students' artefacts via a thematic analysis method to explore the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools. Second, a teacher questionnaire will be administered to elementary STEM subject teachers (Science, Mathematics, ICT) in the mentioned schools in order to investigate their perceptions of STEM education. Additionally, the researcher will be examining the elementary students' perceptions of STEM education and their interest in STEM careers through a student questionnaire.

The following research objectives are shaped in light of the study's purpose:

1. Explore the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools.

2. Investigate the elementary STEM teachers' and students' perceptions of STEM education in private schools in Abu Dhabi.
3. Investigate if there are any demographic differences in elementary teachers' and students' perceptions of STEM education in private schools in Abu Dhabi.

1.4 Research Questions

Studies of STEM education revealed that teachers' perceptions of STEM education are dependent on several variables such as the age, gender, educational background, level of education, taught subjects, STEM curriculum, and years of experience which seem to play a critical role in teachers' perceptions of STEM education. For instance, Margot and Kettler (2019) argue that the teacher's age, gender, and education background are factors that affect the teacher's perception of STEM education as the teacher's positive attitude towards STEM increases when the teacher's age increases. In general, male teachers have a more positive view of STEM education than female teachers and the number of related STEM courses taken in college eases the teachers' job and prepares them to teach STEM. Regarding the teachers' years of experience factor, Thibaut et al. (2018) assert that novice teachers express a less positive view of STEM education compared to experienced teachers. Parker, Kruchten, and Moshfeghian (2017) added that when the teachers' years of experience increase, the teachers' readiness to STEM implementation increases, but only if they value STEM education, and if not, the increasing number of years of experience does not affect the teachers' feelings of readiness to teach STEM. Furthermore, research disclosed that despite the teachers' positive attitude towards STEM education, teachers ask for pre-service and in-service professional development learning opportunities to improve their skills and abilities in planning STEM activities, in implementing STEM curriculum, in evaluating educational approaches suitable for each STEM activity, and in assessing STEM students (Altan & Ercan, 2016). Yet, the students' perceptions and practices of STEM education are affected by the extent of their enjoyment, motivation, engagement, and interest in STEM activities (Hwang & Taylor, 2016; Srikoorn, Hanuscin & Faikhamta, 2017) and by their teachers' perceptions and practices of STEM education (Bell, 2016). Moreover, the gender, the ability to access STEM knowledge, and the skills to solve real-world problems seem

to be vital factors for students in perceiving and practicing STEM education (Murphy, MacDonald & Danaia, 2020).

Hence, the main objective of this study is to investigate the teachers' and the students' perceptions of STEM education in private elementary schools in Abu Dhabi. In order to tackle the main objective, the following main question is shaped: What are the teachers' and students' perceptions of STEM education in private elementary schools in Abu Dhabi?

Yet, to address the main question, the following overarching research questions will be answered:

RQ 1: What are the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools.

RQ 2: What are the elementary teachers' and students' perceptions of STEM education in private schools in Abu Dhabi?

RQ 3: Are there any demographic differences in elementary teachers' and students' perceptions of STEM education in private schools in Abu Dhabi?

1.5 Significance of the Study

STEM education is known as a learning approach that integrates science, technology, math, and engineering. Hence, STEM is way beyond the idea of incorporating different subject areas together in one lesson. It derives from the teachers' mindfulness that the real-world problems are not split into distinct disciplines; therefore, students have to be taught with approaches that intentionally assemble knowledge, skills, and values from distinctive subject areas to teach a notion in a better way (Czerniak et al., 1999).

Sanders (2008) defined integrated STEM as an approach that explores teaching and learning between two or more of the STEM subject areas and/or between a STEM subject and one or more other school subjects (p.2). The path and the degree of STEM integration are highlighted in the literature by two approaches: the interdisciplinary and the multidisciplinary approaches (Wang et al., 2011). In the interdisciplinary approach, all the STEM-related subjects are integrated into one course while in the multidisciplinary approach, knowledge is integrated from separate STEM disciplines (Al Murshidi, 2019; McDonald, 2016; Ritz & Fan, 2015). Overall, STEM has to be approached by utilizing strategies of project-based learning, problem-

based learning, and inquiry-based learning and have to be swathed with collaboration, authentic problem-solving skills, design and technology, and higher-order thinking skills to decipher present issues and real-life problems (Ashton, 2014; Chalmers et al., 2017; Kennedy & Odell, 2014; Lesseig et al., 2016; Mandeville & Stoner, 2015; Mitts, 2016; Psycharis, 2016; Shernoff et al., 2017). Therefore, motivating and engaging students through hands-on activities are necessities to engage students in STEM. Besides, making real-world connection by creating relevant, authentic, and meaningful experiences for students can greatly motivate them and facilitate their problem-solving processes (Hwang & Taylor, 2016).

In UAE, studies reveal that most of the STEM teachers agree on defining STEM as a holistic approach that enhances the students' critical thinking and that intends to offer meaningful education, by integrating knowledge and skills from the four STEM disciplines (Al Basha, 2018). Yet, findings disclose that the teachers' perceptions and attitudes towards STEM fluctuate depending on many factors, especially on the level they teach. The way they implement and practice STEM differs from one school to another and from one level to another especially that curricula in UAE schools are founded on teaching classes of separate disciplines (Al Basha, 2018).

UAE, which is considered one of the advanced countries in the Gulf Cooperation Council (GCC), is undergoing a speedy expansion in several areas (Al Basha, 2018; Forawi, 2020). Focusing on STEM education programs, policies, perceptions, and practices in the UAE is fundamental and key for its sustainable development. UAE should have a foremost emphasis in the educational reform agendas. For instance, shedding light, exploring, and expending the investigation of STEM education in the UAE offer an opportunity to discuss its education and economic advantages. Additionally, this highlights the means to practice STEM efficiently. In fact, teachers are required to be knowledgeable and well-experienced with the development and innovation in science and technology to move from being technicians to professionals. Subsequently, teachers will be able to facilitate their students' active learning as well as providing them with opportunities to develop their innovative and creative skills to be able to survive in a highly competitive world (Forawi, 2020).

The private education system is well-developed in the UAE. Around forty percent of the total K-16 Multinational students attend the private schools in the UAE which exhibit diversified curricula that are displayed on different systems. The education system in the UAE follows a model of primary education (KG- G6) and secondary education (G7- G12). Moreover, tertiary education is well-developed with several foreign universities which are operating in the UAE. Yet, science education in general and STEM education in specific, are facing challenging problems. For instance, the deficiency of science teacher trainings and workshops, the unsustainable STEM curricula, and the ineffective implementation and practices of STEM education turn the private schools' students away from science and mathematics, and therefore away from STEM domain (Forawi, 2020).

This study is unique in the UAE as no studies up to the best of the researcher's knowledge were conducted to investigate the teachers' and the students' perceptions of STEM education in private elementary schools in Abu Dhabi. Hereafter, this study is significant by contributing to the STEM literature in the UAE. Throughout the present mixed-approach study, the researcher will collect qualitative and quantitative data from STEM private elementary schools in Abu Dhabi to enrich the literature on STEM education in general, and to provide valid conclusions on teachers' and students' perceptions of STEM education in private elementary schools in Abu Dhabi in specific. The results of this study are estimated further to reveal the extent of STEM implementation and the authenticity of the elementary STEM learning environments in the mentioned schools. Findings will provide information about the implemented STEM curricula, the learning settings and access to hands-on activities. More, the results of the study might be valuable in terms of stipulating implications for STEM elementary education program developers as teachers' perceptions affect and shape their decisions in STEM field and the students' perceptions affect their careers in the future. Additionally, this study will be a basis and a reference for further research in elementary STEM education by tackling the dearth of quantitative analysis and by adding to the present pool of qualitative knowledge vis-à-vis the elementary STEM education in the UAE.

1.6 Structure of Dissertation

STEM education is considered one of the most essential reforms in education in the UAE as it is known for preparing learners for the technological revolution that the world is experiencing, and for a country as a whole, for an economic boost and for national security. Teachers, who are considered as the vanguard of STEM implementation, should positively perceive STEM education so that it is implemented in an effective way. Furthermore, to pursue STEM careers in the future, students should have a positive perception of STEM education starting from the early years. This study will investigate the teachers' and the students' perceptions of STEM education in private elementary schools in Abu Dhabi in order to sustain its development in the mentioned schools. Chapter one provides an overview of the study by clarifying multiple definitions related to STEM education and by stating the problem of the research study along with its purpose. More, it highlights the significance of this investigation for the private elementary schools in Abu Dhabi within the UAE context. Lastly, the research questions were identified to guide the present research study and were addressed through a mixed-method research design. Chapter two will reveal the related literature to situate the present study and to be able to explain and compare its results with similar studies in the field. It will also propose a conceptual and a theoretical framework for the study. Chapter three will identify the choice of the mixed method design and the means to collect the quantitative and qualitative data for this study. Likewise, the validity and the reliability of this study will also be emphasised in this chapter. Chapter four will present the findings of the study, while chapter five will outline the discussion of the results, the conclusion, and the recommendations.

CHAPTER 2: THEORETICAL FRAMEWORK AND LITERATURE REVIEW

Overview of the Chapter

The purpose of this study is to explore the current provisions that are on offer in relation to STEM education and to investigate the teachers' and the students' perceptions of STEM education in Abu Dhabi private elementary schools.

STEM education focuses on student-centered and problem-solving approaches to learn via hands-on activities while equipping the students with skills, knowledge, and real-life experiences that prepare them to adjust to and to resolve real-life problems by taking well-versed decisions, especially in a high technological world-context (Al Quraan, 2017). The following chapter sheds light on the theoretical and conceptual foundations of STEM education as well as highlighting the different constructs of the study via three different sections: the theoretical framework, the conceptual framework, and the review of related literature.

The theoretical framework describes and discusses the key theories related to the topic of the study. It encompasses Vygotsky (1978)'s Sociocultural Development Theory, Dewey (1938)'s Theory of Integration, and Piaget (1957)'s Cognitive Development Theory. The conceptual framework involves a network of related components and a series of systematic associations linking different concepts that influence STEM education which is the main construct of the study. The different concepts that influence STEM education are categorized under the interpersonal and the structural categories. The interpersonal category includes the teacher knowledge and willingness, the value teachers place on STEM, the relevant authentic and meaningful experience for participants alongside with the teacher collaboration, and the outside support, such as support from advisors and scientists. Thus, the structural category is related more to physical things that should be in place for an effective STEM implementation such as STEM curriculum, STEM content, subject integration, PBL, PjBL, Design-based learning (DBL), time, professional development opportunities, and outside support such as support from organisations, museums, science centers, and industries. The review of the relevant literature is associated with recent studies that are related to the present study's constructs. It

offers a comprehensive delineation of STEM education and a gestalt of its four disciplines which are science, technology, engineering, and mathematics. It highlights the different STEM instruction approaches which are the disciplinary, the multidisciplinary, the interdisciplinary, and the transdisciplinary approaches. In addition, it offers wealthy reasons to ponder STEM education in elementary schools by emphasizing its significant effect on student achievement and motivation. Additionally, the related literature highlights the teachers' and students' perceptions and practices of STEM education alongside the challenges they confront to implement it. Furthermore, it identifies the STEM best practices leading to effective STEM integration. And lastly, it sheds light on the STEM schools' criteria and the STEM practices in the UAE schools. The review of literature is presented in this chapter under eight sections: 1) Definition of STEM education, 2) Integrated STEM education, 3) STEM teaching disciplines, 4) STEM teachers' perceptions, 5) Elementary STEM education, 6) Elementary STEM students' perceptions, 7) Obstacles in STEM education, and 8) STEM best practices. Undermentioned, a chapter summary will emphasize the major findings of the related literature to the teachers' and students' perceptions.

2.1. Theoretical Framework

Based on the literature, the learning techniques and approaches to STEM education are rooted in principles of problem-solving, inquiry-based learning, and learning via social-interaction. STEM integration is strongly associated to theoretical foundations that are grounded on overarching learning theories that can be referred to in order to implement an effective STEM education and therefore to positively affect the teachers' and students' perceptions and practices towards STEM education. Accordingly, the below theoretical framework (Figure 1) will be adopted for this research paper as a justification for STEM education. It includes Vygotsky (1978)'s Sociocultural Development Theory, Dewey (1938)'s Theory of Integration, and Piaget (1957)'s Cognitive Development Theory.

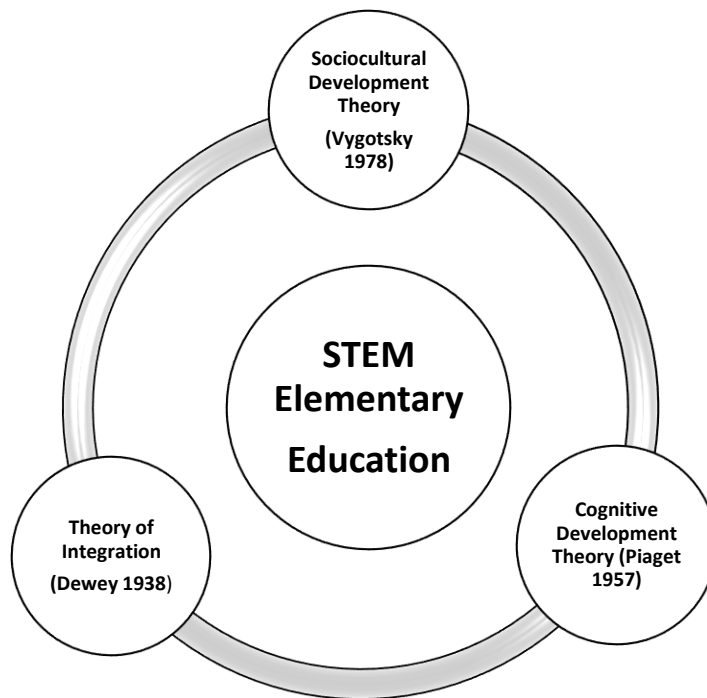


Figure 1: The theoretical framework of the present study

2.1.1 Vygotsky's Sociocultural Development Theory

Lev Vygotsky, the Russian social constructivist, claimed that learning is a social practice. Social interaction and communication are fundamental for the student's cognitive development and for the student's capability of constructing reality (1978). The social constructivism theory emphasizes the social contribution to the process of knowledge construction and states that human development is socially situated and knowledge is constructed through interactions with others. Therefore, it rejects the assumption of the possibility to segregate the learning from its social context (Vygotsky, 1978). Furthermore, Vygotsky believed that social interactions enhance and transform the students' learning experiences. These learning experiences via social interactions allow the students to construct new meanings from their knowledge base (Schunk, 2012).

The methodology of Vygotsky is similar to Socrates and Plato's one in calling for social interaction to enhance individuals' understanding in general and self-development in specific, via effective educational approaches that incorporate meaningful communication and effective social connections with more knowledgeable individuals in a language-rich environment (Alterio

& McDrury, 2003; Schunk, 2012). Additionally, Vygotsky (1978) stated that learning is a higher function that initiates from relationships among people, thus it occurs in two levels. Learning happens first, via social interaction on a social or inner-psychological level and second, through the integration into the learner's mental structure on an individual or intra-psychological level. Additionally, Vygotsky posited that besides playing a significant role in students' cognition development, the social contribution enhances the students' learning. For instance, the student's learning occurs through social interaction, via cooperative or collaborative dialogues between a More Knowledgeable Other (MKO) and the student (Vygotsky, 1978). The MKO refers to a tutor, such as a parent, a teacher, or a peer who is more knowledgeable or has better experience than the student concerning a specific concept or task. The MKO principle is integrated into the Zone of Proximal Development (ZPD) principle which denotes the difference between what a student can attain independently and what a student can attain with support from a MKO (Vygotsky, 1978). The ZPD is described as the limit of the cognitive development potential and the most suitable area for the delivery of sensitive instructions from a teacher or a more skillful peer in a language-rich environment (Schunk, 2012). These instructions allow the student to perform better than he/she does when alone. They also help the students to develop knowledge and skills necessary for the development of higher mental functions. Furthermore, Vygotsky pointed out the significance of the social interaction on developing the student language and the verbalization of ideas which are considered keys in the process of learning and the main individuals' means to communicate with the external world and to collaborate to achieve a given task (Vygotsky, 1962).

Hence, within a cognitively and linguistically stimulating learning environment, the Sociocultural Development Theory accents the need for collaborative learning through collaborative instructional activities such as problem-solving activities to enhance the students' creativity, to foster their higher-level thinking, and to push them to work in their ZPD beyond their comfort zone (Brown & Glasner, 1999; Schunk, 2012). Consequently, Vygotsky's sociocultural theory will be embedded in this study as it offers a framework for effective STEM education under the umbrella of student-centered instruction, where students can learn by constructing and scaffolding knowledge, by creating real and meaningful physical objects (Papert, 1980), or by programming meaningful models (Barak & Assal, 2018). They also learn

by understanding, interpreting, and exhibiting the STEM disciplines while interacting with each other in groups with different levels of ability where the more knowledgeable and experienced peers can help the less advanced ones to operate in their ZPD with their teachers, with their environment, or via interactions with and between networked nodes (Siemens, 2005) through problem-solving and project-based learning activities. In fact, “STEM PBL is grounded in the theoretical background of constructivism where students are engaged in the diverse components of problem-solving, interdisciplinary curriculum, open-ended questions, hands-on activities, group work, and interactive group activities” (Han, Capraro & Capraro, 2015, p.1093). Also, Drake and Burns (2004) defined STEM PBL as an interdisciplinary approach with constructivism method which permits the learners to approach their learning via a holistic means by collaborating with knowledgeable individuals. Smith (2018) described PBL as a learning approach that enhances the students’ knowledge scaffolding skills by collaborating, enhancing the scientific language via the enhancement of scientific verbal expressions, and transforming the acquired knowledge into a three-dimensional model to reveal the solution for a real-world problem.

Additionally, Adams (2006) argued that by applying STEM PBL projects in classrooms, teachers focus more on students’ interaction and collaboration rather than the subject matter. This shift enhances the students’ cognitive development by emphasizing the role of social interaction in constructing individual knowledge.

2.1.2 Dewey’s Theory of Integration

As the researcher is interested in exploring STEM education which is an integrative educational approach through which apprentices learn science, mathematics, technology, and engineering by doing, the researcher will be embracing the theory of integration (Dewey, 1938). John Dewey’s theory of integration is a pragmatic student-centered educational philosophy that states that reality has to be experienced and practical life skills via hands-on approaches are vital for the student’s progressive education. These powerful thoughts were translated later on to the basic principles of problem-based learning and projects-based learning (Westbrook, 2005).

Moreover, just like Vygotsky, the American philosopher Dewey asserted that engaging in real-world activities via collaboration and creativity enables the students to exhibit higher levels

of knowledge (Behling & Hart, 2008). Furthermore, Dewey's research claimed that learning does not happen through repetitive lectures and rote memorisation, rather it occurred via the connection between meaningful school activities and life experiences that meet the students' needs and not the teachers' ones (Bentley, 2021; Dewey, 1938). Additionally, Dewey touted progressive education which is based on the philosophy that learning occurs in social contexts such as in classrooms where students can communicate and collaborate besides being active, interactive, and lively involved in their learning via real-life experiences and age-appropriate activities (Bentley, 2021; Dewey, 1938; Doddington, Heilbronn & Higham, 2018).

Dewey and Vygotsky both asserted that teachers' observation is critical for students' learning. In fact, by observing the active learners in their student-centered classrooms, teachers can pinpoint the students' interests and skills. They can also assess the students' performance and build on each learner's knowledge by implementing a curriculum that is shaped to serve the needs of each learner and not the teachers' ones. Dewey's studies inquired for an integrative and experimentalist curriculum for learners to build a logical sense of the world where they live, to understand what they pursue as a whole, and to be able to deal efficiently with the modern world (Gutek, 2004). Moreover, in his experimentalist curriculum, the students would be using scientific methods in a meaningful way in order to solve real-world problems in their classrooms.

Dewey's experiments-centered curriculum would focus on using experiments to construct meaning and knowledge at the right developmental level (Bentley, 2021). According to Dewey's studies, subject matters would not be delivered in isolation, they would be taught in an integrated and natural manner in an experimentalist and student-centered classroom where students' interests and interactions are the major guiding force in teaching and learning. Therefore, Dewey would be a promoter of STEM education that is deeply rooted in integrative approaches that tout for integration of different disciplines in one classroom in order to solve real-world and meaningful problems via hands-on learning activities by interacting, collaborating, and communicating (Bentley, 2021; Julià & Antolí, 2019; Shahali et al., 2016). So, for effective STEM education, the whole child curriculum model can be suggested in addition to the experimentalist curriculum of Dewey as it encompasses the five main foci that

serve the learner as a whole. The five foci comprise engagement, challenging activities, support from others, safety, and health (Slade & Griffith, 2013).

According to Dewey (1938), the scientific method has significant power in involving students in their learning. For instance, when students formulate a hypothesis, search for information, collect and analyse data, and present meaningful conclusions, they move to be the center of learning in an educational environment where teachers play the role of facilitators (Schunk, 2012). The inquiry-based teaching approach is based on the scientific method where students are highly involved in their learning and touted to build their own knowledge by using practices of the scientific method and by being guided by a facilitator. Thus, the scientific method and inquiry-based learning are fundamental practices of STEM integration (Bentley, 2021). Like Dewey, Schiro (2013) pinpointed the significance of the learning context, especially for young students, in building knowledge and asserted that subjects should be delivered in an integrated way within the schools' classrooms where students are the center of learning. This learning method lends itself well to STEM education where teaching is centered around the students' needs and choices and where teachers focus on students' interaction and engagement to solve integrated problems by using inquiry-based teaching methods (Bentley, 2021).

2.1.3 Piaget's Cognitive Development Theory

The Swiss psychologist Piaget (1957) claimed that in an attempt to adapt to the environment, the learner utilises two processes: assimilation and accommodation. Assimilation is defined as the process of translating the environment in a way to fit the pre-existent cognitive structures or schemas, while accommodation is described as the practice of cognitive structures or schemas' modification in a way to acknowledge and accept new things or new information from the environment. The two processes are utilised in simultaneous and alternative ways through the learners' lives in order to achieve the required cognitive development and to adapt to the surrounding complex environment (Huitt & Hummel, 2003).

An elementary classroom includes students whose cognitive development is more logical than the kindergarten students but less abstract than the middle schoolers as per Piaget (1957). In an elementary STEM classroom, STEM students collaborate in small groups to explore and solve real-world problems via hands-on inquiry to make sense of their surrounding world, to be

successful; therefore, to adapt to their environment by floundering practically through several failed approaches and attempts till they reconnoiter the right option (Ormrod, 2009). This continuous practice or active learning that occurs through the interaction between the students' environment experiences/ engagement/product construction and their biological maturation helps the students to continuously acquire new knowledge, cognitive abilities, and skills.

Consequently, due to STEM education, the students undergo a healthy and continuous mental growth and they build a mental model of the world to adapt to their environment through two cognitive complementary processes related mainly to their mental thinking and reasoning known as assimilation and accommodation as per the cognitive development theory of Piaget (1957).

Furthermore, Piaget (1957) claimed that individuals are active learners. They play an active role in the learning processes while they go through four different stages of cognitive or mental development throughout their lives. Each stage is built upon its prior stage and is marked by a shift in the way the individuals perceive the world around them. For instance, the sensorimotor stage goes from zero to two years old and it is marked by the utilization of the five senses and rapid motor development, while the second stage is the preoperational stage. It occurs from two to seven years old; it is marked by the use of language to tell stories and describe things and the intensive use of the brain to upload information and build skills. The third stage is the concrete operational stage. It goes from seven to eleven years old and it is characterised by inductive logic and reasoning. The last stage is the formal operational stage. It goes from 12 years throughout the entire life. It is characterised by abstract thinking, deductive logic, and systematic planning.

At the elementary school level, the students fall in the concrete operational stage where they are required to experiment with different activities to develop their logical thinking and to learn how things work. Therefore, STEM education fits well this stage as problem-based activities are considered concrete events based on hands-on activities which require students to mentally or logically operate to find real solutions and succeed in solving problems (Cherry, 2018). Zollman (2012) argued that by exposing students to STEM education, they face real-life problems. Besides, students communicate, collaborate, and innovate to find real solutions; therefore, they are prepared for future careers. By doing so, the STEM education model fosters the four reflective abstractions of Piaget's theory which are interiorization, coordination,

encapsulation, and generalization within which the students acquire and construct their knowledge (Piaget, Mays & Beth, 1966). For instance, interiorization is defined as the translation of sequential actions into a creation of an internal process, while coordination is described as the process of coordinating two processes or more to gain a new one. Encapsulation is the translation of a dynamical process into a static one identified as a thematic object of thought. Lastly, the generalisation happens when the learner employs a prevailing schema to a broader compilation of concepts (Piaget, Mays & Beth, 1966). Zollman (2012) added that STEM projects such as problem-based projects require the students to synthesize the four STEM disciplines to innovate, create, and solve problems. Besides, PBL requires the students to intensively communicate and collaborate to find real-world solutions. Therefore, PBL can be identified as an educational strategy that meets the four, interiorization, coordination, encapsulation, and the generalization constructs suggested by Piaget.

2.2. Conceptual Framework

To meet the purpose of this study, which is to explore the current provisions that are on offer in relation to STEM education and to investigate the teachers' and the students' perceptions of STEM education in Abu Dhabi private elementary schools, it is beneficial to construct a conceptual framework (Figure 2) that encompasses a network of related components that influence the main concept of the study which is the STEM education (Kelley & Knowles, 2016). Therefore, the teachers' interpersonal factors and the STEM structural factors will be explored via the following conceptual framework which was created by the researcher based on the insights of recent research studies to better comprehend STEM education.

Studies disclose that STEM education is affected by a series of systematic associations linking different concepts that can be categorized under two categories: interpersonal and structural (Al Quraan & Forawi, 2019). The interpersonal category includes the teacher's knowledge and willingness, the value teachers place on STEM, the relevant, authentic, and meaningful experience for participants alongside the teacher collaboration, and the outside support, such as support from advisors and scientists.

For instance, the teacher's knowledge of STEM education is described as all the accommodated information about the characteristics of STEM education, its benefits and

drawbacks as well as the integration of its different disciplines (Sujarwanto & Ibrahim, 2019). The knowledge required for effective STEM education is broad and multifaceted. In fact, content knowledge, pedagogical knowledge, technological knowledge, student knowledge, assessment knowledge, and curriculum knowledge are the essential components of teacher knowledge (Chan, Yeh & Hsu, 2019).

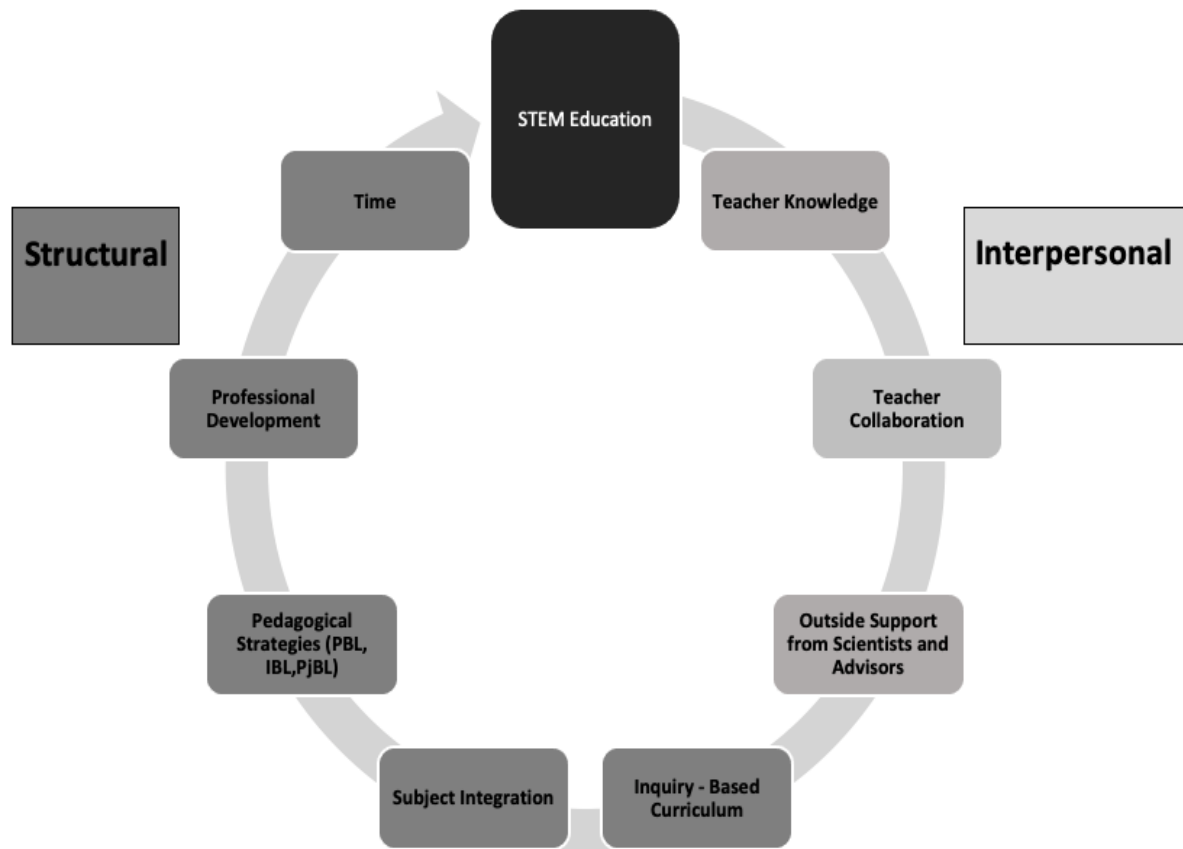


Figure 2: The conceptual framework of the present study

Collaborating with other STEM teachers enhances the sustainability of STEM programs and creates an effective learning atmosphere where the teachers' preparation for STEM lessons are improved (Herro & Quigley, 2017; Margot & Kettler, 2019). Also, the earlier teaching experience using pedagogical methods such as PBL or IBL as well as student-centered methods seems to increase the confidence of teachers in practicing STEM education (Park et al., 2016).

Thus, the structural category is related more to physical things that should be in place for an effective STEM implementation such as STEM curriculum, STEM content, subject integration, PBL, PjBL, DBL, time, professional development opportunities, and outside support, such as support from organisations, museums, science centers, and industries. Yet, for effective STEM integration, the latter factors should be present and should interact within an effective STEM learning environment. For instance, the presence of a quality, coherent, rigorous, inquiry-based, well-defined, flexible, and experiential integrated 21st-century STEM curriculum design founded on STEM concepts, tightly driven by standards, and compelled with clear goals and objectives would improve the probability of realization of STEM initiatives and implementation (Lehman, Kim & Harris, 2014). Moreover, STEM curriculum should be present with its STEM pedagogical content emphasizing the four STEM disciplines (S-T-E-M) and the different integrated subjects that should target real-world issues by adopting different pedagogical strategies with their various integrating methods such as PBL, PjBL, and DBL and their assorted cognitive integration areas such as planning, applying, experiencing, and discovering.

The STEM pedagogical content is related to the teacher's content knowledge and willingness to implement STEM which is affected by the teacher's authentic experience afforded by the school leadership and management. The school district support is mentioned as a vital factor for STEM success (McMullin & Reeve, 2014) and the teacher administrative support and guidance by constant communication along with teacher flexibility to expand the instruction beyond the national standards are mandatory for a successful STEM implementation (Bruce-Davis et al., 2014; El-Deghaidy, 2017). The teacher's content knowledge along with the professional development (PD) opportunities which are considered the main implementation factors for integrated STEM. For instance, research demonstrates that the availability of frequent and well-organised professional learning opportunities influences positively the teachers' practices and eases the success of STEM implementation (Lesseig et al., 2016).

Eventually, constant training and workshops are also needed for teachers' collaboration which is considered a must in a STEM community or a 21st-century learning environment. Teachers should acquire, adapt, and sharpen the questioning skills and the tactics for effective classroom management where they are expected to call on a range of strategies for illuminating

STEM topics, planning scientific experiments, directing students in scientific inquiry, and making sense of data (Ejiwale, 2012). Also, time is needed for PDs, planning, collaboration, reflection, teaching, implementation, and authentic STEM assessment. Time availability is considered a crucial factor for a successful STEM implementation besides the availability of funding, advisory services, outside support, and resources such as high-quality materials and technology tools which are considered the main factors for an effective STEM implementation. Lastly, studies reveal that the support of and the partnership with science community-based-centers are beneficial for teachers as they help them feel more comfortable in taking risks and in delving deeper into STEM concepts outside their comfort area (Al Quraan & Forawi, 2019; El-Deghaidy, 2017; Honey et al., 2014; Margot & Kettler, 2019; McLoughlin et al., 2020; Pugalenth, 2019; Walker et al., 2018).

For students to be granted increased access to STEM success, the literature suggests that they have to be well equipped with STEM content knowledge and skills to be able to solve complex problems in the real-world context, starting from the early years. To do so, elementary students have to acquire STEM knowledge in an integrative manner which allows them to learn problem-solving skills within science contexts while they engage in hands-on activities that promote their engineering skills and by using various types of technology whenever it is possible. Besides, motivating and engaging students is a necessity to engage them in STEM. Making real-world connections by creating relevant, authentic, and meaningful experiences for students and integrating music and art into a lesson plan can greatly motivate the students and facilitate their problem-solving processes (Hwang & Taylor, 2016). Furthermore, the students' STEM understanding and skills have to be assessed in an authentic manner to understand how they connect knowledge and skills from multiple disciplines. Therefore, assessments such as the interdisciplinary practices which focus on process, present diverse formats, and are related to engineering designs are the most recommended as they stress assessing the students' design knowledge and skills, concurrently (Gao et al., 2020).

2.3. Review of the Related Literature

The foundation of the present study is revealed by the following related literature which is associated with recent and related studies to STEM education. It offers a comprehensive

delineation of STEM education and a gestalt of its four disciplines which are science, technology, engineering, and mathematics. Also, it highlights the different STEM instruction approaches which are the disciplinary, the multidisciplinary, the interdisciplinary, and the transdisciplinary approaches. It offers wealthy reasons to ponder STEM education in elementary schools by emphasizing its significant effect on student achievement and motivation. Additionally, the related literature highlights the teachers' and students' perceptions and practices of STEM education alongside the challenges they confront to implement it. Furthermore, it identifies the STEM best practices leading to effective STEM integration. And lastly, it sheds light on the STEM schools' criteria and the STEM practices in the UAE schools. Therefore, the following review of literature is presented under eight sections: 1) Definition of STEM education, 2) Integrated STEM education, 3) STEM teaching disciplines, 4) STEM teachers' perceptions, 5) Elementary STEM education, 6) Elementary STEM students' perceptions, 7) Obstacles in STEM education, and 8) STEM best practices. Finally, a chapter summary will emphasize the major findings of the related literature to the teachers' and students' perceptions and practices of STEM education and will situate the present research paper.

2.3.1. Definition of STEM Education

The acronym STEM denotes science, technology, engineering, and mathematics (Tsupros, Kohler & Hallinen, 2009). The interest in STEM education originated in the U.S. when educational stakeholders recognized the significance of the STEM disciplines in solving problems in the states via technological innovations. Initially, the combination of the four STEM disciplines was well-thought-out to be “a strategic decision made by scientists, technologists, engineers, and mathematicians to combine forces and create a stronger political voice” (STEM Task Force, 2014, p.7). Consequently, the STEM acronym was generated and the STEM concept continued to feed education reforms and policies in the U.S. between the 1960s and the 1980s (Mohr-Schroeder, Cavalcanti & Blyman, 2015). In 2009, the National Academy of Engineering stated that STEM education helps the students in shaping the future by promoting their problem-solving skills (National Academy of Engineering and National Research Council, 2009). In 2016, STEM education was perceived as offering “frameworks in which new problems can be tackled” (Office of the Chief Scientist, 2016, p.2). In 2017, Fitzallen and Brown argued that students are

enabled with entrepreneurial behaviours once they are engaged in rich STEM experiences. Thus, despite the recognition of STEM importance in the workforce, there is always a lack of students' participation in STEM education. Accordingly, there have been calls to engage and attract students to STEM education by developing more engaging STEM curricula and by understanding, collectively, the meaning, the value, and the way of implementing and integrating STEM education in teaching and learning (Australian Industry Group, 2015).

Forty years after conceiving STEM acronym in education and with all the given attention to educational reforms in STEM, what fundamentally constitutes STEM is still ambiguous and remains an issue for the educational stakeholders. For instance, scholars did not succeed to agree upon one significant definition of STEM education (English, 2016). On one hand, "STEM education refers to solving problems that draw on concepts and procedures from mathematics and science while incorporating the teamwork and design methodology of engineering and using appropriate technology" (Shaughnessy, 2013, p.324). Contrarily, Breiner et al. (2012) argued that a specific systematic conceptualization of STEM is not crucial when starting a STEM initiative, as it will emerge, subsequently, while working on shared outcomes. This ambiguity in the definition of STEM education appeals the STEM scholars to deconstruct the STEM concept to create an alternative, understandable, and meaningful definition in learning, starting from the intrinsic connectivity of the four disciplines: science, technology, engineering, and mathematics (Siekmann & Korbel, 2016). Consequently, a definition with high level of clarity helps the teachers to significantly assist their students while implementing STEM practices to solve world-problems by using the four different disciplines.

Bybee (2010) stressed the importance of STEM literacy. He claimed that it should be an educational priority for all students. Balka (2011) added that a STEM literate student can understand, innovate, and solve complex problems by integrating concepts from STEM disciplines. Similarly, Zollman (2012) asserted that being literate in STEM is crucial as it helps the students in becoming productive and satisfied citizens by being knowledgeable in addressing their own economical and societal demands. In 2009, the first main point addressed by President Obama, via his *Educate to Innovate* campaign, was to improve the students' STEM literacy to develop their critical thinking (Asunda, 2011) which is defined as the art of thinking about thinking in an intellectually disciplined manner (Forawi, 2012), and which involves three

fundamental components: analyzing, assessing, and improving (Paul, 2005). Therefore, locating STEM literacy as an ultimate goal of STEM education helps in leveraging the conservation level and shifts it from the conventional enactment of the STEM curriculum which addresses the individual disciplines in STEM to a higher level and a wider perspective that has the potential to address the STEM goals adopted and supported by educational stakeholders, internationally (Fraser, Beswick & Crowley, 2019).

STEM has been perceived and defined by STEM scholars differently during the last decades (Fraser, Beswick & Crowley, 2019). According to Brown et al. (2011), STEM vision is ambiguous even among scholars who acknowledge its significance. Additionally, there is a lack of understanding among the STEM-related field professionals of what STEM is and how to implement it (Bybee, 2010). Herschbach (2011) argued that the multi-definitions of STEM in teaching and learning can threaten its successful implementation. Hughes (2009) stated that some educators perceive STEM as a new educational approach to teaching STEM subjects, while Peters-Burton et al. (2018) espouse STEM as a new curriculum or an advantageous combination of STEM disciplines. Thus, unifying the STEM definition and clarifying its specifications turn out to be imperative to advancing STEM education. STEM Task Force (2014) stated that STEM is a way more than the advantageous combination of the STEM subjects. It is a consistent active way of learning to solve real-world problems by connecting the four STEM disciplines. English (2016) added that STEM is one of the furthestmost emerging areas in educational reforms in the 21st century. This reform intends to move student learning from the traditional rote memorization of the information to start to think about real-life problems in a holistic way. Therefore, STEM pushes the students to be more knowledgeable and better critical thinkers by enacting as problem-solvers (Asghar et al., 2012). Additionally, Roberta (2015) confirmed that STEM is a way of learning that associates the STEM concepts with daily life experiences. Thus, STEM subjects should not be taught separately as they are not separated in the real world. In fact, they should be practiced by the students in a way to reflect how the real world works. By doing so, STEM allows the students to act as scientists, engineers, or mathematicians while thinking across its disciplines (Moye, Dugger Jr & Starkweather, 2014). Furthermore, adopting STEM as a new reform in teaching and learning helps in leveraging the students' academic achievement in

fostering their critical thinking and problem-solving skills, in improving their social and communication skills, in developing their 21st century skills, and in achieving global competitiveness (English, 2016; Erdogan & Ciftci, 2017; Sahin, Ayar & Adiguzel, 2014; Zeidler, 2016).

Several more definitions have described STEM over the last few years in the science of teaching and learning (Bruce-Davis et al., 2014). For instance, STEM is portrayed as an interdisciplinary approach to teaching STEM disciplines via real-world learning experiences (Vasquez, Comer & Sneider, 2013), or an instructional approach that integrates mathematics and science into engineering design and scientific practices (Johnson, 2013). Thus, Tsupros, Kohler and Hallinen (2009) defined STEM education as “an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy” (para. 3). STEM is defined as an integrative teaching method that integrates STEM subjects with no traditional barriers and embarks students with real-world and relevant experiences (Daugherty et al., 2017; Kennedy & Odell, 2014). STEM is emphasised further as a means to construct knowledge and skills collaboratively from different areas of STEM subjects to prepare students to be competent in a technology-based context (Corlu, Capraro & Capraro, 2014). Additionally, STEM is considered a holistic approach that falls back on constructivism and connects different disciplines to achieve a meaningful education (Fitzallen, 2015; Wise Lindeman & McKendry, 2015). In a study, STEM was defined as a puzzling endeavor with well-defined results (Sahin, Ayar & Adiguzel, 2014). In 2014, (Ashton) stated that STEM is a synergetic bond between the science, technology, engineering, and mathematics disciplines. Basham and Marino (2013) added that these four disciplines have to get together to contribute to an integrated unit of study. Whereas the Department of Education in the United States defined STEM as a learner-centered approach that enhances the student learning by utilizing skills and knowledge from each STEM discipline in order to promote the students’ twenty-first-century skills, creativity, and collaboration to address open questions, accomplish realistic projects, and solve real-world problems (Shernoff et al., 2017). Therefore,

the STEM education practice is not simply an incorporation of the four STEM subjects into a unit of study or a curriculum. Thus, it is an integration of the four subjects into a single discipline of education (Chen et al., 2011).

2.3.2. Integrated STEM Education

Integrated STEM is considered an effective means utilized to enhance the STEM learners' scientific knowledge and literacy besides fostering their aspirations and attainment by encompassing them in a comprehensive curriculum with related and connected instructions from the four STEM disciplines which are science, technology, engineering, and mathematics (Kelley & Knowles, 2016; Walker, 2017). A comprehensive literature review conducted by the National Academy of Engineering and the National Research Council's Board on Science Education examined the status of K-12 integrated STEM (iSTEM) education in the United States and revealed by exploring the integrated STEM education programs that there is no one single definition of STEM Integration (National Academy of Engineering and National Research Council, 2013). Rather, there is a sum of unique characteristics that are expended to differentiate integrated STEM from further content fields and teaching methodologies. Thus, these characteristics are outlined as the following: teaching two or more STEM subjects in parallel including different teaching and learning approaches to explore the different STEM subjects' fields, intentionally integrating the math and/or science content and processes with the engineering and/or technology content and processes, encouraging teachers and/or students to participate with their ideas across STEM disciplines, enhancing the development of the 21st century skills such as communication, collaboration, and creativity, including common teaching and learning approaches such as PBL, PjBL, DBL, and IBL approaches, applying learner-centered educational pedagogies including design thinking and inquiry-based learning, challenging and motivating students to find out solutions for real-world problems and situations, making connection with the real-world context to involve learners in meaningful and authentic learning, and authentically assessing the STEM learning outcomes (Burrows et al., 2017; Capraro & Nite, 2014; English, 2016; Han, Capraro & Capraro, 2015; Heil, Pearson & Burger, 2013; Kelley & Knowles, 2016; Sahin, Ayar & Adiguzel, 2014).

Implementing integrated STEM has a considerable effect on the 21st-century generation's interest in STEM careers and the students' 21st-century skills (DeJarnette, 2012). 21st-century skills are identified as learning dispositions, skills, or abilities that are compulsory for success in the 21st-century digital society. These skills are not content-knowledge-based. Thus, they are related to deeper learning which is founded on problem-solving and analytical reasoning (Cuban, 2015; Stedman, 2015). Trilling and Fadel (2009) identified the 7C skills: critical thinking and problem solving, creativity and innovation, cross-cultural understanding, communications, information, and media literacy, computing and ICT literacy, and career and learning self-reliance. Moreover, integrated STEM is considered a fundamental part in the educational reform process which aims to promote student achievement and curriculum development (English, 2016). Student achievement is described as the extent of the academic amount a student learns in a certain period. It is generally assessed by the student's performance on standardised tests (Cunningham, 2017). Becker and Park (2011) stated that integrated STEM education has a positive effect on students' learning. Likewise, Bicer et al. (2015)'s findings showed that STEM students achieved better than non-STEM students on state-based mathematics tests in Texas. Similarly, the results of Sahin, Ayar, and Adiguzel (2014)'s qualitative study revealed that students who were engaged in integrated STEM problem-based-learning activities in Texas's Harmony Public Schools were highly interested in STEM subjects and had improved twenty-first-century skills and academic achievement due to the motivating learning approaches, collaboration, communication skills, and hands-on activities involved in problem-based-learning pedagogical approach. Indeed, PBL is considered a valuable asset to the quality of integrated STEM education (Alumbaugh, 2015) and one of the best pedagogical practices for integrated STEM in elementary and secondary levels (Lamberg & Trzynadlowski, 2015). A study conducted by Hamdan Alghamdi and Saud Al-Salouli (2013) emphasized the significance of integrated STEM education via interactive curricula in improving the middle schoolers' understanding of scientific concepts and their academic achievement. Yet, Capraro and Slough (2013) asserted that STEM integration via the problem-based-learning approach has to be implemented starting from the early years, at the elementary levels to help students develop and apply their conceptual knowledge and to motivate them to expand their knowledge in STEM education to solve authentic problems as a lower motivation in STEM education results in lesser

efficacy in the utilization of metacognitive strategies and lower academic achievement (Al Quraan, 2017).

According to (Margot & Kettler, 2019), collaborating and practicing hands-on and kinesthetic integrated STEM activities in group work seem to be vital for successful STEM practices and better academic achievement. Similarly, Kelley and Knowles (2016) added that if implemented efficiently, integrated STEM education can benefit the student's educational performance and achievement significantly. Generally, studies disclosed that integrated STEM curricula improve the students' engagement and aspiration levels in learning by improving their scientific knowledge and consequently their educational outcomes and by enhancing the learner's abilities during problem-solving and consequently their innovations and logical thinking skills. They also affect positively the students' attitude, motivation, and interest in attending their schools, especially their STEM courses; they leverage the students' retention level by improving their critical thinking and problem-solving techniques. In addition, they help the students achieve better levels in their national standardized tests by involving them in a comprehensive curriculum with related instructions from different disciplines and they offer the learners engaging learning experiences via the four integrated STEM disciplines which are relevant to real-life contexts (Forawi, 2020; Hartzler, 2000; Kelley & Knowles, 2016; Walker, 2017). Thus, the benefits of integrated STEM have no limits. Generating a teacher-student bond goes beyond the STEM classrooms and that helps the students understand the significance of STEM education within their contexts and its effect on their communication, learning, and professional skills (Soomro, 2019).

The path and the degree of STEM integration are highlighted in the literature by different approaches. STEM integration is gestated in a framework titled "The inclined plane of STEM education" (Figure 3). The framework pinpoints the differences among the disciplinary, multidisciplinary, interdisciplinary, and transdisciplinary approaches to STEM. Although the disciplinary approach might be the most appropriate in certain contexts, studies identify the transdisciplinary approach to STEM as the uppermost level of integration and the disciplinary approach to STEM as the lowermost level of integration (Vasquez, 2015). The following discusses the four approaches to STEM education.

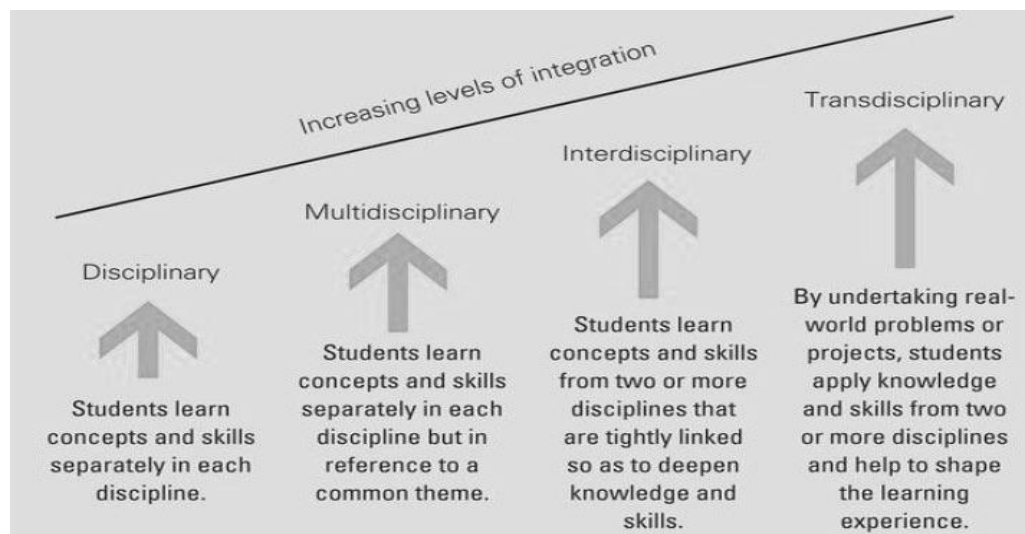


Figure 3: The inclined plane of STEM education (Adopted from Vasquez, Comer & Sneider, 2013)

2.3.2.1. The Disciplinary Approach

In the disciplinary approach, the silo approach, or the discipline-specific approach to STEM education, students acquire “concepts and skills separately in each discipline” (Vasquez, Comer & Sneider, 2013, p.73). In educational practices, scholars intend to utilize the disciplinary approach in some contexts to meet the learning standards and to enhance the students’ achievement. Moreover, the silo approach helps the students be knowledgeable in STEM disciplines. This knowledge helps the students in comprehending the overlapping STEM concepts in an integrated STEM curriculum (Honey et al., 2014; Vasquez, Comer & Sneider, 2013). Bybee (2013) added that the discipline-specific approach might be valuable in sustaining and improving the STEM disciplines, coordinating, correlating, and connecting the STEM disciplines, implementing or integrating STEM at lower elementary levels, and in supporting high schoolers with sophisticated knowledge of concepts of separate disciplines. Thus, Brown et al. (2011) criticized the silo approach by asserting that the basic knowledge of each STEM discipline can be acquired via the integrated STEM education. Similarly, Sanders (2008) affirmed that teaching STEM via a discipline-specific approach does not differ from traditional education where the instructional approach is disconnected from the disciplines.

The disciplinary approach strongly focuses on enhancing students’ knowledge and skills in several disciplines, but particularly in math and literacy. Proficiency in math is vital to STEM

education. In fact, competency in maths reflects a rigorous curriculum that engages students in deeper learning rather than focusing on covering a wider number of topics. Accordingly, the United States education scholars adopted the Common Core State Standards in mathematics, which are inquiry-oriented and which aim to foster the students' critical, analytical, and problem-solving skills (Griffin & Ward, 2015).

Discipline-specific literacy is considered a crucial skill in STEM education as there is a significant relationship between the students' reading skills and their maths performance, as well as with their science achievement (Pugalee, 2015). In fact, in maths or science units, students have to read complex texts and have to comprehend them to meet the learning goal. Therefore, teachers have to teach content area literacy while reading instructions as studies reveal that students who have difficulties with reading science and maths instructions are not assisted sufficiently to develop their reading comprehension and eventually end up with a poor academic performance in these specific disciplines (Gunning, 1996; Halvorsen et al., 2012). Therefore, literacy or reading skills are fundamental to the mathematical and scientific domains. A rigorous reading program that includes texts from different disciplines has to be implemented from elementary levels to improve the students' cognitive strength and to support their comprehension abilities in the content area. Furthermore, this prepares them to encounter complex literacy at higher levels, especially in STEM education (Halvorsen et al., 2012). Debroy (2017) posited that by implementing a STREAM (Science, Technology, Reading, Engineering, Arts, and Mathematics) based curriculum, teachers can encounter the overall students' academic needs. Besides, the STREAM approach promotes the students' 21st-century-skills and permits them to interpret and systematize knowledge, develop cognitive skills and flexible thinking, and form a coherent and multidimensional picture of the world while examining a phenomenon under study not in isolation but in combination with other subjects, phenomena, or events (Kruty, 2020).

2.3.2.2. Multidisciplinary Approach

In a multidisciplinary approach, knowledge and instructions are integrated. Each participating discipline maintains its conventional concentrations and content in a module delivered via a multidisciplinary approach (Al Murshidi, 2019; Vasquez, Comer & Sneider, 2013). Honey et al. (2014) added that in a multidisciplinary approach to STEM education,

educators elaborate on the recurrent concepts among the four STEM disciplines. Lederman and Niess (1997) utilized the metaphor of chicken noodle soup to describe the multidisciplinary approach to STEM education. The researchers stated that in a chicken noodle soup/ multidisciplinary approach, the ingredients/subjects preserved their uniqueness without a direct mixture; nevertheless, they still, congregate to create a whole. In other words, the authors advocated that in the multidisciplinary approach, the student could straightforwardly recognize each subject.

The multidisciplinary approach to STEM education enhances the students' career readiness in the STEM field. For instance, engineers and scientists cooperate regularly on multidisciplinary teams as the real-world problems they try to solve encompass two STEM disciplines or more (Honey et al., 2014). Furthermore, to implement STEM education with a multidisciplinary approach, the STEM scholars and education developers should validate the teachers' knowledge and comprehension of integration approaches. To do so, professional development, cooperation, and scaffolding are needed to help the teachers identify and make clear connections among the different STEM disciplines (Honey et al., 2014). Back-to-back, the teachers help the students create a connection among several branches of knowledge in different classes to resolve a real-world issue to make STEM education more interesting (Vasquez, Comer & Sneider, 2013). Additionally, the STEM education proponents assert the STEM literacy significance in the STEM field. They recommend that students read STEM-related texts to enhance their comprehension of the mathematics, sciences, and engineering fields and their understanding of the goals of the STEM practical activities (Cummins, 2015).

2.3.2.3. Interdisciplinary Approach

In the interdisciplinary approach, all the STEM-related subjects are integrated into one course (Al Murshidi, 2019). In most cases, the STEM proponents refer to STEM integration as a program that integrates the different concepts of the STEM subjects in an interdisciplinary approach (Fisher, 2015). Lederman and Niess (1997) utilized the metaphor of tomato soup to describe the interdisciplinary approach to STEM in which all ingredients/subjects were blended and could not easily be parted. In different words, the authors advocated that in the interdisciplinary approach, the student could not differentiate the subjects as the boundaries

among them are blurry. In 2013, (Bybee) affirmed that the STEM subjects are interrelated in nature and therefore the interdisciplinary approach is the most effective in applying them efficiently. Some teachers consider the multidisciplinary approach as the most effective one (Çevik, 2017), while other teachers believe that STEM education has to be grounded, delivered, and implemented through an interdisciplinary approach as they assume that within this approach, students are allowed to build real-world connections and are better prepared for STEM pathways and careers (Gomez & Albrecht, 2013; Ritz & Fan, 2015). However, to implement STEM effectively in an integrated classroom, the teacher has to be a *STEM thinker*. A STEM thinker was defined by Reeve (2015) as a teacher who utilizes real-world and inquiry-based activities to deliver the STEM concepts of the different STEM subjects in an integrated classroom. Danielson (2013) added that the STEM thinker teacher is the one who comprehends the content, knows the means of delivering the content, and connects the concepts and the practices of STEM education to the daily useful systems in students' lives purposefully and via an array of teaching techniques and approaches. Similarly, Pryor and Kang (2013) asserted that the teacher can enhance the students' ability to connect and to apply their knowledge to authentic situations by delivering a STEM integrated curriculum beyond single subject content in an interdisciplinary approach. Additionally, Kelley and Knowles (2016) stated that the interdisciplinary approach to STEM helps the students experience authentic contexts while applying their content knowledge from two domains or more. Besides, the two researchers affirmed that a well-integrated approach to STEM stimulates the students to learn and enhances their problem- solving skills. Likewise, Mansilla (2010) asserted that the purposeful and integrative approach that integrates instructions from several disciplines provides the students with a greater and richer understanding of the investigated problems. Moreover, Fisher (2015) emphasized that the interdisciplinary and experience-based instructions are the superlative practices for STEM education and the most advantageous to students' achievement and learning.

Younker and Bracken (2015) stated that the inquiry-based approach to learning fits well the interdisciplinary approach to STEM education. Inquiry-Based Learning (IBL) represents a student-centered approach that focuses on enhancing the students' intrinsic motivation to scientifically construct new knowledge (Carvalho et al., 2011; Eltanahy & Forawi, 2019). Within the constructivist IBL pedagogical approach students are required to work actively and

cooperatively to construct their knowledge, understand the nature of science, and discover new meanings of reality (National Research Council, 2013a; Ramnarain, 2016). Moreover, in an interdisciplinary STEM educational approach, the inquiry instructions are compulsory to comprehend the core ideas in STEM disciplines. For instance, via the IBL pedagogical approach, STEM content can be taught by enabling students to: think critically at a higher-order level, ask investigative questions, observe, hypothesise, carry out investigations, gather evidence, explain, and justify the results as scientists (Deshmukh, Forawi & Jaiswal, 2012; Forawi, 2016; Kelley & Knowles, 2016; Psycharis, 2016).

The characteristics of the interdisciplinary approach have been identified by Spelt et al. (2009). The researchers stated that the integrative approach is the capability to acquire a piece of new knowledge from learning throughout several disciplines. Moreover, it is the ability to explore and comprehend the relationships among the concepts of the different disciplines. And, it is the integration of instructions cohesively under the umbrella of real-world applications. Lastly, it aims to solve real-world issues and the investigated problems by utilizing multiple perspectives and methods and by using different skills and techniques. In his turn, Bybee (2013) presented a further description of the interdisciplinary approach. For instance, the researcher suggested that the integrative approach entails coordinating two different topics or more concurrently so the content acquired in one topic is straightforwardly applicable to another. Moreover, the integrated subjects in an integrative approach are purposefully introduced in a lesson for the contents of the different subjects to complement the primary subject. The integrative approach entails connecting disciplines and combining different approaches utilized to deliver instructions in different subjects to accomplish a final project. An additional defining characteristic of an interdisciplinary approach to STEM education was emphasised by Howes, Hamilton, and Zaskoda (2003) who stated that the integrative approach accommodates the students' diversity in a STEM classroom by allowing the students to investigate, explore, present, express, and report their understanding collaboratively in novel ways by being creative and by utilizing different techniques. Furthermore, studies reveal that the interdisciplinary approach helps the students to compete and succeed in challenging situations and the uncertain world by motivating them and by enhancing their knowledge, their approach to learning, and their twenty-first-century skills (Kuhlthau, 2010). Likewise, Morrison (2006) stated that the integrative approach has a goal to develop

critical thinkers and problem solvers who can identify the connections between crossing disciplines in a STEM classroom and their daily lives.

2.3.2.4. Transdisciplinary Approach

While the disciplinary approach to learning is vital to understanding the basics of the themes and content of the subjects, studies reveal that the interdisciplinary approach to learning is fundamental as it has the potential to construct the students' higher-order thinking skills. Moreover, it helps them generate meaningful connections among the different subject areas (Ivanitskaya et al., 2002).

Jacobs (1989) defined the interdisciplinary approach as the thoughtful connection and integration of numerous educational disciplines and methods to investigate a real problem. Thus, Taylor et al. (2006) stated that the interdisciplinary approach refers to “the explicit recognition and connection of content and instruction from more than one subject or academic discipline in teaching and/or learning experience” (p.7). While Honey et al. (2014) stated that Problem Based Learning is an alternative and conventional transdisciplinary approach to STEM education. Similarly, Vasquez (2015) confirmed that the transdisciplinary approach to STEM education is frequently referred to as problem-based or project-based learning. Yet, Capraro and Slough (2013) stated that they are not synonyms.

Project-Based Learning (PjBL) is a term that stems from the work of Dewey (1938). The PjBL is prototypical for engineering practices in STEM and can be defined as a transdisciplinary approach or a type of inquiry that starts with an ill-defined task or an authentic and complex open-ended question and ends with a well-defined solution, tangible product, or design (Capraro, Capraro & Morgan, 2013; Capraro & Slough, 2013; Gonzales, 2015; Han, Capraro & Capraro, 2015). Researchers reveal that PjBL allows students to exploit creativity and critical thinking while collaborating and communicating offering them a deeper self-regulated understanding via the trial and error problem-solving method (Gonzales, 2015; Hall & Miro, 2016). Problem Based Learning (PBL) is considered the most prominent instructional approach in transdisciplinary STEM education that focuses on ill-structured, open-ended, messy, and complex problems (Ronis, 2008; Tawfik & Lilly, 2015). In PBL, students try to define the authentic problem, creatively generate a knowledge inventory and possible solutions via the execution of analytical

and critical thinking in searching, communicate via a self-learning approach, work in collaboration with their colleagues to solve the learning issues whilst the teacher plays the role of a facilitator, and lastly, share the findings and solutions (Chan, 2016; Kasza & Slater, 2017; Morrison, Roth McDuffie & French, 2015; NGSS Lead States, 2013).

Capraro, Capraro, and Morgan (2013) stated that STEM PBLs are integrally interdisciplinary as they are well-designed to enable content integration from multiple subject areas. Moreover, they are collaborative and help the students construct their conceptual knowledge and better achieve by collaborating to solve problems and real-world issues. Furthermore, PBLs are designed in a way to appeal to the students' interests and motivate them to learn and work cooperatively within groups on activities that are relevant to real-world problems.

In their book, titled *STEM project-based learning: An integrated science, technology, engineering, and mathematics (STEM) approach*, the three researchers Capraro, Capraro and Morgan (2013) summarized the characteristics and the differences between a traditional classroom and a PBL pedagogical approach. For instance, a PBL classroom starts with an ill-defined task and ends up with well-defined outcomes. The lessons are interdisciplinary, standards and problems driven, with cooperative activities. Furthermore, in a PBL classroom, the teacher plays the role of the facilitator of knowledge who assesses the students' success based on their performance. A PBL curriculum is a comprehensive problem-based curriculum that focuses on cooperative activities which motivate and challenge the students to gain knowledge. The knowledge gained at the end of each unit is manifested by an artifact or relevant learning experience. While in a traditional classroom, the unit starts with a defined task and ends up with loosely defined outcomes. The lessons are specific-disciplinary and objectives are driven to cover skills. The teacher is the giver of knowledge based on textbooks. The curriculum is narrow with individual activities and the student success is evaluated based on tests and grades. Hence, Vasquez, Comer, and Sneider (2013) identified the main components of PBL which is a transdisciplinary approach to STEM education. As per the researcher, the three main components in a STEM PBL are: (a) the main question that engages the student in a real-world context, (b) clear STEM standards-based objectives which offer the roadmap to the real-world learning experience, and (c) students' prior experiences which deed as guidelines via the learning experience. Yet, Honey et al. (2014) emphasized that "student-centered, experiential, open-

ended, authentic, real-world, challenge-based, and concrete” are the main characteristics of a PBL.

Capraro and Slough (2013) supported the application of PBL in STEM classrooms as it enhances the students’ mastery of different learning skills. Yet, Alumbaugh (2015) believed that PBL is critical in implementing a successful STEM program. Likewise, Honey et al. (2014) confirmed that PBL is one of the most successful educational strategies utilized in STEM teaching. While Lamberg and Trzynadlowski (2015) considered it a valuable instructional model for a high-quality STEM program. Additionally, studies revealed that the PBL learning model improves the students’ self-confidence, communication skills, and twenty-first-century skills. Moreover, it fosters the students’ interest in STEM education and their will to cooperate in learning activities. Furthermore, it helps the students to reflect on the final outcome and to assess their learning (Sahin, 2015; Vega, 2015).

The PBL offers the students real-world opportunities to engineer valid solutions to real-world problems by situating their scientific inquiries and by offering real-world contexts where they can apply their mathematical, engineering, and technological skills (Flores, 2016; Sanders, 2008). PBL also helps the students to develop their conceptual knowledge, apply their knowledge, and construct collaborative learning skills, especially if it is applied at the elementary levels (Capraro & Slough, 2013).

PBL is based on constructivism (Chiu, Price & Ovrachim, 2015). A STEM classroom provides the students with cognitive building blocks and offers them experiences with real-life problems. It enhances their problem-solving skills and their knowledge in different areas and stimulates their interest in the STEM field (Pugalee, 2015). Furthermore, the research disclosed that STEM students who learned via the instructional PBL approach were more likely to solve engineering problems and design STEM activities compared to the students who were instructed in a traditional classroom (Lesseig et al., 2016). Thus, teaching STEM education via PBL interdisciplinary approach helps the students perform better by integrating and infusing the scientific, technological, engineering, and mathematical concepts. Yet, regular adjustments in school organizations, practices, and policies are mandatory to foster the teachers’ knowledge and best practices; therefore to implement an efficient integrated STEM education (Lesseig et al., 2016).

2.3.3. STEM Teaching

The four STEM teaching disciplines are Science, Technology, Engineering, and Mathematics. The National Research Council (2013a) separated the four STEM disciplines for additional analysis and more transparency and defined each of them as the following:

1. “Science is the study of the natural world including laws of nature associated with physics, chemistry, and biology and the treatment or application of facts, principles, concepts, or conventions associated with these disciplines.
2. Technology comprises the entire system of people and organizations, knowledge, processes, and devices that go into creating and operating technological artifacts as well as the artifacts themselves.
3. Engineering is a body of knowledge about the design and the creation of products and it is a process for solving problems. Engineering utilizes concepts in science, mathematics and technological tools.
4. Mathematics is the study of patterns and relationships among quantities, numbers, and shapes. Mathematics includes theoretical mathematics and applied mathematics”.

Yet, the STEM education policy statement of Ireland (2017, p.6) outlined the four STEM disciplines as the following:

4. “Science enables us to develop our interest and understanding of the living and the material and physical world and to develop the skills of collaboration, research, critical enquiry, and experimentation.
5. Technology covers a range of fields that involve the application of knowledge, skills, and computational thinking to extend human capabilities and to help satisfy human needs and wants, operating at the interface of science and society.
6. Drawing on scientific methods to provide the skills and knowledge to solve real-world problems, Engineering is about the design and creation of products and processes.
7. Mathematics equips us with the skills needed to interpret and analyze information, simplify and solve problems, assess risks, make informed decisions, and further understand the world around us through modelling both abstract and concrete problems”.

The related literature to STEM education reveals additional characteristics of each of the four disciplines in STEM education or STEM classrooms.

2.3.3.1. STEM Education and Science

Science was defined by Kuhn (2012) as the “regular work of scientists theorizing, observing, and experimenting within a settled paradigm or explanatory framework” (p. 84). Thus, Einstein, Beck, and Havas (1987) described science as knowledge or a system of knowledge covering general truths or the operation of general laws, especially as obtained and tested through scientific methods (Merriam-Webster's dictionary, 2011). Yet, Barker and Hungate (1990) stated that in essence, science is a perpetual search for an intelligent and integrated comprehension of the world we live in (Cassimally, 2011). The initial letter S in the STEM acronym stands for science. In 2013, the Next Generation Science Standards or NGSS established several science standards intending to enhance the students’ ability to understand and apply the scientific concepts in place of rote memorization. These standards promote the teachers’ STEM application by pushing them to apply student-centered along with inquiry-based and hands-on pedagogical approaches to science education instead of a teacher-centered or lecture-based approach. The National Science Teachers Association (2014) posited that “a practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested” (p.50). The science standards focus on integrating engineering design, mathematics, and literacy in science education (Bybee, 2014; Dare, Ring-Whalen & Roehrig, 2019; NGSS Lead States, 2013). Likewise, Midrack (2019) asserted that in integrated STEM education, science classes include maths, engineering, and technology in scientific studies, in addition to involving biology, physics, and chemistry lessons. Similarly, Park, Wu and Erduran (2020) emphasized the role of STEM in a science classroom and they stated that approaching the science subject by integrating mathematics, engineering design, and technology is eventually seen as an excellent approach to teaching science education. Furthermore, studies reveal that participating in science experiences, especially in the early years, raises the likelihood of pursuing STEM majors and careers (Dou et al., 2019; Park, Wu & Erduran, 2020).

2.3.3.2. STEM Education and Technology

T is the second letter in the STEM acronym and it stands for Technology. The definitions and the uses of technology have significantly varied in the last decades (Ellis et al., 2020). For instance, the International Technology Education Association described technology as the “innovation, change, or modification of the natural environment to satisfy perceived human wants and needs” (ITEEA, 2000, p.242). The American Association for the Advancement of Science added that: “In the broadest sense, technology extends our abilities to change the world by cutting, shaping, or putting together materials, moving things from one place to another, reaching farther with our hands, voices, and senses” (American Association for the Advancement of Science, 1993, p.41). Furthermore, technology was defined by Carroll and Scott (2017) as something that is always inherently intelligent enough either to function, to be used to function, to be imbued with, or to be interpreted as having a function that only intelligent beings can comprehend. This inconsistency in defining the technology role in STEM education has deep implications for instructional purposes in STEM education. Moreover, it inherits the teachers the task of identifying the role of technology discipline within the STEM classroom. This identification depends profoundly on the teachers’ principles, previous experience, and instructional purposes of technology in STEM classrooms (Ellis et al., 2020). It however culminates in a conceptual dilution that might lead to the misapplication of technology-related concepts in STEM classrooms (Bull et al., 2019). A study conducted by Ellis et al. (2020) aimed to uncover the different teachers’ perspectives of the technology discipline role in a STEM classroom over the last thirty years. Findings revealed that technology is mostly perceived as the tools and practices utilized by engineering, mathematics, and science practitioners. On the other hand, it is less often perceived as coding or computational thinking, industrial arts, or artifact of engineering. Hence, the American Association for the Advancement of Science tried to address this issue by stating that technology is the implementation of knowledge as well as the application of tools to elucidate practical problems and increase human capabilities (Johnson, 1989). The International Society for Technology in Education added that technology has the power to renovate teaching and learning, enhance the students’ innovation, and decipher real-world problems in the educational domain by engaging students in design processes via tools

that support knowledge construction and computational thinking (ISTE, 2000). In STEM education, technology enhances the students' achievement especially if technology activities are strongly integrated within STEM focused science classes (National Assessment of Educational Progress, 2018). To integrate technology in an efficient way, STEM teachers need to understand what technology is. Most studies reveal that teachers refer to technology as the *mystery piece* and are unable to describe verbally its meaning, especially in STEM education. This struggle in identifying the role of technology in integrated STEM disallows the teachers to incorporate strong technology experiences to enhance the students' understanding and enrich STEM education (Dare, Ring-Whalen & Roehrig, 2019; Guzey et al., 2019).

Pencils, whiteboards, digital software, computers, iPads, laser cutters, 3D printers, and much more are technological tools or products needed to replace, amplify, and transform learning in this changing world to drive scientific research, support investigations, and meet the human needs. Therefore, technology has to be incorporated and infused in STEM education and not treated as a stand-alone course to develop the students' decision-making abilities, creativity, design skills, questioning and communication skills (Bevan, 2017; Hughes, Thomas & Scharber, 2006; National Research Council, 1996; Rodriguez, Harron & DeGraff, 2018). However, without considering professional learning development, the glamour of technology can overshadow its pedagogical significance. Therefore, STEM scholars need to focus on teachers' development to empower them to be critical consumers and be more familiar with technological tools and pedagogical strategies. The purpose is to promote their ability in tinkering and fiddling with technological STEM-specific tools to make strong connections among technology and other disciplines of STEM, to facilitate the students' learning and to engage them in real-world contexts where they can imitate how scientists work, to enhance the students' problem-solving, digital and twenty-first-century skills in inquiry-based classrooms to promote the students' scientific understanding via visualization and imagery, and to enhance their inquiry via collaboration and communication (Bell & Bull, 2008; Honey et al., 2014; Novak & Krajcik, 2006; Peterson & Scharber, 2018).

Syukri, Yulisman, and Nurina (2020) stated that STEM teachers need to carry out STEM teaching and learning activities that ally with the present educational and technological development by using suitable technology to deliver STEM content and pedagogy. Likewise,

Mishra and Koehler (2006) proposed the technological pedagogical and content knowledge framework or TPACK (Figure 4) that features approaches to integrate technology in STEM education and helps teachers for an optimal STEM delivery and application as the teacher's optimal STEM delivery and application positively affect the student's perception and practices of STEM education (Hacioglu & Gulhan, 2021; Lazarides & Warner, 2020; Permanasari, Rubini & Nugroho, 2021; Sirajudin & Suratno, 2021). For instance, the teacher's ability to use proper technology, effective interdisciplinary content knowledge of STEM disciplines, and pedagogical knowledge needed to deliver the STEM challenging standards to transfer the correct knowledge for learners and to face the STEM students' learning difficulties and misconceptions in a technology-based learning environment can be seen via the TPACK framework (Mishra & Koehler, 2006; Yulisman et al., 2019).

Mishra and Koehler (2006) posited that TPACK is viewed as the new model of the teachers' expertise for the twenty-first-century classroom. Chai (2019) stated that if technology has to be incorporated into regular classes, its significance in STEM education is even more critical. For instance, all the related STEM professions require profession-specific technologies that STEM specialists need to master e.g., engineers need to be proficient in computer-assisted design and biologists need to be skilled in bioinformatics. Chai (2019) added that technology is fundamental to both, TPACK and STEM education. Hoeg and Bence (2017) argued that TPACK and STEM aim to develop the students' twenty-first-century skills. Hence, Parker et al. (2015) stated that STEM association with TPACK is fundamental in developing the students' twenty-first-century skills as STEM education requires teachers to integrate technology, pedagogy, and associated content knowledge through design and TPACK facilitates the teachers' job and the authentic students' learning via design thinking.

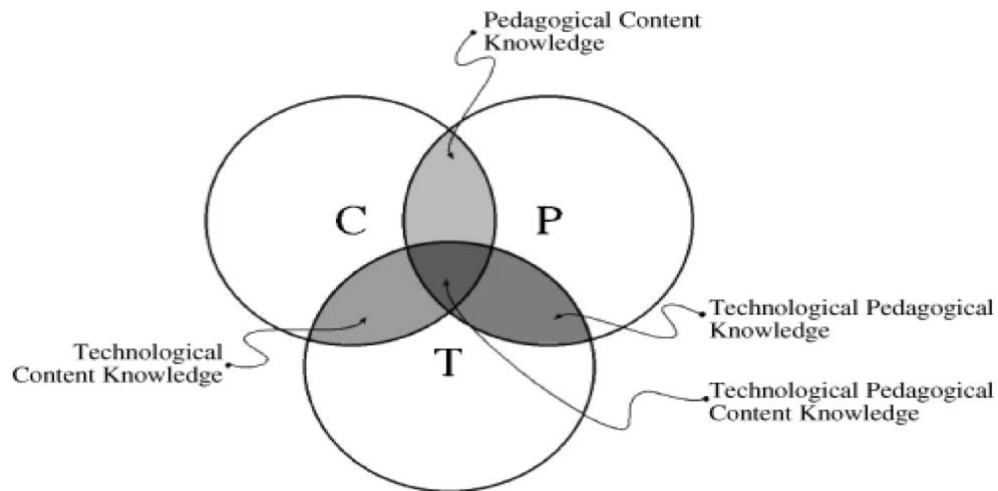


Figure 4: The TPACK framework (Adapted from Mishra & Koehler, 2006)

2.3.3.3. STEM Education and Engineering

E is the third letter in the STEM acronym and it stands for Engineering which is a term derived from the Latin “Ingenium”, denoting "cleverness" (Cambridge international dictionary of English, 2021). Engineering is described as a creative application of scientific principles to design or develop structures, machines, apparatus, or other items including bridges, roads, and buildings (International Association of Engineers, 2021). According to the National Academy of Engineering (National Academy of Engineering and National Research Council, 2009), engineering is a valuable catalyst for STEM integration that motivates the students to accomplish better achievement. Moreover, it provides a vehicle for real-world context for learning and applying scientific and mathematical disciplines. As well as “engineering questions clarify problems to determine criteria for successful solutions and identify constraints to solve problems about the designed world” (National Science Teachers Association, 2014, p.50).

Furthermore, significant rationales for integrating engineering in STEM education were revealed by several studies in the last decade. For instance, Brophy et al. (2008) stated that engineering design tasks provide the students with a framework to develop their problem solving and communication skills via a simple problem-solving process that goes through several phases of asking, imagining, creating, and improving or through a more sophisticated process that goes via the following complicated steps: 1- identify the problem and gather the significant information, 2- realize the project, 3- consider alternative solutions, 4- distribute the final design,

and 5- re-evaluate the quality of the solution (Atman et al., 2007). Moreover, engineering design promotes teamwork and enhances the students' -twenty-first-century skills by exposing and engaging them in authentic and interdisciplinary problems. It also promotes the students' attitude toward STEM careers by offering them opportunities and by understanding problems via rich and engaging authentic experiences. Additionally, they are provided with a fun framework that integrates the different STEM disciplines and hands-on settings that imitate the real-world context where engineering facilitates STEM integration and the students' learning of mathematics and science (Hirsch et al., 2007; Koszalka, Wu & Davidson, 2007; Purzer, Strobel & Cardella, 2014). Lastly, Wang and Chiang (2020) posited that integrating engineering in STEM education in an effective way provides the students with authentic experiences and improves their -twenty-first-century skills and their attitudes towards mathematics.

To integrate engineering effectively in STEM education, teachers, first, need to understand the nature of engineering practice. Dym (1999) and the report Standards for K-12 Engineering Education (National Research Council, 2010) identified engineering practice as a decision-making process or a way of thinking to identify, evaluate, and solve problems to meet a desired performance or objective by taking into consideration the identified set of constraints. Second, teachers need to involve in their practices and classrooms with cooperative and problem-based learning, meaningful hands-on opportunities or engaging learning experiences that foster the students' comprehension of STEM education, and a curriculum that recognizes the interaction between scientific and mathematical concepts and engineering as these connections are evident and needed for students to perceive how the real-world works (Purzer, Strobel & Cardella, 2014).

The NGSS or the Next Generation of Science Education Standards framework (2013) which was published by the (National Research Council, 2013a) articulated and discussed the role of engineering in science education and included engineering concepts as part of the science academic standards. The NGSS has a three-dimensional design representing the STEM foundation areas including the disciplinary core ideas, the engineering and science practices, and the crosscutting concepts which have to be integrated into science curricula, teacher pedagogical strategies, and student assessment from the kindergarten level up to the twelfth grade including the elementary school. It is where students should start reasoning, understanding, and solving the

big ideas and problems in science as well as behaving similarly to scientists and engineers; if not, a foremost strain in attaining the established goals in the NGSS will be inevitable (Roehrig et al., 2012). The NSTA quick reference guide to NGSS (National Science Teachers Association, 2014) suggested that elementary students can define a simple design problem based on their prior knowledge “that can be solved through the development of an object, tool, process” (p. 50) or they can “use a model to test cause-and-effect relationships concerning the functioning of a natural system” (p. 51), or even “make observations and/ or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon” (p. 52) in science and engineering practices.

2.3.3.4. STEM Education and Mathematics

There is no single definition that can define Mathematics. James and James (2001) defined Mathematics as the science of logical study of numbers, shapes, arrangement, quantity, measure, and many related concepts. Thus, it was described by Peirce (1852) as the science that draws necessary conclusions. Du Sautoy (2009) portrayed Mathematics as the Queen of Science... the main driving force behind scientific discovery. Yet, Yadav (2017) stated that Mathematics is the study of assumptions, their related properties, and applications. In the STEM acronym, the last letter stands for Mathematics. Midrack (2019) stated that in STEM education, Mathematics classes involve models and exercises that appeal to the use of science, technology, and engineering in mathematics, in addition to algebra and geometry. Li et al. (2019) added that approaching mathematics in classes via the STEM educational strategies of inquiry and creativity helps the students make meaning and acquire deeper learning in math. Moreover, it enhances the students’ acquisition of the twenty-first-century skills as the literature reveals that there is a strong connection between math education, STEM education, and twenty-first-century skills (Maass et al., 2019). According to Delaney and Devereux (2020), math is considered a skill included in the STEM focus instead of being a major objective to be communicated. English (2016) suggested that math has to be presented, more often, as the focus of the STEM units. Additionally, teachers have to support the students’ literacy in STEM education as it enhances their ability to deal with real-life situations and apply math concepts in significant ways. Furthermore, studies reveal that math self-efficacy and mathematical ability affect the

students' likelihood of pursuing STEM careers and majors (Lin et al., 2018). Therefore, exposing students to math concepts starting from the early years and fostering them via student-centered and STEM strategies help the students earn mathematical self-efficacy, acquire the mathematical skills needed for better achievement, for pursuing STEM majors, for future jobs, and deal with the changing world (Delaney & Devereux, 2020; Maass et al., 2019). The NSTA quick reference guide to National Research Council (2015) suggested that elementary students can “describe, measure, estimate quantities such as area, volume, weight, and time to address scientific and engineering questions and problems” (p. 54) in using mathematics and computational thinking.

2.3.3.5. STEAM and STREAM Education

While STEM scholars agree on the effect of STEM integration on developing the students' higher-order thinking skills, STEM identifications remain ambiguous, and debates about its effective implementation and its future as an advantageous concept in guiding future education are incessant (Fraser, Beswick & Crowley, 2019). According to OSC (Office of the Chief Scientist, 2016), the degree to which STEM can function effectively in an integrated classroom depends on the level of students' comprehension of humanities and social sciences subjects within the social context where STEM operates (Fraser, Beswick & Crowley, 2019). Therefore, several scholars and studies encouraged the inclusion of Arts in integrated STEM education to become STEAM education (Deloitte, 2015; Taylor et al., 2006). STEM and STEAM have different roots (Bush et al., 2020). STEM proponents claim that it is entrenched in meeting the needs of industry and the workforce, college and career readiness, and global competitiveness (Bush et al., 2020). Whereas, STEAM proponents argue that arts integration helps in increasing the students' motivation to learn and to gain the perceived level of problem-solving skills. Also, it enriches and expands STEM education to be a holistic form of education that helps the students in attaining further education and STEAM careers (Payton, White & Mullins, 2017). Therefore, STEAM focuses on students solving authentic problems to make the world a better place. In addition, it emphasises the inclusion of the arts which focus on creativity, aesthetics, personal expression, and meaning which help in designing solutions for others and solving problems in our world (Bush & Cook, 2018). Taylor et al. (2006) stated that

interdisciplinary STEAM education engages the students in transformative learning by exposing them to different interrelated types of knowledge which are necessary to address the daily real-world problems and the key global issues. Furthermore, STEAM promoters argued that there is a symbiotic relationship between STEM and arts as they both motivate the students' creativity, inquiry skills, collaboration, and communication within exciting and evocative spaces (Guyotte et al., 2015; Nguyen, Sivapalan & Hiep, 2021). Bush and Cook (2018) stated that STEM and STEAM education share the main idea which is the necessity to "move beyond traditional curricula, in which the disciplines are siloed, and to purposefully and meaningfully cross disciplinary boundaries in order to solve complex and authentic problems" (para.3). However, studies show that there is an agreement that the STEAM approach is more sustainable than the STEM approach in nurturing the students' engagement and competencies in professional fields (Nguyen, Sivapalan & Hiep, 2021). On the far side, the National Research Council (2012) suggested that the "Three Rs" (Reading, wRiting, and aRithmetic) were found no longer satisfactory in addressing the developmental needs of students especially in this era of Industrial Revolution 4.0 and Halvorsen et al. (2012) posited that literacy or reading skills are fundamental to the mathematical and scientific domains in STEM education. Consequently, Debroy (2017) posited that a STREAM (Science, Technology, Reading, Engineering, Arts, and Mathematics) based curriculum can bridge this gap by improving the students' cognitive strength, by supporting their comprehension abilities in the content area, and by promoting their 21st century skills including collaboration, communication, creativity, and critical thinking. Furthermore, Kruty (2020) argued that the STREAM integrated approach permits the students to interpret and systematize knowledge, to develop cognitive skills and flexible thinking, and to form a coherent and multidimensional picture of the world while examining a phenomenon understudy not in isolation but in combination with other subjects, phenomena, or events.

Lastly, whether the interdisciplinary STEAM or STREAM approaches or the integrative STEM education is adopted in an integrated curriculum, teachers in integrative classrooms need to be well-prepared and STEM knowledgeable, supported by a strong integrative curriculum, and sustained by professional development to enhance the content, pedagogical, and technological knowledge of their students (Fraser, Beswick & Crowley, 2019).

2.3.4. STEM Teacher Perceptions

Teachers play a significant role in implementing STEM education successfully (Wang et al., 2011). Yet, the teachers' STEM practices are highly influenced by their perceptions of STEM (Thibaut et al., 2018). Existing studies and related literature (2010- 2020) reveal insights into the teachers' perceptions of STEM education. In their study, Margot and Kettler (2019) claim that teachers' perceptions of STEM education are dependent on teachers' demographics and they argue that the teacher's age, gender, and education background are factors that affect the teacher's perception of STEM education as the teacher's positive attitude towards STEM increases when the teacher's age increases. In general, male teachers have a more positive view of STEM education than female teachers and the number of related STEM courses taken in college eases the teachers' job and prepares them to teach STEM. Hence, this claim contradicts Srikoom, Hanuscin and Faikhamta (2017)'s findings which state that teachers' backgrounds do not influence the teachers' perceptions of STEM education, but support Park et al. (2016)'s claims which suggest that teachers' preparation to teach STEM seems to be a valuable factor that affects STEM education and its implementation.

Regarding the teachers' years of experience factor, Thibaut et al. (2018) assert that novice teachers express a less positive view of STEM education compared to experienced teachers. Contrarily, Srikoom, Hanuscin, and Faikhamta (2017) declare that the teachers' years of experience seem to be inconsistently related to teachers' perceptions of STEM education, and the teacher's interest in STEM education may intervene in this inconsistent relationship. Parker, Kruchten, and Moshfeghian (2017) added that when the teachers' years of experience increase, the teachers' readiness to STEM implementation increases, but only if they value STEM education, and if not, the increasing number of years of experience does not affect the teachers' feelings of readiness to teach STEM. Margot and Kettler (2019) affirmed that the value the teachers place on STEM education does not only affect the feeling of readiness to teach STEM, yet it also influences the teachers' willingness to implement STEM curriculum. Bell (2016) added that the teachers' perceptions of the importance of STEM education affect their ability to learn and develop STEM and therefore the way to teach STEM. Additionally, Holstein and Keene (2013) stated that teachers' beliefs in student abilities affect their perceptions of STEM education.

The teaching subject seems to play a critical role in teachers' perceptions of STEM education. For instance, studies reveal that science teachers have a more positive view and a better willingness to implement integrated STEM education compared to mathematics teachers who feel that it is challenging to help students in solving authentic problems (Wang et al., 2011). Moreover, teachers of different grade levels have different perceptions of STEM education. A study conducted by Al Basha (2018) in the UAE revealed that the middle school and the secondary school teachers unveiled higher optimistic perceptions and better implementation of STEM education compared to the elementary school teachers. They also showed better collaboration and more understanding of STEM content and pedagogical approaches.

Furthermore, teachers with different educational levels develop altered knowledge levels and different personal perceptions of STEM education. For instance, teachers with master's and doctoral degrees reveal a better understanding and a more positive view of STEM education (Thi To Khuyen et al., 2020). Similarly, teachers with different backgrounds or majors might have dissimilar perceptions of STEM education (Thibaut et al., 2018). The reason for this dissimilarity, as per the researchers, goes back to the way the teachers had been taught and guided during their education (Jarski, Kulig & Olson, 1990). Alternatively stated, the way each teacher perceives and teaches STEM is dependent on her/his own experience when he/she was a student (Bandura, 1977). For instance, Al Basha (2018)'s findings revealed that teachers' majors have significant impacts on STEM implementation and problem-solving practices and teachers with science and technology backgrounds exhibited positive and better practices of problem-solving than teachers with mathematics backgrounds.

Furthermore, teachers believe that STEM education is required to promote the students' 21st-century skills such as collaboration, creativity and research, reasoning, problem-solving, and technological and inquiry skills. Thus, despite the in-service teachers' positive beliefs and views towards STEM education, teachers ask for in-service professional development learning opportunities such as workshops to deal with the challenging implementation of interactive STEM curricula, to improve their skills and abilities in planning STEM group-oriented activities, to be able to evaluate educational approaches suitable for each STEM activity, and to authentically assess STEM students (Altan & Ercan, 2016). For instance, research studies reveal that group-oriented activities within an interactive curriculum increase the teachers' enjoyment

of teaching science and enhance the students' scientific achievement (Wang et al., 2011). For that reason, the delivered professional development (PD) sessions have to be coherent, active, reflective, collaborative, and sustained. Moreover, they need to focus on the teacher content and technology knowledge. The PD needs to emphasize the pedagogy of enactment such as how to apply different student-centered learning approaches along with problem-solving techniques as major components to integrate STEM disciplines. Lastly, PD needs to emphasize how to implement PBL, PjBL, and IBL strategies, for authentic knowledge construction and real changes to occur in practice (Estapa & Tank, 2017; Jordan, DiCicco & Sabella, 2017; Margot & Kettler, 2019; Mitts, 2016; Moore et al., 2014; Wang et al., 2011).

Being not well-prepared to teach STEM education efficiently during the pre-service period, the in-service STEM teachers have to deal with STEM curricula and their challenging implementations in STEM schools, leading to unsuccessful STEM teaching and learning. Therefore, STEM scholars need to take into consideration the preparation of the pre-service STEM teachers that need to be effective future STEM teachers and stakeholders (Chalmers et al., 2017). Cooper and Gilbert (2016) stated that pre-service teachers (PST) always express a desire to deliver and teach STEM in more successful and engaging methods than they were taught. Thus, their future pedagogical practices of STEM education depend not only on their desire to implement STEM effectively but on their perception of STEM education.

The PSTs' perception of STEM education is affected by STEM conceptualization. The teachers' conceptualization of STEM forms a mental framework that implicitly guides their teaching and practices of integrated STEM and prioritizes concepts over each other during their future careers as STEM teachers. Studies reveal that in most cases, PSTs conceptualise STEM as an integrative approach that utilizes PBL and IBL by emphasizing the connections between the four STEM disciplines to develop the students' skills and prepare them for future careers (Chalmers et al., 2017).

Furthermore, several psychological factors affect the teachers' perception of the PSTs of STEM education. For instance, teachers' attitudes to teaching STEM influences the teachers' perceptions and practices of STEM education. Attitude is defined as an influential construct or a salient predictor that affects the direction and the intensity of future behavior (Ajzen, 2005). Commonly, PSTs reveal a positive attitude to teaching STEM education. Yet, they claim an

uncertainty in developing their professional capacities at a time when they are exposed to limited engaging opportunities to enhance their STEM teaching (Blackley & Howell, 2019; Chalmers et al., 2017). Additionally, a higher self-efficacy in teaching STEM is related to good teaching practices, specifically student-centered pedagogies. Self-efficacy portrays the individual's perception of how skillful, knowledgeable, and able he/ she is to perform a determined behavior (Kraft et al., 2005). Moreover, it is the belief of how successful an individual is in achieving an important task (Estrada et al., 2016). Hinojosa et al. (2016) confirmed that self-efficacy is a significant predictor of the STEM PSTs success. However, Chalmers et al. (2017) claimed that PSTs expressed low levels of self-efficacy in teaching STEM education disciplines, especially engineering and technology.

Accordingly, STEM stakeholders need to modify and develop the current approaches in teaching STEM education by assisting the PSTs in identifying the different STEM models and pedagogical approaches of integrated STEM, by providing them with authentic opportunities and engaging them in STEM activities to develop their teaching capacities and improve their attitude towards STEM, and by increasing their self-efficacy in STEM teaching, especially in engineering and technology to improve their perception of STEM education and to prepare them for fruitful future STEM careers (Blackley & Howell, 2019; Chalmers et al., 2017).

2.3.5. Elementary STEM Education

Numerous STEM initiatives such as the Common Core State Standards (CCSS), the Next Generation Science Standards (NGSS), and the Framework for 21st Century Learning stressed on the integration of STEM disciplines in educational curricula. However, the emphasis of integrating STEM mostly focuses on high school and college levels (Lynch et al., 2013; Peters-Burton et al., 2018; Woodruff, 2013) leading to an indifference towards science in elementary level in general (Keeley, 2009), particularly in girls (Abell, Appleton & Hanuscin, 2013). Bentley (2021) added that research and interest in K-12 STEM education has increased in the last decade. Yet, the elementary level has unquestionably the least focus amid all educational levels. However, Ricks (2012) affirmed that “early learning experiences can contribute to positive academic trajectories in STEM fields, thus a concentration in STEM at an early age can encourage children to believe they can succeed in STEM domains” (p.43). Additionally, Hayden

et al. (2011) and Sahin (2013) argued that STEM education enhances the students' interests and attitudes towards science education in elementary school. Similarly, DeJarnette (2012) noted that STEM education in the early years enhances the students' motivation towards science and encourages them to pursue a STEM career in the future. Likewise, Tai et al. (2006) stated that a sturdy positive relationship is established between the students' experiences in STEM at the elementary level and their choice of studying STEM disciplines in their higher academic journey. Also, Holter (2017) confirmed that fostering STEM education in elementary level improves the students' communication skills and vocabulary use. Moreover, it develops their motor and technological skills better when compared to implementing it in high school. Equally, the STEM education policy statement of Ireland (2017) stated that by engaging in STEM experiences, elementary students develop "curiosity, inquisitiveness, critical thinking, and problem-solving capacities" (p.5). Furthermore, McDonald (2016) and Schmidt and Fulton (2016) advised to teach STEM as a new educational reform from early schooling years to benefit from its educational advantages on teaching and learning. Hom (2014) added that the goal of STEM at elementary levels is to stimulate the interest of students in STEM disciplines in a way to pursue them in the future instead of feeling obliged to practice them with no choice. Besides, the Wheelock College Aspire Institute (2010) stated that by fostering STEM education starting from the early years, teachers help boost the students' overall learning by stimulating their curiosity and interest in engineering and hands-on experimentation. Additionally, implementing STEM at elementary levels ensures the establishment of the required knowledge and skills in students for a successful STEM career. Yet, this exertion requires the schools to shift from the traditional instructional approach and to focus on integrating STEM disciplines with a greater emphasis on science and engineering. Additionally, Chesloff (2013) and Toma and Greca (2018) asserted that although investing in STEM education in early childhood is considered an issue for educational stakeholders, it is mandatory to foster STEM education at elementary levels and to focus on Mathematics discipline as of the ages of one to four when the brain is remarkably alert to acquire mathematics. Thus, Alumbaugh (2015) affirmed that an introductory level STEM within a high quality learning environment provides the elementary students with a structure that can help them explore, build, and question in a natural way. Alumbaugh (2015)'s findings revealed that young students who practice STEM education at elementary levels via hands-on

learning acquire and sustain a superior understanding of STEM disciplines when they progress to middle and high school. While Pfeiffer, Overstreet and Park (2009) confirmed that STEM education enhances the elementary students' creativity, understanding, and learning especially when PBL is used. Bilgin, Karakuyu and Ay (2015) added that the executed creativity in STEM pushes the students to be more adventurous, to search for solutions for the current challenges in a nation, and consequently to achieve national goals in the future.

Elementary teachers usually focus on mathematics and literacy most of the instructional time. This is mainly because of the push for standardized tests (Rosenshine, 2015). Yet, the teacher has to give more attention to science and social science in elementary classrooms as evidence shows that STEM skills built from early learning years help students in developing the required knowledge to prompt an interminable STEM understanding and proficiency. STEM education is an integrated model that connects Science, Technology, Engineering, and Mathematics. Via PBL and through design, students intertwine their understanding of STEM into an interconnected use of skills rather than perceiving them as four separate subjects. To craft a STEM lesson in an elementary level, teachers have to be knowledgeable in STEM and well prepared to teach STEM. Nadelson et al. (2012) posited that the more the elementary teacher is knowledgeable and prepared to teach STEM, the better the student academic achievement is. In crafting their STEM lessons, teachers have to take into consideration four basic elements: (1) posing questions: questions have to be related to real-world problems, (2) inquiry-based lessons: lessons have to be inquiry-based where students use their inquiry-based skills to conduct original research, to test, and analyze data, (3) collaboration: students have to collaborate to design and improve probable solutions, (4) communicate findings: students should communicate and explain their findings or solutions to their peers at the end of each STEM lesson (Bush & Cook, 2019; Peters-Burton et al., 2018; Reagan, 2016). Besides, STEM teachers can benefit from many STEM educational products and programs to build their proficiency in STEM education in the elementary grades. These educational products provide the teachers with the needed support to fit hands-on and interactive science instructions into their demanding schedules. Step into STEAM by Bush and Cook (2019) is one recommended book that guides and inspires K-5 teachers through a seamless process of designing and implementing STEAM inquiries that align carefully to key mathematics and science content and practices. Moreover, Science4Us is one of

the highly recommended educational programs that helps the teachers create meaningful and transformative learning experiences that guide the students' exploration to build a firm foundation in STEM skills via numerous innovative online-interactive activities and several hands-on offline activities. Via their participation in these designated hands-on activities or virtual games, the students explore, investigate, learn concepts, acquire scientific vocabulary, and build better skills in scientific inquiry, technology, and engineering. Additionally, teachers are advised to utilize online STEM applications, such as kid weather, animals HD, ABC go, crayons physics deluxe, and bugs and numbers. Information regarding the mentioned applications and advice from STEM experts to elementary teachers and much more can be found on *we are teachers* blogs. Furthermore, Kim et al. (2015) proposed four suggestions for elementary STEM teachers to prepare their students for lifelong success in their educational and career journeys. For instance, the researchers posited that (1) starting a robotics club in the school to engage students and to incorporate technology and engineering in elementary education, (2) incorporating digital literacy via computer games that teach students keyboarding and coding skills, (3) planning for a science fair in the classroom on regular basis, for students to communicate their scientific insights with their peers, and (4) teaching basic lessons in chemistry via STEM activities starting from elementary levels such as preparing a slime recipe are all suggestions to be taken into consideration for a better STEM implementation and for giving elementary students a leg up when preparing for middle school.

2.3.6. Elementary STEM Student Perceptions

The teachers' perceptions and practices of STEM education affect the students' perceptions and practices of STEM education (Bell 2016), yet few other factors affect the students' perceptions and practices of STEM education which are associated with three equal interconnected and interacting factors which are the (1) knowledge or the student ability to access STEM knowledge and how to deal with its uncertainty, (2) the skills to solve real-world problems, specifically the student problem-solving skills, critical thinking skills, creativity skills, and (3) the student motivation or engagement by experiencing relevant, authentic, and meaningful experiences (Murphy, MacDonald & Danaia, 2020). The students' engagement in STEM education is described as the extent of the students' attention, interest, passion, and

curiosity while they are learning STEM. Moreover, the students' engagement can be discussed from different perspectives including intellectual, emotional, behavioral, physical, and social engagement (Alumbaugh, 2015). For instance, STEM education provides a means for teachers to facilitate the students' engagement from different perspectives (Sulaeman et al., 2021).

Alumbaugh (2015) asserted that STEM lessons design or projects engage the students: 1) intellectually, by satisfying their interest, provoking their curiosity, by building on what they already know, and by providing them opportunities to engage in STEM practices; 2) emotionally, by promoting their positive academic emotions related to the affective domain of STEM that will facilitate their learning process; 3) behaviorally, by lessening the students' potential disengagement that follows a daily classroom routine and by engaging the bored and unmotivated students while introducing a variety of learning pedagogical approaches and projects to cover the STEM content; 4) physically, by engaging students in kinesthetic and physical activities; 5) and socially, by allowing students to work in collaborative teams or groups. Sulaeman et al. (2021) added that STEM education allows the students to be more active; therefore, more engaged in their own learning in a way to better remember what they have learned. Yet, Marzano (2013) encouraged the teachers to reflect on four main questions in order to engage the students in STEM learning. For instance, teachers need to ask themselves if they are providing a safe, caring, and stimulating STEM learning environment for their students; if they are making STEM education interesting; if they are demonstrating why the STEM content is significant; and if they are helping the students realize that their efforts in STEM are key to their success. While Goldston and Downey (2012) suggested numerous tips for the teachers to follow to engage students in STEM education. For instance, teachers have to utilize the students' interests and input in STEM education to facilitate their learning, they have to encourage students to ask questions and address their concerns in STEM education, and they have to offer non-compulsory challenging STEM activities once students have accomplished their initial work.

Besides, enjoyment and interest are considered crucial factors that affect the students' perceptions and practices of STEM. Enjoyment and interest can be fulfilled by integrating music and art into STEM activities (Hwang & Taylor, 2016; Srikoom, Hanuscin & Faikhamta, 2017) or by introducing STEM focus extracurricular robotics programs (Bentley, 2021). Sullivan and

Bers (2019) stated that robotics programs have positive effects on the students' motivation and interest in STEM, especially for girls. Moreover, gardening projects seem to be enriching activities that increase the students' interests in STEM education (Graves, Hughes & Balgopal, 2016). Furthermore, Koul et al. (2018) found out that there is a statistically significant relationship between the integration of technology and engineering in a unit of study and the students' interest in learning. Additionally, gender seems to be a vital factor in perceiving and practicing STEM as most studies state that boys do express higher interest in and better attitude towards STEM education than girls do (Abdallah, 2017; Iskander et al., 2013). The reason behind this discrepancy, as per Vincent-Ruz and Schunn (2017), is the student self-efficacy towards STEM. In general, girls have lower self-efficacy towards STEM and they are less likely to participate in STEM activities and courses compared to boys. Yet, Ellis, Fosdick and Rasmussen (2016) argued that girls show a lack of confidence in STEM areas which lead them to quit STEM majors. In addition, Bernasconi (2017) claimed that male students demonstrate higher skills in STEM careers despite the fact that the female students reveal higher school accomplishment. However, Malaka (2018)'s study outcomes revealed that there were no significant differences between the responses of the male and female students on STEM perception and practices although Stoeger et al. (2013) reported that males' interest in STEM areas is three times greater than that of the girls.

2.3.7. Obstacles to STEM Education

Alumbaugh (2015) stated that there are key obstacles that hinder the implementation of STEM education in school, such as the teachers' misperception that STEM education is too costly and too challenging to fit in standard curricula; the teachers' motivation and belief that STEM education is too difficult to implement without consistent training; the teachers' beliefs that the STEM certification process is very demanding and their preference to teach to the test as they lack STEM experience; and the teachers' beliefs that students are not prepared to take STEM classes. In addition, another obstacle is the unavailability of time and budget to implement the challenging STEM curriculum in their classrooms. Likewise, Berlin and White (2012) stated that although the teachers value STEM education and recognize its benefits, they believe that it is a challenging and complicated endeavour with many obstacles such as the

insufficient funding, professional development, and the lack in content and assessment knowledge. Similarly, Hammack and Ivey (2019) claimed that although elementary teachers support STEM integration in their classes, they presented numerous barriers that hinder its implementation, such as lack of training, material, time to plan and implement STEM lessons and activities, background knowledge, and administrative support to integrate STEM education in their classrooms. Park et al. (2016) added that unstructured educational STEM curricula and the school rigidly designed curricula hinder effective STEM implementation. While Forawi (2020) added that deficiency in teachers' understanding and in content knowledge of STEM education do not only hinder the STEM integration process, but do negatively influence the students' accomplishment and inspiration towards STEM education. Additionally, Lim et al. (2015) found out that it is significant for teachers and students to have educational textbooks related to STEM objectives and practices for better STEM results.

STEM is implemented in most cases via problem-based learning approaches. PBL was described as "a well-defined outcome with an ill-defined task within an interdisciplinary framework" (Capraro, Capraro & Morgan, 2013, p.14). Accordingly, teachers find PBL approach complex and messy by nature, i.e., problematic and challenging (Al Quraan, 2017). Additionally, Katzenmeyer and Lawrenz (2006) argued that evaluation is a must in effective STEM integration. Yet, there is a lack of well-qualified STEM evaluators to evaluate STEM programs and projects across schools. Also, there is a severe deficiency in valid and reliable instruments to measure the STEM teachers' knowledge and skills, the students' comprehension of STEM content, and the outcomes of STEM intervention and classroom practices. Furthermore, Forawi (2020) stated that the absence of a unified framework of STEM application and the lack of quality assessment for STEM implementation are considered obstacles for STEM integration.

Alumbaugh (2015) added that the parents' misperception of STEM education is considered another key obstacle for STEM implementation. For instance, parents believe that STEM education is only for collegiate and smart students and it is mostly about mathematics and science; therefore, not for girls. Moreover, the lack of extra-curricular activities that support STEM education and the lack of collaboration between schools and colleges about the best curricula to be implemented are considered significant factors that hinder STEM implementation

in schools (Alumbaugh, 2015). Lastly, the students' lack of confidence and interest in STEM education inhibit them from pursuing STEM courses and majors. This is due to the students' beliefs that STEM education is too challenging and tedious and to the teachers' incompetence in implementing effective STEM activities. In addition, the traditional teaching methods and the rigid curricula have overlooked students and left them untrained to cope with practices required to implement and achieve in STEM education (Forawi, 2020).

Consequently, Hammack and Ivey (2019) suggested that teachers have to be well-educated and supported with needed training and resources to perceive STEM education in a positive way and to be able to integrate STEM education in their classrooms. Fisher, Frey and Pumpian (2012) advised the delivery of professional development over a lengthy period of time to provide the maximum impact on teachers' learning. On the other hand, Berlin and White (2012) recommended teachers to be more exposed to STEM concepts, processes, and skills to become more knowledgeable of the content and approaches to STEM education. Also, Forawi (2020) stressed on the significance of several factors for an effective STEM implementation such as: delivering professional development for teachers to explore STEM as an integrative approach to learning by focusing on student-centered and problem-solving techniques in order to meet the twenty-first-century skills requirements and to recognize its importance in motivating students in teaching and learning. Other factors included identifying proper STEM policies to develop a unified framework and correct STEM application, reforming and standardizing curricula to integrate STEM objectives, allocating proper funding for STEM integration to provide materials, resources, and related textbooks necessary for STEM activities, integrating technology to cope with the technological revolution, motivating teachers via psychological training to change their mindset to accept integrating STEM in their classrooms since many are afraid of STEM education, and creating quality assurance centers that control, assess, and evaluate STEM implementation and educational outcomes. Another factor was, addressing the students' lack of motivation and interest in STEM education by involving them in innovative STEM oriented activities and programs and by offering them the opportunities to interact with scientists and engineers in order to understand the STEM value in solving the real-world problems. Finally, The Carnegie Science Center (2014) proposed that parents have to be well educated on STEM

characteristics and benefits since STEM is for every student, no matter what the gender, the socioeconomic status, or the academic level is.

Once proper reforms are met, STEM stakeholders including policy-makers, administrators, teachers, parents, and students can generate a skilful generation which is able to effectively participate in knowledge-based economy and sustainable development (Forawi, 2020).

2.3.8. STEM Best Practices

STEM education is considered a beneficial educational program that helps schools develop a generation of professional scientists and engineers who are able to compete and achieve economic growth in this changing world by being innovative and critical thinkers, especially when it is implemented as of the early years (Alumbaugh, 2015; Chen et al., 2011). Achat-Mendes et al. (2020) added that STEM education boosts the students' confidence and helps them stay up to date. Besides, it helps them succeed in their education, find better jobs with higher income, and shape a better world. Likewise, Forawi (2020) and Soomro (2019) aimed that STEM education benefits the students in several ways. For instance, it helps them in promoting their problem-solving and critical thinking techniques, in enhancing their technical knowledge, academic achievement, and their level of retention. Additional ways are: fostering their skills in solving real-life issues, pushing them to be self-reliant, self-confident, innovators, and logical thinkers, leveraging their communication and collaborative skills, and providing opportunities to for future careers and national prosperity. Nevertheless, for students to desire the pursuit of STEM education, teachers have to motivate them by increasing their interest in STEM and promoting their learning via effective classroom practices (Gullapyan, 2020). Numerous studies described the characteristics of successful practices in STEM education (McKinnon, 2018).

2.3.8.1. Project Based Learning

Gullapyan (2020) reported that applying student-centered educational approaches such as PBL, PjBL, IBL, and cooperative learning is considered the most successful practice for effective STEM education. Similarly, Forawi (2020) added that the student-centered advantageous learning approach brings life to the classroom and allows students to learn STEM

effectively by applying their manual, decision-making, and problem-solving skills. Likewise, Tapia-Nunez (2021) stated that PBL is an educational approach associated with students' engagement in STEM classes. Al-Balushi and Al-Aamri (2014) disclosed that PBL is correlated with better STEM achievement. These findings are in line with Jacobs and Shahbazi (2019) study which emphasized the significance of hands-on activities and PBL in influencing positively STEM practices and in promoting students' 21st -century skills, engagement, positive attitude, and academic along with non-academic students' performances in STEM education. Hence, Smith and Hung (2017) investigated the effect of PBL on STEM education with seventh graders. Findings revealed that PBL had a significant effect on developing students' science knowledge in STEM subjects. Thus, several studies revealed that STEM PBL increased STEM students' enjoyment and piqued their curiosity and imagination (Jolly, 2016). It additionally enhanced their science content comprehension, retention of knowledge, academic achievement, collaborative behavior, group communication, and economic future workforce skills (Forawi, 2020; Jacobs & Shahbazi, 2019; Marshall & Harron, 2018; Tapia-Nunez, 2021).

2.3.8.2. Authentic Classroom Environment

Furthermore, Gullapyan (2020) stated that providing students with positive, safe, and authentic learning environments is considered an effective practice in STEM education. In fact, teachers' priority has to be providing students with safe spaces where they feel comfortable asking questions and make mistakes. Moreover, STEM concepts should be authentically related to real-world contexts and the STEM topics should be relevant to students' lives and interests. Beier et al. (2019) agreed with Gullapyan (2020) by stating that the students' enjoyment, interest, and career aspiration in STEM areas improve once they participate in authentic learning experiences. Furthermore, Jacobs and Shahbazi (2019) confirmed that engaging in authentic and real-world experiences enhances the students' self-confidence, self-efficacy, and interest in STEM. Yet, Yohannes, Juandi and Diana (2020) argued that sometimes it is difficult to find real-life problems related to some abstract topics to STEM, especially in mathematics subjects, and that hinders the teachers' ability to contextualise STEM in their classrooms.

According to Paechter, Luttenberger and Ertl (2020), teachers can enhance the students' attitude toward STEM by fostering positive learning experiences in their classroom

environments through their interaction with students and their choice of adequate instructional approaches and appealing content. In fact, teachers' feedback is considered one of the most influential factors on students' attitudes toward STEM, especially on girls. For instance, girls rely on teachers' feedback more than on their grades to assess their performance (Skipper & Leman, 2017). Moreover, Harks et al. (2014) stated that teachers' process-related feedback which focuses on students' learning processes in STEM education motivate the students and support their growth mindset development. Furthermore, they influence the students' persistence, enjoyment, and interest in STEM. Paechter, Luttenberger and Ertl (2020) added that teachers' feedback in STEM education promotes the students' beliefs that they can improve and achieve better once they make more efforts in their learning journey.

2.3.8.3. Teacher Knowledge

Another key finding related to STEM successful practices is the teachers' knowledge of STEM subjects. To implement STEM effectively, teachers need to have a deep understanding of the STEM different teaching strategies and they have to be knowledgeable of STEM subject-specific content to enhance the students' comprehension of the STEM content to ask and answer exploratory questions (Gullapyan, 2020). The STEM education policy statement of Ireland (2017) posited that teachers should have the satisfactory pedagogical content knowledge to support their elementary students in designing and enacting high-quality learning experiences. For instance, in challenging engineering STEM activities, teachers need to understand not only the content of the main investigated discipline which is engineering, but also comprehend the science, mathematics, and technology, as they all relate to the challenge (Yohannes, Juandi & Diana, 2020). Additionally, the teachers' pedagogical content knowledge (PCK) is significant in STEM practices as it assists the students in overcoming the learning challenges in STEM education (National Research Council, 1999). Chan, Yeh, and Hsu (2019) added that the knowledge required for effective STEM education is broad and multifaceted. Content knowledge, pedagogical knowledge, technological knowledge, student knowledge, assessment knowledge, and curriculum knowledge are the essential components of teacher knowledge. Furthermore, teacher efficacy and teacher confidence are highly correlated with teacher knowledge and student success in STEM education. Thus, motivating teachers and providing

them with the necessary time to accomplish positive experiences in STEM classrooms can highly impact their knowledge in STEM (Gunner, 2019).

2.3.8.4. Classroom Resources

Marshall and Harron (2018) suggested that classroom resources affect the implementation of STEM education in schools. Likewise, Malaka (2018) stated that funding for the resources of STEM education from energy and government authorities is a must for supporting and executing an effective STEM practice. Yet, Yohannes, Juandi and Diana (2020) argued that the absence of adequate learning tools and materials reduces the teacher's desire to conduct learning activities by utilizing STEM approaches. Moreover, inviting scientists, engineers, or experts to work closely with students positively affects STEM implementation. In fact, studies reveal that students enjoy and benefit from engaging, challenging, and interactive presentations by passionate and enthusiastic mentors or experts. Time availability is also considered a valuable resource to implement STEM education. Several studies revealed that teachers always complain about time limitation when teaching STEM projects. Furthermore, a successful teacher-student relationship based on trust and teachers' awareness of their students' interests, abilities, strengths, and weaknesses has significant implications for STEM education (Malaka, 2018).

2.3.8.5. Integrative Curriculum and Lesson Plans

A clear, supportive, and integrative curriculum with clear targets under STEM implementation is mandatory for effective STEM practices. Lehman, Kim and Harris (2014) claimed that the presence of a quality, coherent, rigorous, inquiry-based, well-defined, flexible, and experiential integrated 21st century STEM curriculum design which is founded on STEM concepts, tightly driven by standards, and compelled ¹with clear goals and objectives would improve the quality and the efficiency of STEM practices. Moreover, the STEM curriculum should cover the different STEM instructional disciplines via different pedagogical strategies and methods such as PBL. Yet, Yohannes, Juandi and Diana (2020) claimed that by

implementing an integrative curriculum, teachers help students build a logical sense of the world where they live, understand what they pursue as a whole, and be able to deal efficiently with the modern world. Alumbaugh (2015) argued that for a STEM curriculum to be selected as a highly effective STEM elementary curriculum, it should meet specific criteria. For instance, the curriculum has to be challenging, experiential, and inquiry-based with clearly-defined objectives and assessment where educational goals are well-defined and attainment is measured against them. Moreover, STEM curriculum has to be implemented within inquiry learning classrooms where students and teachers interact and collaborate as active learners. Furthermore, it has to be sustained by teachers' commitment and supported by the community via solid leadership and sufficient resources.

Nevertheless, STEM curricula need to undergo reforms to meet the growing needs of today and the future society, as Barcelona (2014) stated. For instance, curricula reforms have to take into consideration the urgent need to educate students to be future innovators who can cope with the changing world by involving them in problem-solving and innovative thinking challenges and by sparking their interest in STEM areas via high-quality hands-on and real-life-related experiences. Moreover, the reforms have to be supported by the school administration and embraced by STEM teachers through their collaboration and commitment in addition to, continuous training and workshops that focus on their needs to apply the curricula modifications (Barcelona, 2014).

To practice effective STEM activities, teachers need to design and apply effective lesson plans which allow the students to seek solutions for relevant real-world issues by making connections between the STEM acquired content in classrooms and the real-world concepts. Hands-on activities fit well the STEM lesson plans as they require the students to build, design, create, role-play, and find solutions for relevant problems by mimicking real-world scenarios. Moreover, collaboration and communication are key to effective STEM lessons. Roche et al. (2021) advised teachers to play the role of facilitators and to apply student-centered approaches besides fostering group work in their classrooms because studies revealed that students are more productive and able to solve problems once they work in teams. Furthermore, the engineering design process is highly recommended in STEM lessons as it allows students to utilize their

cognition in defining the problem, planning the research, applying different solutions, testing the results, and evaluating their learning (Roche et al., 2021).

2.3.8.6. Celebrating STEM

Introducing STEM to young kids helps in enhancing their cognitive, social, and emotional skills. And, implementing STEM via interest-based learning turns the challenging subjects into fun activities that students can easily understand and enjoy; therefore augmenting their interest in STEM and future STEM careers (Nam, 2021). Thus, due to its significance, it is necessary to highlight STEM achievements, whether large or small. For instance, the students' gains can be celebrated by posting them on the school website, newsletter, in the school halls, or by inviting the community to a STEM fair. This ongoing celebration of the STEM students' wins sparks the students' motivation, enjoyment, and interest in STEM areas. In addition, it allows them to be highly engaged in scientific discussions and experiments. Furthermore, STEM celebration helps the STEM scholars to identify what works and needs to be improved in STEM education (Barcelona, 2014; Munn et al., 2018).

2.3.8.7. Professional Development

Teacher professional development is considered the cornerstone of all kinds of education reform (Chai, 2019). Professional development and workshops play a significant role in STEM implementation as they support teachers by allowing them to embrace STEM programs (Al Quraan, 2017). Malaka (2018) added that PDs enhance the teachers' knowledge of the different instructional STEM approaches by teaching them how to utilize them for specific disciplines and by offering them the opportunities to collaborate and reflect on their teaching. PDs also instruct the teachers on the importance of creating safe, authentic, and positive learning environments for STEM education. Furthermore, workshops and training help the teachers embrace digital tools and engineering design in the STEM classroom. For instance, to imitate engineering design experiences in their classrooms, teachers need to be trained to successfully teach students via the lens of engineers. It also enhances teachers' knowledge of STEM content and prepares them better to deliver efficient STEM education by enhancing their inquiry-oriented teaching methods (Jolly, 2016). Besides, Avery (2013) asserted that PDs facilitate the teachers' teaching by

training them on how to motivate and engage students with the subject matter and by educating them on how to foster problem-solving skills in their students. Similarly, Gunner (2019) claimed that PDs present educational models that exhibit how teachers could enhance problem-solving and real-world applications.

Gao, Shen, and Sun (2020) claimed that PDs educate teachers on how to develop efficient STEM lesson plans and how to assess group work. The students' STEM comprehension has to be assessed in an authentic way to understand how students connect knowledge and skills from multiple disciplines. PDs support teachers in assessing their students via suitable interdisciplinary practices that stress assessing the students' STEM knowledge and skills, concurrently. Huang and Jong (2020) claimed that employing rubrics in STEM education is considered a promising method to promote learning and augment instructional impact by helping teachers communicate their expectations of performance to their students. The researchers added that well-designed rubrics allow the teachers to give feedback on students' achievement. Hence, they suggested that STEM work can be assessed via six aspects which are: the ability to define the problem, the practicality, the usability, the group work, the entrepreneurship, and the whole presentation and explanation. Avery (2013) argued that PDs influence the teachers' confidence and address their limited background. Lastly, PDs impact the longevity and sustainability of teachers' careers by contributing to their professional development. Hence, PDs help in reducing teachers turnover which is considered a prominent school issue.

2.4. STEM Education practices in the UAE

Education is considered one of the key components of sustainable development in the UAE. The UAE is aiming at building a knowledge-based society by making efforts to improve its educational system and by setting several educational policies in an attempt to improve the public education sector which is lagging behind the private sector. For instance, in coordination with the ministry of education, the government is building new schools and institutes in the seven emirates, in addition to preparing high-quality teachers who can implement rigorous curricula with advanced technology techniques. Forty percent of the total number of students in the UAE attend the private sector which is considered well developed with varied curricula that

are exhibited in different systems, such as the American, British, Australian, and Indian systems (Forawi, 2020).

STEM education supports the development of human capital which is indispensable for all processes of innovation in a nation by preparing a considerable number of graduates ready to be serviceable for national and international careers (Hathcock et al., 2015). Loyalka, Liu and Chirikov (2021) added that STEM education contributes to the growth of the national human capital and fosters innovation so nations can grow and compete in the economical global knowledge by enhancing the students' academic knowledge, higher-order thinking skills, and competencies. Additionally, Savkov et al. (2020) stated that by attracting one percent of the American population to STEM professions, the USA's Gross Domestic Product (GDP) increases by fifty billion dollars which means that STEM education is capable of changing the economic status of a country and it promotes innovation and competition. Therefore, engaging, preparing, and graduating students in STEM disciplines is vital for every country including the UAE which needs to meet its self-sufficiency and self-sustainability, and achieve its goals. In fact, STEM education is new in the Arabic region in general and in the UAE in specific (Al Murshidi, 2019). It was renowned in the UAE in 2010 when several schools adopted the three-dimensional NGSS in their science curricula (Ahmed, 2016). Many initiatives were taken by the STEM promoters in the UAE to implement effective STEM education as the UAE economy is moving from being oil-based to knowledge-based and that requires more students to graduate as scientists and engineers (National Academies of Sciences, 2018). Sheikh Mohammed bin Zayed, Crown Prince of Abu Dhabi and Deputy Supreme Commander of the UAE Armed Forces, stated that the students' pursue of engineering, technology, and finance are imperative to the information-economic revolution in the UAE and he encouraged UAE students to join scientific fields and careers. Yet, despite the remarkable initiatives toward STEM education in the UAE, few students are joining the STEM fields (Forawi 2020).

Geesa, Stith and Rose (2020) claimed that to help students succeed in a global technology-driven economy, educational leaders must provide students with authentic educational environments that enhance their critical thinking and facilitate their problem-solving to resolve real-world problems and be ready for the future careers. Moreover, educational leaders need to be knowledgeable about how to lead and support the STEM education leaders in their

educational organizations in an efficient way to integrate STEM education via innovative and different approaches and methods to facilitate STEM subjects' integration, foster life-long learning, and improve the students' preparation and success in future careers. Likewise, Ferrara-Genao (2015) argued that a differentiated and integrated STEM curriculum that is customized to deliver meaningful learning opportunities for students with different abilities, an innovative passionate and transformational leadership that is knowledgeable and conscious that a compassionate staff is a major key in the success of STEM integration, and the district and the administration support are all keys for successful STEM integration. In the UAE, studies revealed that there are many reasons behind the student's indifference toward STEM education. For instance, Alyammahi et al. (2016) stated that the deficiency of STEM capable teachers, the lack of STEM role models, and the difficulty of the language of instruction are a few of the many reasons affecting the students' choices in STEM education. Likewise, a study conducted by Malaka (2018) regarding the educational stakeholders and students' perceptions of STEM practices in the UAE disclosed that STEM implementation in the UAE necessitates further support for teachers via professional training and workshops, adequate time for teacher collaboration, availability of the necessary STEM resources and environments such as STEM labs and campuses, in addition to strong leadership for better guidance. The researcher added that strong coordination among the UAE government, the energy authorities, and the educational institutions contribute to a sturdy STEM reform and an effective STEM implementation. Similarly, in a study related to teachers' perceptions and implementation of STEM education in private American system schools in the UAE, Al Basha (2018) claimed that although the teachers were well-informed in inquiry learning and scientific literacy, they totally agreed on the high significance of implementing STEM, especially via project-based learning with engineering practices. However, according to NGSS Lead States (2013), they showed misunderstandings of STEM disciplines' contents and core concepts required for STEM implementation. Besides, teachers complained about a dearth of professional training and a lack of STEM resources and funding. They also reported a deficiency of significant collaboration among the diverse parties in school and the inadequate time to implement STEM activities which all result in implementing STEM as an activity per term or as an extra-curricular activity.

One of the essential reforms in education is STEM education (Al Basha, 2018). To meet the students' needs in STEM education, STEM leaders are required to provide teachers with professional development such as training and workshops to support them, motivate them, and clarify their misunderstanding of STEM content and core concepts. PDs need to enhance the teachers' STEM skills and practices because well-informed teachers have the power to deliver successful STEM education (Han, Capraro & Capraro, 2015). Moreover, STEM teachers' satisfaction and well-being have to be fulfilled by increasing their wages and by providing them with a welcoming and positive STEM environment with necessary educational resources, STEM labs, and maker-space to implement clear, updated, and practical STEM curricula (Al Basha, 2018; Malaka, 2018).

To provide the teachers with the required resources and to prepare the STEM environments, STEM scholars have to deal with STEM educational resource providers. For instance, Edutec and ATLAB are two leading educational companies in the UAE that provide schools with STEM resources and learning solutions. They also offer professional development for STEM teachers and their students. Indeed, the STEM educational stakeholders in the UAE are conscious of the significance of PD activities in supporting and enhancing teachers' learning, professionalism, and skills in STEM, which in turn improve student education (Mahil, 2016). Lastly, by meeting the students' and the teachers' needs in STEM education, teachers will be capable of implementing STEM education with effective methods and students will be motivated to enroll and embrace STEM areas which are keys to economic and technological development in the UAE (Malaka, 2018; Zahran, Pettaway & Waller, 2016).

Summary of the Chapter

In this chapter, the researcher included the theoretical lenses through which the findings of the study will be interpreted as well as the recent related literature to STEM education which was reviewed and discussed. The relevant literature pinpointed significant insights to effectively implement STEM education in schools, especially in elementary classrooms.

For instance, studies consider STEM education a recent educational approach and scholars are still perceive it in dissimilar ways which can threaten its successful implementation (English, 2016). Yet, a consensus is reached on the fact that STEM education practice is not simply an incorporation of the four STEM subjects into a unit of study or a curriculum. Thus, it

is an intentional integration of the four subjects into a single discipline of education (Chen et al., 2011). The path and the degree of STEM integration are highlighted in the literature by different approaches: the disciplinary, the multidisciplinary, the interdisciplinary and the transdisciplinary approach. These approaches have to be attempted by utilizing instructional strategies of PjBL, PBL, and IBL and have to be swathed with collaboration, authentic problem-solving skills, design and technology, and higher-order thinking skills to decipher present issues and real-life problems by applying and combining science, technology, engineering, and mathematics disciplines (Chalmers et al., 2017; Kennedy & Odell, 2014; Lesseig et al., 2016; Mandeville & Stoner, 2015; Mitts, 2016; Psycharis, 2016; Shernoff et al., 2017).

The transdisciplinary approach is identified as the uppermost level of integration (Vasquez, 2015) and is frequently referred to as problem-based or project-based learning. Capraro and Slough (2013) stated that PBL offers the students real-world opportunities to engineer valid solutions to real-world problems by situating their scientific inquiries and by offering real-world contexts where they can apply their mathematical, engineering, and technological skills and construct collaborative learning skills, especially when applied in elementary levels.

STEM teacher perception is identified as one of the ultimate significant processes that need to be considered by the STEM education stakeholders as the teachers' STEM practices are highly influenced by their perceptions of STEM (Srikoom, Hanuscin & Faikhamta, 2017; Thibaut et al., 2018). The literature related to teachers' perceptions of STEM education is vast. Yet, the researcher could identify several factors that can affect the teachers' perceptions of STEM education. For instance, the teacher's age, gender, and educational background are demographical factors that can affect the teacher's perception of STEM education. In addition to the teaching subject and the educational level, several psychological factors, such as the teachers' attitudes and self-efficacy seem to play a critical role in teachers' perceptions of STEM education. Hence, recent studies documented that the students' perceptions and practices of STEM education are associated with interacting factors such as the ability to access STEM knowledge, the skills to solve real-world problems, and the student motivation while experiencing relevant, authentic, and meaningful experiences. The teachers' perceptions of

STEM education, the student gender, the level of enjoyment, and the interest in STEM education are considered crucial factors that affect the students' perceptions and practices of STEM.

The focus of this study is STEM education at the elementary level is. Implementing STEM starting from early years is highly advantageous as it improves the students' communication skills and vocabulary use. It develops their motor and technological skills in a better way when compared to implementing it starting from high school. It also enhances their interests and attitudes toward science education, boosts their overall learning by stimulating their curiosity and interest in engineering and hands-on experimentation, and it ensures the establishment of the required knowledge and skills in students for a successful STEM career. Therefore, STEM has to be implemented at elementary levels. Yet, findings revealed that STEM at the elementary level has unquestionably the least focus among all educational levels as its exertion requires the schools to shift from the traditional instructional approach to integrating STEM disciplines within high-quality-earning environments that provide the elementary students with a structure that can help them explore, build, and question in a natural way; therefore enhance their motivation, interest, enjoyment, and skills in STEM education (Bentley, 2021).

Several studies focused on teachers' perceptions as teachers have to perceive STEM positively to better implement it. The relevant literature showed that professional development learning opportunities such as workshops or trainings help teachers deal with the challenging implementation of interactive STEM curricula and improve their skills and abilities in planning STEM group-oriented activities. Studies around the best practices in STEM education were reviewed as well. Findings documented that project-based learning is considered the most successful practice for effective STEM education. However, implementing STEM education based on clear, supportive, and integrative curricula with clear goals within resourceful, positive, safe, and authentic learning environments seem to be mandatory for effective STEM practices. Additionally, teacher knowledge is considered a major key beside the professional development in implementing effective STEM education. Yet, many obstacles can hinder the implementation of STEM education in schools. For instance, teachers' misperception that STEM education is too costly and too challenging to fit in standard curricula; teachers' motivation and belief that STEM education is too difficult to implement without consistent training; teachers' beliefs that the

STEM certification process is very demanding and their preference to teach to the test as they lack STEM experience; teachers' beliefs that students are not prepared to take STEM classes, and the unavailability of time and budget to implement the challenging STEM curriculum in their classrooms are all considered main obstacles in STEM implementation.

Despite the existence of a plethora of information regarding STEM school standards, there are limited studies in the literature that shed the light on STEM integration and practices in UAE schools. STEM education is new in the UAE. Yet, the related literature reveals that the STEM promoters took several initiatives to implement effective STEM education in the UAE. However, students are still not joining the STEM fields. The deficiency of STEM capable teachers, the lack of STEM role models, the difficulty of the language of instruction, and the unavailability of time and the necessary STEM resources and environments are all good reasons behind the students' refutation of STEM education in the UAE. STEM leaders are required to provide teachers in the UAE with the required resources and professional development to clarify their misunderstanding of STEM content and core concepts. Hence, more in-depth examination of teachers' perceptions of STEM education in the UAE are needed. To this end, this study will add value to the literature related to STEM education in the UAE by addressing the gap in the literature and by revealing significant outcomes on the offered STEM provisions in the elementary private schools in Abu Dhabi. It will shed the light on the teachers' and students' perceptions and practices of STEM education in the mentioned schools. Additionally, it would be interesting for this study to highlight the obstacles the elementary teachers are confronting to implementing STEM education in their classrooms.

CHAPTER THREE: RESEARCH METHODOLOGY

Overview of the Chapter

Leedy and Ormrod (2001) described Research methodology as “the general approach the researcher takes in carrying out the research project” (p. 14). Thus, the following chapter reveals and justifies the research approach and methods selected by the researcher to meet the purpose of this study which is to explore the current provisions that are on offer in relation to STEM education and to investigate the teachers’ and the students’ perceptions of STEM education in Abu Dhabi private elementary schools and to answer the following research questions:

RQ 1: What are the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools.

RQ 2: What are the elementary teachers’ and students’ perceptions of STEM education in private schools in Abu Dhabi?

RQ 3: Are there any demographic differences in elementary teachers’ and students’ perceptions of STEM education in private schools in Abu Dhabi?

The two sections of this chapter which are the research approach and the research methods are discussed in detail. In the first section, the selections of the elements of the research approach, such as the pragmatic philosophical paradigm, the mixed methods approach, and the exploratory sequential mixed-methods design are justified and discussed to entail their significant application in encountering the multiple objectives of the research under study. These objectives are (1) exploring the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools, (2) investigating the elementary STEM teachers’ and students’ perceptions of STEM education in private schools in Abu Dhabi, and (3) investigating if there are any demographic differences in elementary teachers’ and students’ perceptions of STEM education in private schools in Abu Dhabi. The second section of this chapter describes and justifies the elements of the research method including the context of the study, the site selection, the population, sampling and participant selection, the data collection instruments including the document analysis protocol, the teacher questionnaire, and the student questionnaire. Moreover,

the distribution protocol of the research under study tools is considered. The validity and the reliability of the research instruments are also discussed to warrant the effectiveness and the credibility of the research. Furthermore, the data analysis plan clarifies how each set of data is analyzed independently in this exploratory sequential study. Additionally, the ethical considerations including the scientific research and society relationship, the researcher and participants relationship, and the professional issues with the role of the researcher are discussed.

3.1 Research Approach

This section identifies and discusses the selection of the research approach elements such as the adopted research method, study design, and paradigm that are utilized to meet the purpose of the study.

Educational research is a systematic investigation that adopts empirical methods to resolve challenges in education. It applies rigorous scientific approaches to gather and analyze data for problem-solving and knowledge development in education (Tuckman & Harper, 2012). The aim of educational research is to provide the researcher with the knowledge that will let him/her achieve a research goal via the most effective methods, while its purpose is to extend the current body of knowledge by providing solutions to different educational problems, especially in teaching and learning (Tuckman & Harper, 2012). The continuing evolution of educational research has given rise to several methods that can be categorized under qualitative and quantitative categories. In general, the quantitative method relies upon objective analyses of quantifiable data via descriptive or statistical methods, while the qualitative method refers to methods that rely on subjective interpretations of rich textual data (Kimmons, 2022). In the last decade, researchers utilized and encouraged the mixed methods approach in educational research as it is useful to solve educational problems in an accurate and situated way. Moreover, evidence provided by these methods appeals to the educational stakeholders (Kimmons, 2022).

Internationally, STEM education is increasing in importance. Since 2010, it has gained its own recognition by several different journals for publication as a hot and important topic area (Li et al., 2020). STEM education can be viewed from multiple perspectives (multidisciplinary, interdisciplinary, or transdisciplinary) which adds more complexity to deciding the extent to which activity can be categorized as STEM education (English, 2016; Li et al., 2020). These

multiple perspectives allowed researchers to conduct studies in multiple methods and to publish them in a vast range of journals. Most studies in STEM education were empirical studies published by American, Australian, Taiwanese, and British researchers. The majority of the published empirical studies utilized quantitative methods, followed by qualitative, and then mixed methods (Li et al., 2020). Yet, these empirical studies are limited and a broad base of empirical research related to STEM education does not yet exist (Al Quraan, 2017).

In the UAE, the teachers' and students' perceptions of STEM education are not clear and the efficiency of their STEM practices is not yet revealed, especially in private elementary schools in Abu Dhabi. To the best of knowledge of the researcher, no research had been conducted to investigate them. In order to solve this educational problem in an accurate and situated way and to provide the evidence of the STEM provisions in Abu Dhabi, the researcher selected the mixed methods approach. The mixed methods approach was the best method to be used in this study as it permitted the researcher to investigate the teachers' and students' perceptions of STEM education. Moreover, the use of both methods permitted the researcher to generate knowledge about STEM education in a rigorous way and to acquire a better understanding of the teachers' and students' perceptions than does the use of either approach alone (Fraenkel, Wallen & Hyun, 2015). Furthermore, the utilisation of both quantitative and qualitative methods enhanced the overall strength of the study by enhancing the reliability and the significance of the attained results and future recommendations (Creswell et al., 2003).

Creswell (2009) defined mixed methods research as “an approach to inquiry that combines or associates both qualitative and quantitative forms” (p. 4). Tashakkori and Teddlie (2003) claimed that together, quantitative and qualitative methods stipulate a superior understanding of the explored issue rather than adopting a solitary method. Cohen and Soto (2007) posited that collecting data via different methods increases the data reliability. The implicit bias that occurs when utilizing a solitary method can be neutralized, minimized, or even annulled in a mixed methods approach and a louder voice is given to the participants in the study (Creswell, 2009; Johnson & Christensen, 2012a). Moreover, by adopting a mixed-methods approach in the proposed study, the researcher attempted to profit from the strengths of both qualitative and quantitative research methods to fulfill the variety, the nature, and the complexity of the research questions related to STEM education and to obtain a more robust conclusion

(Caruth, 2013; Cohen, Manion & Morrison, 2002). Hence, by embracing a mixed-methods approach, the researcher will be attempting to overcome the dearth of quantitative analysis and complement the present body of qualitative analysis related to teachers' and students' perceptions and practices of STEM education (Al Quraan, 2017; Berlin & White, 2012; Eltanahy, 2019; National Research Council, 2013b).

The application of mixed methods approach is fundamentally a triangulation method where collected data in the second phase of a study corroborates the collected data from the primary method (Tashakkori & Teddlie, 2003). Tashakkori and Teddlie (2003) stated that the benefits of adopting a mixed methods approach go beyond the confirmation or the explication of the study results (triangulation), the gain of superior understanding of the studied phenomenon, the discovery of different perspectives, or even the development of new measurement instruments. Yet, conceptual validation and deeper comprehension of the outcomes are the main goals of mixed methods utilization (Thurmond, 2001). Mitchell (1986) argued that the integration of quantitative and qualitative data in research leads to a further conceptual understanding of the studied phenomenon. Morse (2003) claimed that the mixed methods design in a study provides the researcher with a further detailed and broader understanding of the studied phenomenon. Hence, it grants the researcher the confidence of the study outcomes and the ability to reveal, understand, and justify any inconsistencies in the data.

Creswell (1999) suggested that the researcher has to state explicitly the reasons behind mixing qualitative and quantitative methods in the research under study as choosing a mixed methods approach is challenging and should not be adopted except when there is a definite reason to do so. Two noticeable frameworks that list the main reasons for choosing a mixed methods approach were found in the literature. The first framework was developed by Greene, Caracelli and Graham (1989) and the second one was developed by Bryman (2006). Greene, Caracelli and Graham (1989) posited that triangulation, complementarity, development, initiation, and expansion are the five comprehensive and general reasons behind mixing qualitative and quantitative methods. As per the authors, triangulation aims to corroborate the findings emerging from both methods; while, complementarity intends to elaborate and clarify the findings of one method with the findings of the other one. Development purposes the utilization of one method

findings to inform the second method. The expansion aims to flare the breadth of inquiry in research by utilizing various methods for dissimilar inquiry components. Lastly, initiation seeks the questions' re-forming of one method with the questions or results of the second method. Moreover, it aims to discover any contradictions between the two methods and opens the doors to new perspectives of frameworks (Greene, Caracelli & Graham, 1989).

Yet, Bryman (2006) listed and described sixteen reasons for the researchers to utilize a mixed methods approach in research. For instance, triangulation or greater validity, offset, completeness, process, different research questions, explanation, unexpected results, instrument development, sampling, credibility, context, illustration, utility or improving the usefulness of findings, confirmation and discovery, diversity of views, and enhancement or building upon quantitative and qualitative findings are the main reasons behind mixing methods listed by Bryman (2006). In the current research under study, the researcher adopted the mixed methods approach as it is the most suitable method to answer the different research questions. To answer the questions related to the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools, the researcher adopted the qualitative method. Creswell and Creswell (1994) described qualitative method as a holistic approach that comprises discovery and that implicates purposeful use for describing, elucidating, and understanding collected data. Thus, to answer the questions related to the teachers' and the students' perceptions of STEM education in private elementary schools in Abu Dhabi, the researcher adopted the quantitative method. Creswell posited that quantitative method "employs strategies of inquiry such as experimental and surveys, and collect data on predetermined instruments that yield statistical data" (2003, p.18).

Another reason behind adopting the mixed methods approach was counterweighing the weaknesses of each method and drawing on the strengths of both methods (offset). Besides, the adopted approach allowed the researcher to generate a more comprehensive elucidation of the STEM area (Completeness). Additionally, by exploring the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools in the first phase via a qualitative method, the researcher was able to generate closed-ended questions to be added to the quantitative questionnaire for the second phase of the study (Instrument development). Lastly, the

researcher was keen to exploit a mixed methods approach to enhance the integrity of the research findings (Credibility).

Four different mixed methods types or designs were identified by Creswell et al. (2003) and Creswell (2002 and 2015). The triangulation (concurrent or parallel) design, the embedded mixed methods design, the explanatory mixed methods, and the exploratory mixed methods design.

The concurrent or parallel design aims to gather both, quantitative and qualitative data concurrently. The researcher is advocated to use the triangulation design when he/she needs to validate different forms of data with each other or when there is a need for data comparison. In such a design, the researcher gives similar attention to both, the quantitative and the qualitative methods. The strength of the concurrent design resides in its ability to combine and compare different data coming from different approaches in a study by overcoming limitations executed by selecting one definite data collection method. The embedded design is embraced in research when there is a need to meet the research objectives by collecting both quantitative and qualitative at the same time, but by prioritizing the quantitative data collection over the qualitative form. In such a design, the generated qualitative data support the quantitative data. The strength of the embedded design resides in its ability to provide a further source of data to the research under study which is not provided by the main data collection form.

The explanatory mixed methods design involves the gathering of the quantitative data followed by the collection of qualitative information. In such a design, the different types of data are not collected simultaneously. In a sequential manner, the quantitative data collection and analysis precedes the qualitative data collection and interpretation. The researcher is encouraged to use the explanatory design when the overall purpose of the study can be met by collecting quantitative data in the first phase. Yet, the qualitative data collection in the second phase aims to further elucidate and enhance the overall gestalt of the studied phenomenon postulated by the quantitative results. On the other hand, the exploratory mixed methods design involves the gathering of the qualitative data in the first phase followed by the collection of the quantitative information in the second phase. In the exploratory design, the collection and the interpretation of

the qualitative data are emphasized and used by the researcher to explore the overall studied phenomenon. Then, the quantitative data analysis in the second phase helps the researcher to further explain the qualitative data outcomes.

The exploratory sequential mixed methods design (Figure 5) which involves the gathering of the qualitative data followed by the collection of the quantitative information is the selected design for the present study (Clark, 2011). Creswell (2015b) posited that the researcher can use the exploratory sequential mixed methods design to meet specific aims such as testing an emerging theory stemming from a qualitative phase, generalizing a study outcome to different samples, developing a research tool, and exploring a phenomenon within a definite population. The reason behind the researcher's choice for the exploratory sequential mixed methods design was first to explore the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools and then to expand on the qualitative findings to investigate the teachers' and the students' perceptions of STEM education within the same context for the succeeding quantitative phase. Therefore, within the context of the current study, this method comprises two phases (Figure 5) where a qualitative document analysis is conducted in the first phase to answer the first question and to explore the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools. The results of the first phase of the study informed its second phase as its results along with the literature review and the conceptual framework of the study were used to add to the adopted quantitative teacher questionnaire a qualitative section with multiple open-ended questions. These questions addressed the research questions related to the teachers' perceptions of STEM education in elementary private schools in Abu Dhabi and validate the findings.

The application of the mixed methods approach in this study is grounded upon the pragmatic paradigm (Tashakkori & Teddlie, 2003) to provide answers to the current research questions. A paradigm is a bundle of beliefs and directives which influence the scientists' and the researchers' selections in a particular discipline of "what should be studied, how research should be done, and how results should be interpreted" (Bryman, 2016, p.637). Creswell (2009) identified paradigms as worldviews and defined them as "a general orientation about the world

and the nature of research a researcher holds” (2009, p.6). Hence, in his book titled *The structure of scientific revolution*, Kuhn (1962) defined paradigm as an analytic lens via which a scientist views the world. In 2018, Blackstone considered paradigms to be delineations of the manners we outline what we know, what we can know, and how we can know it. In 2009, Creswell identified three main elements that can affect the researcher's selection of worldviews; therefore, the adoption of a specific research design for a research study. Actually, Creswell claimed that the researcher's discipline area, the researcher's nature of beliefs, and the researcher's past experiences affect the scientific assumption and the nature of knowledge a researcher seeks.

This study adopted the pragmatic paradigm as a philosophical assumption as it allowed the researcher to freely utilize all the accessible and suitable methods or techniques that best encounter the needs of the study (Creswell, 2009). Moreover, it offered the researcher the ability to utilize all the different approaches, such as the mixed methods approach to comprehend the investigated problem, and the aptitude to implement the utmost appropriate research method to answer the research questions and meet the purpose of the study (Creswell, 2009).

The pragmatic paradigm arose in the 1950s (Al Quraan, 2017). The pragmatism emphasizes action and change at its main core (Onwuegbuzie & Leech, 2005). Goldkuhl (2012) posited that “the world is changed through reason and action and there is an inseparable link between human knowing and human action” (p.7). Creswell claimed that a pragmatic worldview “opens the door to multiple methods, different worldviews, and different assumptions, as well as different forms of data collection and analysis” (2009, p. 11) for the researcher to meet the purpose of a study. Moreover, the pragmatic paradigm is commonly acknowledged as the furthest common alternative to the dichotomy between the constructivist (interpretivist) and the post (positivistic) paradigms (Fraenkel, Wallen & Hyun, 2015) as it combines both of them under the same umbrella. Shirish (2013) posited that pragmatists select what suits their research problem without being trapped in theoretical debates about which approach is the best. Yet, they acknowledge that each approach has its limitation and the divergent approaches can complement each other (Rampino, 2012).

The pragmatic paradigm offers multiple philosophical stands by combining both, the constructivist (interpretivist) and the positivistic stances, which entail mutually, single and

multiple realities. Besides, it helps the researcher to answer the questions of the research under study, practically (Creswell & Creswell, 2017; Fraenkel, Wallen & Hyun, 2015). Since the teachers' and students' perceptions of STEM education in private elementary schools in Abu Dhabi are not clear and the efficiency of their STEM practices is not yet revealed, adopting divergent perspectives from different paradigms will help the researcher to build a more comprehensive picture of the investigated reality or phenomenon by having the freedom to choose the most suitable approach and data collection methods that best answer the research questions (Creswell et al., 2003; Fraenkel, Wallen & Hyun, 2012; Johnson & Christensen, 2008). Hence, the researcher will first adopt the interpretivist paradigm to analyze authentic, credible, and representative documents including primary data related to STEM education to identify the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools. Second, the researcher will adopt the post-positivistic paradigm to deduct an approximation to realities related to the elementary teachers' and students' perceptions of STEM education in private schools in Abu Dhabi from the analysis of the quantitative part of the teacher questionnaire and the student questionnaire. Then, the interpretivist paradigm will be adopted to analyze the open-ended questions in the qualitative part of the teacher questionnaire to identify the teachers' perceptions of STEM education.

Researchers who adopt the interpretivist paradigm in their studies attempt to build knowledge from the participants' life experiences within specific circumstances (Creswell, 2009). Moreover, they endeavour to reveal the rudimentary motivation, beliefs, and values of the research participants in a particular setting. Creswell and Creswell claimed that researchers who adopt the interpretivist paradigm utilize the qualitative research method in an attempt "to make meanings from individuals' complex views on their experience of the situation being studied" (2017, p. 8). Therefore, they emphasize the interactions between the research subjects and their natural context or social constructs (Creswell & Creswell, 2017). In an interpretivist paradigm, the researchers are the instrument of data collection. In an attempt to identify the reality, they ask the participants to freely express their opinions about the studied subject via open-ended questions (Creswell, 2009). Hence, it is significant for the interpretivists to admit that by interpreting their findings, they might stamp the identified reality by their personal backgrounds

and experiences (Creswell, 2015b). Opposite to the (post) positivistic paradigm, the interpretivist paradigm is inductive. Generating theories via patterns' identification from subjects' interaction with each other, their context, and their community is the main attempt of an interpretivist researcher (Cohen & Soto, 2007).

Positivism is a social scientific paradigm that pursues the truth and emphasizes the principles of objectivity, knowability, and deductive logic. The positivist researchers assume that society can and should be explored empirically and scientifically. Post-positivism is a more recent paradigm. It is based on a quantitative method and proclaims that there is an objective reality. Yet, this objective reality can be approximately measured and comprehended. The post-positivist researchers focus on identifying and measuring the causes that affect the outcomes (Creswell et al., 2003). However, it admits that all observation is imperfect and that every theory is revisable. Therefore, while the positivist researchers consider that the goal of science is to reveal the truth, the post-positivist researchers suppose that the goal of science is to hold firmly to the goal of reaching the right reality even if they cannot ever achieve it (Creswell & Creswell, 2017).

Two other different paradigms were identified by Blackstone (2018) but were not considered in this study: the critical paradigm and postmodernism. Each paradigm was identified with its distinctive ontological and epistemological perspectives. The critical paradigm emphasizes power, inequality, and social change at its main core. It assumes that social science can never be value-free and should be led with the explicit goal of social change in mind. Yet, the postmodernism paradigm defies nearly every means of knowing that social scientists take for granted. It assumes that truth can or cannot be knowable. The postmodernists assert that scientists or sociologists can never really know the truth since, in each study or report, the researcher imprints his/ her own and unique truth while searching for the real truth.

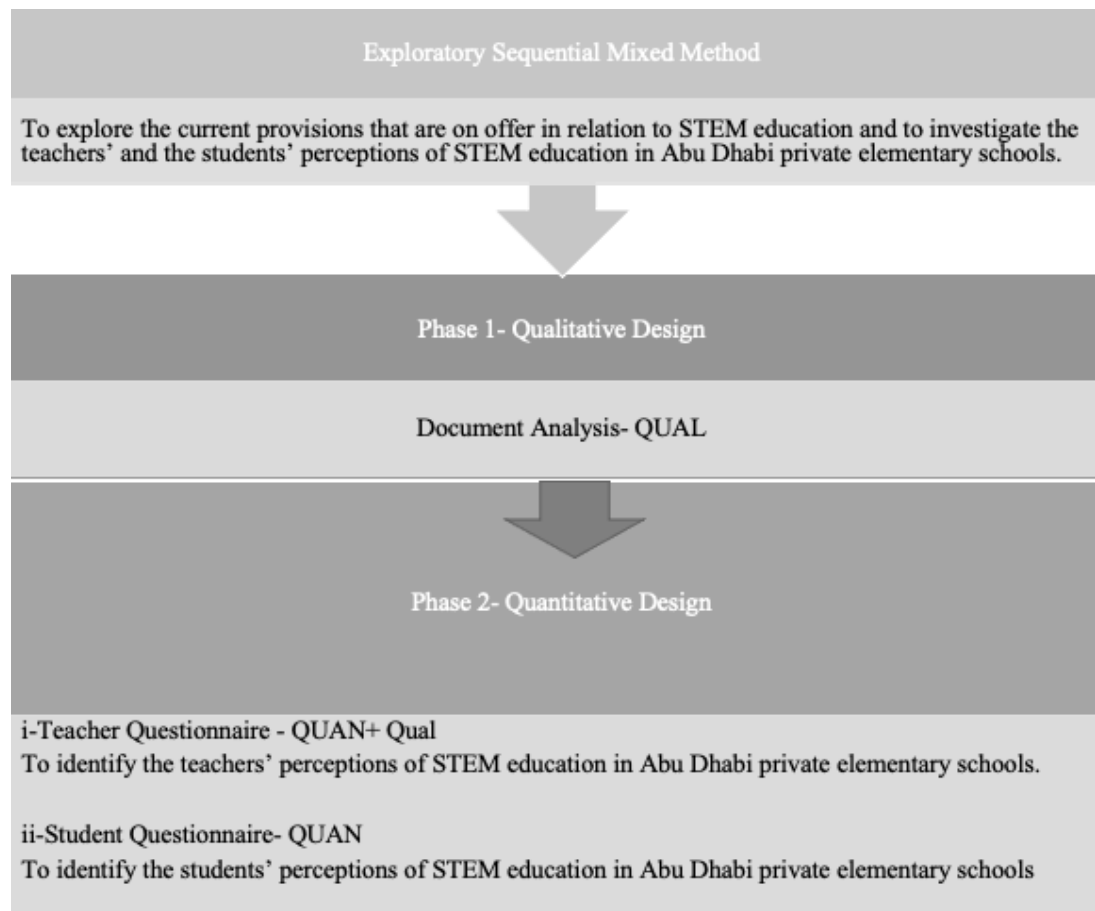


Figure 5: Illustration of the selected sequential mixed-methods approach in the present study

3.2 Research Methods

The research methods section describes the context, the site, the population, the sampling method, the data collection tools, the distribution protocol, the validity and reliability of the instruments, the data analysis along with the ethical considerations that the researcher has to take into consideration in this study.

Table 1 illustrates the skeleton of the methodology applied in this study to achieve its purpose and address its questions. It displays each of the research questions with the nature of the adopted approaches to answer each question, the adopted tools for data collection, the minimum number of participants needed in each phase of the study, and the sampling technique. Since the pragmatic researcher adopted the exploratory sequential mixed methods design, the qualitative

phase took place first to explore the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools by analyzing representative documents including primary data related to STEM education. Then, a quantitative phase took place to deduct approximate realities related to the elementary teachers' and students' perceptions of STEM education in private schools in Abu Dhabi via the analysis of the quantitative part of the teacher questionnaire and the student questionnaire.

3.2.1 Context of the Study

The Emirates, the UAE, or the United Arab Emirates is a federation that was founded on the second of December, 1971. It consists of seven integrated, but independent emirates which are Abu Dhabi, Dubai, Sharjah, Umm al-Quwain, Fujairah, Ajman, and Ra's al-Khaimah. Abu Dhabi which is the largest emirate in the UAE is the capital (Morris, 2009). The location of the UAE is advantageous, especially for its economy, as it is situated between Africa, Asia, and Europe. The UAE is covered with sandy and rocky deserts. It has hot and humid summers, yet its winters are pleasant. It is considered the third richest country in the world after Qatar and Luxembourg. It is rich in natural resources such as marine resources, petroleum, and natural gas. The UAE has people from different nationalities. The Emirati citizens mark the one-ninth of the UAE residents or population and this number is growing to be around ten million (Crystal & Peterson, 2022).

Education is considered one of the key components of sustainable development in the UAE. The UAE economy is moving from being oil-based to knowledge-based. Sheikh Mohammed bin Zayed, Crown Prince of Abu Dhabi and Deputy Supreme Commander of the UAE Armed Forces stated that the UAE needs to graduate more scientists and engineers to meet the information-economic rebellion in the UAE (National Academies of Sciences, 2018). Accordingly, the UAE is aiming to build a knowledge-based society by making efforts to improve its educational system and by setting several educational policies in an attempt to improve the public education sector which is lagging behind the private sector. For instance, in coordination with the Ministry of Education, the government is building new schools and institutes in the seven emirates besides preparing high-quality teachers who can implement rigorous curricula with advanced technology techniques (Forawi, 2020).

Investigating Teachers' and Students' Perceptions and Practices of STEM Education in Private Schools in Abu Dhabi

Main Purpose	To explore the current provisions that are on offer in relation to STEM education and to investigate the teachers' and the students' perceptions of STEM education in Abu Dhabi private elementary schools.
Approach	Mixed Methods Approach
Philosophy	Pragmatism
Design	Exploratory Sequential Mixed Methods Design

Research Questions	Approach	Instruments	Participants	Sampling Technique
RQ 1: What are the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools	Qualitative	Document Analysis	A minimum number of good quality and STEM content related documents	Convenience Sampling
RQ 2: What are the elementary teachers' and students' perceptions of STEM education in private schools in Abu Dhabi?	Quantitative and Qualitative	Teacher Questionnaire	A minimum of 70 STEM Teachers in STEM private elementary schools in Abu Dhabi	Convenience Sampling
	Quantitative	Student Questionnaire	A minimum of 1100 students in STEM private elementary schools in Abu Dhabi	Convenience Sampling
RQ 3: Are there any demographic differences in elementary teachers' and students' perceptions of STEM education in private schools in Abu Dhabi?	Quantitative	Teacher Questionnaire	A minimum of 70 STEM teachers in STEM private elementary schools in Abu Dhabi	Convenience Sampling
	Quantitative	Student Questionnaire	A minimum of 1100 students in STEM private elementary schools in Abu Dhabi	Convenience Sampling

Table 1: Skeleton of the adopted methodology

Also, the UAE has asserted via its national agenda (2017-2021) that the foremost emphases of educational reform are innovation and leadership to prepare the students of today for the jobs of tomorrow of which more than half have not been created yet (Ministry of Education, 2016). Additionally, the UAE has declared via its 2021 vision plan its focus on upgrading and modernizing the schools in a way to reflect progressive educational changes and reforms, updated policies, and effective assessments (Vision UAE, 2021). The educational reforms in the UAE are mostly grounded in curricular reforms and enhancement, technological innovations, and teacher implementation of innovative teaching and learning strategies such as PBL within safe, student-centered, engaging, and motivating learning environments (Ministry of Education, 2016). Moreover, there were efforts to hire qualified and skilled teachers who teach students via strategies that enhance their critical thinking, problem-solving skills, and innovation skills, rather than memorization to foster their autonomy and independent learning (Ministry of Education, 2016). Hence, remarkable initiatives were taken in the UAE to promote STEM education which is an integrated approach to learning engineering, technology, maths, and science via innovative strategies such as PBL to enhance students' problem-solving skills and prepare them for future careers (Alyammahi et al., 2016).

On the other side, forty percent of the total students in the UAE attend private sector schools which are considered well developed with varied curricula that are exhibited in different systems such as the American, British, Australian, and Indian systems (Forawi, 2020).

Over the last decade, STEM education has been integrated into the UAE education system with minor focus and coverage (Mahil, 2016). Yet, STEM education is highly needed in the UAE as it helps in achieving the UAE vision 2021 which was declared in 2010 and which aims to locate the UAE among the world's topmost sustainable countries. The UAE Vision 2021 is based on different values and it focuses on unity, knowledge, destiny, and prosperity to develop an evolving socioeconomic environment. More focus is to establish a strong economy, and cultivate a sustainable environment comprising quality education, good services, and health (Radwan & Khalil, 2021; Vision UAE, 2021). Moreover, STEM education is indispensable in the UAE schools as it prepares students to graduate in STEM-related fields such as engineering and

science investigation that help to shift the UAE from an oil-based economy to a knowledge-based economy (Al Quraan, 2017).

A study conducted by Radwan and Khalil (2021) at the University of Sharjah explored the importance of technology integration role in education and its significance in enhancing undergraduates' learning. It also highlighted the significant effects of the availability of technological resources, the educators' preparation programs, and the teachers' perceptions of technology integration in education. Hence, in the light of the significance of integrating technology, science, math, and engineering into the schools' education system to enhance the schoolchildren's learning and to leverage the level of the UAE among the other middle east countries as a prominent supplier for technology and science development by preparing scientists, engineers, and technologists, the research under study aimed to investigate the current provisions that are on offer in relation to STEM education and the teachers' and students' perceptions and practices of STEM education in private elementary schools in Abu Dhabi, to reveal the status of STEM education as well as the gaps, challenges, barriers, and the difficulties the teachers face in implementing STEM education and in preparing the students to be innovative and productive in STEM related careers and fields.

To do so, the researcher conducted systematic research via Google search to retrieve the suitable sites of STEM private elementary schools in Abu Dhabi for this study. The keywords STEM, STEAM, PBL, IBL, NGSS, Subjects' Integration, hands-on activities, (multidisciplinary/ interdisciplinary/ transdisciplinary) approach, and Engineering along with in primary/ elementary schools in Abu Dhabi were used in the researcher's searches. Once the school's name was retrieved, the website of the school was surfed and the implemented curriculum along with the extra-curricular activities were identified. Moreover, the vision and the mission of the school were checked.

Any school which claims implementing STEM or STEAM education, PBL, NGSS, hands-on activities, or subjects' integration or multidisciplinary/transdisciplinary approaches including science, and/or maths, technology, and engineering is considered to be part of the study.

As per Google searches, there are about 28 private elementary schools in Abu Dhabi, UAE, which claim, via their websites, to instill STEM activities in classrooms at early stages

(Grade 1- Grade 5). Their goal is to inspire creativity, encourage collaboration, teach the skills of the 21st century, and build bridges between classroom teaching and out-of-school learning experiences to prepare STEM students for a challenging future and instill in them an enduring desire to pursue careers in STEM fields, that don't even exist yet (American Community School (ASC), 2021; Repton Abu Dhabi, 2021; The British International School, 2021). Given that these private elementary schools adopt and implement the STEM education curriculum, the researcher will consider them as a suitable site for the proposed study where both quantitative and qualitative primary data will be collected from teachers and students to meet the purpose of the study.

The researcher chose to investigate the STEM education in private and not governmental elementary schools in Abu Dhabi as the UAE governmental efforts are still inceptive with minimal improvement in regards to the full integration of STEM education in public schools in the UAE, although the goal of the UAE government is to stand among the top twenty highest performing countries in PISA and TIMSS (Kamal & Trines, 2018; PwC, 2019). This scarcity in STEM integration is due to several challenges that hinder the full integration of STEM education in the UAE such as the deficiency of STEM resources in the Arabic language, the absence of capable and expert STEM teachers, the dearth of PD for teaching methods and tools of STEM education, and the high cost of STEM education (Al Murshidi, 2019; Shaer, Zakzak & Shibl, 2019).

3.2.2 Population, Sampling, and Participant Selection

In the research under study, the population is described as a pool of individuals with similar characteristics where the researcher can draw the sample of the study from (Mertens, 2010). In this study, Grade one to Grade five elementary science, mathematics, and technology (ICT) teachers or STEM teachers who teach in private elementary schools in Abu Dhabi which adopt and implement the STEM curriculum with Grades 1- 5 students are the target population. Therefore, two groups denote the population of interest in the present research under study, the elementary STEM teachers and the elementary students in STEM private elementary schools in Abu Dhabi.

The total population of the targeted STEM teachers in the designated schools is expected to be around 700, estimating that there are 20 STEM teachers in each school, 4 for each grade

level. The required target number for a representative sample of STEM teachers for this study is 70 since a good maximum sample size is usually around 10% of the population in basic surveys (Rossi, Wright & Anderson, 2013). A sample is defined as a portion or selected group of the entire population from which the research can collect data with statistical significance (Bryman, 2016; Fraenkel, Wallen & Hyun, 2012). The total population of the elementary students is expected to be around 11,000, estimating that there are 400 students in each elementary school, 80 in each grade level. Hence, the required target number or sample of STEM students for this study is 1100 since a good maximum sample size is usually around 10% of the population in basic surveys (Rossi, Wright & Anderson, 2013).

Convenience sampling, which is a non-random sampling method that considers collecting data from target individuals who conveniently are accessible and ready to participate in a study, was used to access the target population in the second phase of the study (Creswell & Clark, 2017). The convenience sampling is fast and not expensive. It is currently considered the utmost common of the sampling techniques. It is the most preferred by the researchers as it is easy and the participants are readily available and accessible (Creswell & Clark, 2017). The non-probability convenience sampling method is associated with the main assumption that the members of the target population are homogeneous, and it places primary emphasis on generalizability by ensuring that the knowledge gained from a study is representative of the population which the sample was drawn from, but not of the entire population (Suen, Huang & Lee, 2014).

In selecting documents as sources for document analysis to answer the first question of the study, the researcher had to reflect on the selection criteria to choose significant and relevant documents to the aim of the research under study or to the objectives of the question to be answered (Karppinen & Moe, 2012). The researcher conveniently selected among the various and available primary written documents published online, the significant and related written documents that helped in meeting the first objective of the study. The selected documents were identified based on specific criteria, such as being published, clear, up-to-date, and insightful to the STEM provisions in private elementary schools in Abu Dhabi. The chosen documents came dissimilar and in different forms. The selected documents were collected from at least two different resources by using different methods and data sources to seek corroboration and

convergence (Bowen, 2009). The assigned number of the selected documents was determined based on their availability, their quality, and their relativity to the research topic which is the elementary STEM education (Bowen, 2009). After an extensive search, the researcher arrived to collect several documents comprising primary data. Eight STEM based curricula were collected from different schools' websites. The selected schools follow different systems: the American and the British systems. More, eight ADEK inspection reports for the same schools were retrieved from Which School Advisor (WSA 2020) website, which is the world's leading independent international private school reviews based web site, to be analysed and to triangulate the findings of the schools' websites. The schools' performances varied between very good and outstanding. Additionally, the analyst was able to acquire a math study plan for 20 math lessons to be explored from a teacher teaching in a STEM elementary school in Abu Dhabi. Further, an intensive and time-consuming search via the social media platforms allowed the researcher to collect visual and audio-visual primary data. A series of pictures of elementary students performing STEM activities in STEM labs, in natural contexts, and outdoor environments was selected and saved for further analysis. Besides, two YouTube videos of two elementary classrooms performing in STEM labs were collected for analysis. The number of participants or primary documents collected for thematic analysis in this study is decent as Clarke and Braun (2013) recommended 10 to 50 participant-generated text for thematic analysis in small projects.

3.2.3 Data Collection Instruments

The following section elucidates the instruments that are utilized to collect the required data for the study. Instrumentation is described as, "the whole process of preparing to collect data; it involves not only the selection or design of the instruments, but also the procedures and the conditions under which the instruments will be administrated" (Fraenkel, Wallen & Hyun, 2012, p.118). The nature of the current exploratory sequential mixed methods study required the utilization of different instruments such as a teacher questionnaire and a student questionnaire to collect the required primary data related to teachers' and students' perceptions of STEM education. Yet, for the document analysis, the researcher utilized a document analysis protocol.

3.2.3.1 Document Analysis Protocol

Because there is a lack of understanding and little research about the STEM status, the researcher used the document analysis as a starting point to explore the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools. The document analysis which is a purely qualitative approach and a social research method served the researcher in answering the first question of the study by selecting and critically analyzing authentic, credible, and representative primary documents from different resources related to STEM education in private elementary schools in Abu Dhabi.

Document analysis is portrayed as a practice in which the researcher interprets and analyzes a document to generate themes that share mutual features (Al Quraan & Forawi, 2019). Moreover, it is a practice where data related to the research questions are analyzed systematically to give meaning and voice to the assessment topic or to formulate the research results (Bowen, 2009; Johnson & Christensen, 2008; Merriam, 2009). The employment of document analysis in research permits the researcher to become more acquainted with the language the participants use. Moreover, it represents written and objective data that mirror the thoughts of the participants and that cannot be explored in classroom observation or any other data collection method (Merriam, 2009). Yet, few limitations would face the researcher while using the document analysis. In fact, the published data or documents are usually not crafted for research purposes; consequently, they may postulate inadequate and inaccurate material or deceiving samples for analysis (Merriam, 2009).

In the current research, the researcher used the document analysis to explore the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools by selecting and analyzing authentic, credible, and representative documents (Scott, 2014) related to STEM education in private elementary schools in Abu Dhabi.

In selecting documents as sources for document analysis, the researcher had to reflect on selection criteria to choose significant and relevant documents to the aim of the research under study or to the objectives of the question to be answered (Karppinen & Moe, 2012). The selection criteria (inclusion or exclusion criteria) are shaped by the research question and the conceptual framework of the study. They specify the documents to be included in a document analysis; thus, they are a key driver of the search strategy (Zawacki-Richter et al., 2020).

The researcher conveniently selected the significant and related written documents that helped in meeting the first objective of the study among the various and available primary written documents published online. The selected documents were identified based on specific criteria, such as being published, clear, up-to-date, and insightful to the STEM provisions in private elementary schools in Abu Dhabi. The published written documents varied between texts (such as published schools' inspection reports, elementary STEM evidence-based curricula, or STEM study plans developed by STEM teachers) and audio-visual resources of equivalent relevance (such as YouTube videos for elementary students collaborating in STEM lab and schools' advertisements accessible online via the schools' websites or social media platforms such as LinkedIn, Facebook, and Instagram). Furthermore, any other physical arrangement or personal document such as STEM student artifact was considered as a text to analyze to help the researcher reflect more widely on STEM status held opinions (STEM students' artefacts such as STEM students' summative assessments, or STEM products such as programmed robots, or pictures of projects or recorded videos created by elementary STEM students that reflect their learning process).

The chosen documents came dissimilar and of different forms. The selected documents were collected from at least two different resources by using different methods and data sources to seek corroboration and convergence (Bowen, 2009). The assigned number of the selected documents was determined based on their availability, their quality, and their relativity to the research topic which is the elementary STEM education (Bowen, 2009). A document analysis protocol was adopted to collect data from the selected documents related to STEM education implementation and integration in the UAE (Al Quraan, 2017). The protocol involved key elements such as the type, the title, the source, and the rationale of each relevant document to elementary STEM education utilized in the document analysis (Table 2).

After an extensive search, the researcher arrived to collect several documents comprising primary data. Eight STEM based curricula were collected from different schools' websites. The selected schools follow the American and the British systems.

The schools' performances varied between very good and outstanding. Additionally, the analyst was able to acquire a math study plan for 20 math lessons to be explored from a teacher

teaching in a STEM elementary school in Abu Dhabi. Further, an intensive and time-consuming search via the social media platforms allowed the researcher to collect visual and audio-visual primary data. A series of pictures of elementary students performing STEM activities in STEM labs, in natural contexts, and outdoor environments was selected and saved for further analysis. Besides, two YouTube videos of two elementary classrooms performing in STEM labs were collected for analysis (ACS Abu Dhabi Events, 2021; Brighton College Abu Dhabi, 2021b). Table 2 illustrates the summary of the documents selected in the research under study for document analysis.

The Braun and Clarke (2006) thematic analysis method was followed to analyze data of selected documents or data items. Thematic analysis is a method that provides clarity about meanings of the raw data by searching across a data set to reveal repeated themes of meaning (Braun & Clarke, 2006). It is a flexible and accessible analysis method that does not require sophisticated theoretical and technological knowledge of qualitative approaches but allows the researcher to “identify, analyse, and report patterns within the data” (Braun & Clarke, 2006, p.41). In this study, the thematic analysis helped the researcher to reflect on and to generate a thick and rich description of the offered STEM provisions in private schools in Abu Dhabi. The number of participants or primary documents collected for thematic analysis in this study is decent as Clarke and Braun (2013) recommended 10 to 50 participant-generated text for thematic analysis in small projects. For a robust thematic analysis, the researcher needs to apply an analytic eye to analyze and interpret the collected data in light of what is already known about the status of STEM education in the private schools in Abu Dhabi. Furthermore, the researcher has to be keen to explicitly explain the methodological choice or the process from data collection through data analysis and interpretation, to strengthen the validity of the document analysis findings (Karppinen & Moe, 2012).

To achieve a thematic data analysis, the researcher followed the Braun and Clarke (2006) thematic analysis method which depicts six phases: “1) Familiarising oneself with the data, 2) Generating initial codes, 3) Searching for themes, 4) Reviewing themes, 5) Defining and naming themes, and 6) Producing the report” (p. 87) to analyze the collected data in a proper way and to reflect on the findings in an accurate way. The thematic analysis emphasized the understanding of the current provisions that are on offer in relation to STEM education in Abu Dhabi private

elementary schools by exploring the qualitative data collected from related documents. Moreover, it comprised a descriptive and an interpretative analysis of the generated themes to provide a rich sense of the scope and the miscellany of each of them. In this case, the analyst had to tell the reader a coherent and a persuasive story of the identified themes by relating the identified meanings to the literature review and the conceptual framework of the study or to any other academic analysis related to STEM education in order to generate analytic statements about the offered STEM provisions in private schools in Abu Dhabi and to contribute to the literature related to STEM education in the UAE. The analytic claims had to be grounded in the collected qualitative data, although they had to go beyond it to reveal the approximate reality (Braun & Clarke, 2006; Clarke & Braun, 2013).

3.2.3.2 Teacher Questionnaire

The adopted teacher questionnaire (Johnson & Turner, 2003) is one of the instruments of this study. “A questionnaire is a collection of questions administrated to respondents” (Bryman, 2016m p.695). It is intended to gather data about the science, mathematics, and technology (ICT) teachers’ perceptions of STEM education to conduct descriptive and inferential analyses. The questionnaire helped the researcher answer the second question related to the elementary STEM teachers’ perceptions of STEM education in private schools in Abu Dhabi and the third question related to the demographic differences in elementary teachers’ perceptions of STEM education in private schools in Abu Dhabi. The teacher questionnaire of this study is adopted from the valid and reliable cross-sectional Vietnamese survey of Thi To Khuyen et al. (2020) based on their official permission (Appendix 1).

Context/ Source/ Type	Document Title	Rationale for Selection
Abu Dhabi “United Arab Emirates”/schools’ websites / private source/ primary data	STEM/STEAM based curricula.	To get better understanding of the level of STEM integration and implementation in STEM elementary schools, especially for math, technology and science subjects
Abu Dhabi “United Arab Emirates” Which school Advisor website/ private source / primary data	Copies of latest ADEK inspection reports.	To get a better idea about how the schools perform in STEM subjects back to ADEK reports.
Abu Dhabi “United Arab Emirates” Math teacher / private source/ primary data	A teacher material: Math study plan (for 20 weeks)	To find out how teachers are implementing Math curriculum in a STEM school
Abu Dhabi “United Arab Emirates”/ Instagram and Facebook pages of several STEM schools/ media source/ primary data	A series of pictures retrieved from the social media pages of the mentioned schools of elementary students performing STEM activities in STEM labs, in natural contexts, and outdoor environments	To get a better visual idea about the STEM context in STEM schools via the students’ enactment
Abu Dhabi “United Arab Emirates” YouTube / media source/ primary data	Two YouTube videos reflecting STEM activities in the mentioned schools.	To get a better audio-visual idea about how the students enact within STEM natural environments

Table 2: Document analysis protocol in the present study

In fact, although there is plenty of research with surveys that examine the teachers’ perceptions of STEM education (Al Salami, Makela & De Miranda, 2017; Park et al., 2016; Thibaut et al., 2018; Wang et al., 2011), these studies focused on investigating the teachers’ perceptions mainly via a variety of components, such as conception, attitudes, beliefs, difficulties, or self-efficacy (Thi To Khuyen et al., 2020). However, STEM education is framed into three aspects: STEM education, STEM competencies, and STEM difficulties (Berlin & White, 2012; Bybee, 2013; Diana & Sukma, 2021; El-Deghaidy et al., 2017; Lee & Shin, 2014; Margot & Kettler, 2019; Saptarani, Widodo & Purwianingsih, 2019; Thi To Khuyen et al., 2020; Wang et al., 2011). Therefore, the researcher chose and adopted the cross-sectional Vietnamese survey of Thi To Khuyen et al. (2020) as it measures teachers’ perceptions of STEM education following

three components: (1) STEM education, (2) values of STEM competencies, and (3) STEM difficulties.

Before distributing the questionnaire to participants in Abu Dhabi, the researcher had to assess it to decide whether or not it was useful to achieve the target of the research (Williams et al., 2015). The instrument assessment revealed the extent of the instrument's appropriateness for the context of the research study, research questions, and the targeted population. Therefore, the researcher had to test the questionnaire to assess its appropriateness to the participants in terms of clarity, reliability, and validity in order to be confident of the study results (Baker, 1994). Consequently, the researcher piloted the teacher questionnaire by asking a sample of ten experienced STEM teachers to test the teacher questionnaire.

The questionnaire is divided into three sections. The first section consisted of several categorical type questions related to teachers' demographics such the gender, age, education background, the level of education, the overall teaching experience, the teaching experience in STEM, the major and the grade level they teach in addition to the frequency, and the way they integrate STEM in their classrooms. The mentioned personal characteristics or variables are included in the teacher questionnaire as per the literature, they might affect or might have significant relation with the teachers' perceptions of STEM education. The second section involved three parts that addressed queries related to (i) teachers' overall perceptions of STEM education, (ii) teachers' value of STEM competencies, and (iii) teachers' difficulties in STEM implementation. It consisted of twenty-one quantitative questions, scored on a five-point Likert scale (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree). Three questions related to the teachers' overall perceptions of STEM education such as "Teachers can combine optionally science, technology, engineering, and mathematics knowledge in the current curriculum to compose STEM lessons" and "Scientific inquiry and Engineering design are two main factors in a STEM lesson". Seven questions were related to the teachers' value of STEM competencies such as "STEM education can help students acquire critical thinking that is usually conducted by scientists, technologists, engineers, and mathematicians" and "STEM education can help students leverage collaboration literacy with others to execute STEM learning projects". Eleven questions were related to the teachers' difficulties in STEM implementation such as

“Difficulty to implement an inquiry-based curriculum” and “Difficulty to authentically assess students’ achievement (formative and summative assessments)”.

In 1932, Likert developed the Likert scale, which is defined as “a psychometric response scale primarily used in questionnaires to obtain participant’s preferences or degree of agreement with a statement or set of statements” (Bertram, 2007, p.1). “The Likert scale is essentially a multiple indicator or multiple-item measure of a set of attitudes relating to a particular area” (Bryman, 2016, p.154). Constructing a Likert scale should take into consideration several points. Mainly, it should present the items as statements, not as questions; all statements must relate to the same object and all items should be interrelated (Bryman, 2016). It is the furthestmost broadly used form of scale as it does not entail the study subjects to take a categorical standpoint of yes or no towards a specific phenomenon or statement (item). Yet, it grants them to react within a certain level of agreement and variation (Blumberg, 2008). Moreover, the collected responses are quantifiable and subject to be tested and analyzed statistically. Researchers consider Likert scales as an inexpensive and efficient means to collect primary data. Hence, they can be easily circulated to the study subjects either electronically via their emails or manually. In the present research understudy, the elementary STEM teachers were requested to indicate their level of agreement with a set of statements related to their perceptions of STEM education and to the difficulties they face in implementing STEM in their classrooms on an ordinal scale of 1- Strongly Agree, 2- Agree, 3- Neither Agree or Disagree, 4- Disagree, 5- Strongly Disagree.

Despite the advantages of the utilization of the Likert scale questionnaire as a means to gather quantitative data, it is a bit challenging to capture the teachers’ perceptions of a wide topic as STEM education via a limited number of multiple choices questions. Furthermore, participants might understand the different questions differently from what the researcher intended (Madani, 2017). Therefore, an additional qualitative section was added to the questionnaire by the researcher to minimize its limitations and maximize its benefits (Madani, 2017). The last section of the questionnaire consisted of a set of five structured, open-ended qualitative questions, which required the teachers to reflect on their perceptions of STEM education by typing their answers using their own words in a comment box. Bryman (2016) posited that with open-ended questions,

participants are asked questions and are free to reply “however they wish” (p.244). Bryman added that open-ended questions have advantages and disadvantages. For instance, they allow the respondents to answer in their own terms and unusual responses can be derived. They help the researcher in exploring new areas and understanding the participants’ issues. Yet, they are time-consuming and they require an extra effort from the participants, which might generate a lower response rate.

The five questions that helped the researcher to qualitatively interpret and analyze the perceptions of STEM elementary teachers, the difficulties they face when implementing STEM education, and the extent of support they receive to implement STEM effectively were the following: 1) How do you define STEM education? 2) What challenges do you face when you implement STEM education in your classroom? 3) Do you collaborate with other teachers to discuss STEM lessons? And how often? 4) Did you receive professional development to support you in STEM education in your school? and how often? 5) How often did your students participate in STEM competitions? and what types of competitions do your students participate in? Moreover, by using the participants’ own words, the open-ended questions helped the researcher reveal any possible overlooked aspects related to STEM education in private elementary schools in Abu Dhabi. The qualitative questions were developed by the researcher based on the insights from the results of the analysis of the documents in the first qualitative phase of the study in addition to the insights gathered from the conceptual framework and the literature review of the present study. The open-ended questions were utilized to validate the quantitative data and to attain a wider comprehensive understanding of the STEM teachers’ perceptions in private elementary STEM schools in Abu Dhabi (Creswell & Clark, 2017). The questions of the teacher survey were transferred by the researcher to the SurveyMonkey tool and an online link to the online teacher questionnaire was generated to access it. There are several advantages and disadvantages of online questionnaire. For instance, Bryman (2016) posited that online questionnaire has low cost, attractive format, unrestricted compass, fewer unanswered questions, better response to open-ended questions, and better data accuracy. Yet, it displays low response rate and is restricted to online populations. Additionally, it requires motivation and follow up.

The SurveyMonkey website is a commercial website where you can design a questionnaire online and generate a web link to which participants can be directed to to complete it. Exploiting the SurveyMonkey website is not free of charge. The fees are dependent of the duration of time during which the questionnaire is active, the length of the questionnaire, and the number of participants who completed the questionnaire (Bryman, 2016). By transferring the statements of the teacher questionnaire to the SurveyMonkey tool, the researcher took into consideration the recommendations of Dillman, Smyth and Christian (2014) which suggest the utilization of clear instructions for the teachers on how to respond and having consistent font and print sizes (whether the questions or the different suggested answers) not to confuse them. It is to be noted that a box was left open for the participant at the end of the questionnaire to write down his/her e-mail address or phone number if he/she were interested in being observed with the students in their natural context. The questionnaire link was sent via an email to the elementary principals in STEM private schools in Abu Dhabi to be forwarded to the elementary teachers (Appendix 2).

3.2.3.3 Student Questionnaire

To answer the second question related to the elementary STEM students' perceptions of STEM education in private schools in Abu Dhabi and the third question related to the demographic differences in elementary students' perceptions of STEM education in private schools in Abu Dhabi, the researcher developed a questionnaire based on the quantitative, valid, and reliable cross-sectional STEM semantic survey (Tyler-Wood, Knezek & Christensen, 2010) which was adapted from Knezek and Christensen (1998)'s Teacher's attitudes Toward information Technology Questionnaire (TaT) and which is available online. The researcher chose to develop the student survey based on the cross-sectional STEM semantic survey of Tyler-Wood, Knezek, and Christensen (2010) as it identifies both, the student's academic and career potentials in STEM areas whereas other surveys identify the students' academic potential in STEM areas only. Tyler-Wood, Knezek, and Christensen (2010) claimed that they were interested to develop a survey that targets the students' academic and career potentials in STEM areas as a meticulous review of existing career interest instruments revealed a gap in instrumentation that measures interests in STEM careers, especially at elementary and middle

levels. Moreover, the researchers stated that existing instruments tend to target high school students and focus on science instead of STEM, and that there is a critical need of updating and developing an instrument that targets both the students' academic and career potentials in STEM areas.

The developed student survey is short and easy to complete. It aimed at assessing the students' perceptions of scientific disciplines (science, mathematics, engineering, technology) and STEM careers. The survey consisted of two sections. The first section was related to students' demographics, such as gender, age, and grade level as per the literature, they might have significant relation with the students' perceptions of STEM education. The second section consisted of five separated clusters related to 1) science, 2) mathematics, 3) engineering, 4) technology, and 5) STEM careers. Each cluster included five questions or five semantic perception adjective triad: (boring/ neutral/ interesting), (appealing/ neutral/ unappealing), (fascinating/ neutral/ mundane), (exciting/ neutral/ unexciting), and (means nothing/ neutral/ means a lot) which are considered as descriptors for target statements reflecting the student's perception of the mentioned scientific discipline. For each question, the student was encouraged to choose one emoji graphic among three multi-emoji rating options (Appendix 3) for the semantic perception adjective triad related to each indicated scientific discipline to rate or indicate how he/she feels about it. The emoji graphics were utilized to meet the comprehension level of the elementary students, which are considered young ones.

Emojis are an emergent phenomenon that had gained popularity in the digital era (Alismail & Zhang, 2018). They were crafted as two-dimensional pictograph to assist expressive messages of sentiments, attitudes, or moods in modern communication technologies (Lu et al., 2016). Moreover, to express a complexity of emotions that cannot translate easily into words (O'Brian, 2020). Research revealed that using Emojis in surveys is a helpful, successful, and good practice that increases the reliability of the students' responses, especially when working with younger children in research. Moreover, it is considered a technique that provides additional tools to engage younger students; therefore helps in increasing the validity of their answers (Alismail & Zhang, 2018; Fane, 2017; Massey, 2021). The utilization of Emojis in education and behavioral sciences research is increasing (Bai et al., 2019). McCulloch (2019) stated that the use

of Emojis provides familiarity in communication and in self-expression, especially with younger students. Moreover, it bridges differences in literary expression (Mabelis, 2019). Therefore, by using Emojis in the student questionnaire, which are means of language frequently expressed among the age group of the study sample (Grade one to Grade five students), the researcher aimed to increase the validity and reliability of the students' responses. In addition, the utilization of Emojis had a purpose to motivate the students to participate in the study by making the questionnaire easy to understand, fun, and engaging. Their utilization intended to facilitate the students' decision-making process, language proficiency, and thinking style (Alismail & Zhang, 2018).

The questions of the student survey were transferred by the researcher to the SurveyMonkey tool and a link was generated to access it. The SurveyMonkey website is a commercial website where you can design a questionnaire online and generate a web link to which participants can be directed to complete it. Exploiting the SurveyMonkey website is not free of charge. The fees are dependent on the duration of time during which the questionnaire is active, the length of the questionnaire, and the number of participants who completed the questionnaire (Bryman, 2016). By transferring the statements of the student questionnaire to the SurveyMonkey tool, the researcher took into consideration the Dillman, Smyth and Christian's (2014) recommendations which suggest the utilization of clear instructions for the students on how to respond and having consistent fonts and print sizes (whether the questions or the different suggested answers) not to confuse them. However, before distributing the student questionnaire to participants in Abu Dhabi, the researcher had to assess it to decide whether or not it was useful to achieve the target of the research (Williams et al., 2015). The instrument assessment reveals the extent of the instrument's appropriateness for the context of the research study, research questions, and the targeted population. Therefore, the researcher had to test the questionnaire to assess its appropriateness for the participants in terms of clarity, reliability, and validity to be confident of the study results (Baker, 1994). Consequently, the researcher piloted the student questionnaire by asking a sample of ten students to test the student questionnaire. The link was sent via an email to the elementary principals in STEM private schools in Abu Dhabi to be forwarded to the elementary students via their teachers (Appendix 3).

3.2.3.3.1 Distribution Protocol

Once the questionnaires were adjusted to meet the objectives of the study and finalized, the selected STEM primary schools in Abu Dhabi were selected via a Google search and their elementary principals were contacted via emails. The contact details of the elementary principals were found on the websites of the schools or via LinkedIn. If not, the researcher called each school to inquire about the elementary school principals' details. The online delivery model was used to access the schools' principals as it was the most adequate mode used during the Covid-19 pandemic. The email written by the researcher introduced the researcher and explained in detail the purpose of the study, the significance of implementing STEM education at the elementary level, the role of the teacher in implementing STEM education, the data collection methods, the ethical considerations, and the significance of the research under study (Appendix 6). Moreover, the email included the SurveyMonkey link to the teacher and student questionnaires, which were developed by the researcher via the SurveyMonkey tool. In the proposed email, the researcher encouraged and asked the elementary principals to ask their schools' elementary STEM-related subjects' teachers (Science, Maths, ICT) to complete the online teacher questionnaire related to their perceptions of STEM education and have their consent to permit their primary students (G1-G5) to complete an online questionnaire related to their perceptions of STEM education. The researcher elucidated in the email that the elementary teachers' and students' participations were totally voluntary and there were no identified physical, psychological, or social threats related to this study. The researcher confirmed to the principals that the questionnaires' results, as well as notes of the classrooms' observations, will remain completely confidential and anonymous and will be retrieved after being encrypted for the study analysis only; and, if the study is published, only emerging results will be documented. At the end of the email, the researcher provided her contact email and phone number for the elementary principals to contact her if they had any questions or inquiries regarding the research. A follow-up email was delivered to the principals after the first and the second week from the first delivered email to remind them of the purpose and the significance of the study as well as the importance of their schools' participation in the research under study. Once the surveys were answered, the students' and the teachers'

anonymous responses were directly received by the researcher via the SurveyMonkey application.

3.2.3.3.2 Pilot Study

Van Teijlingen and Hundley (2002) stated that a pilot study is a feasibility study or a small version of a full-scale study. Glesne (2016) declared that a pilot study is a fundamental element of the study design. He asserted that it is a valuable tool that contributes to elucidating the researcher's statement, inquiries, and proposed questions in a study. Williams et al. (2015) emphasized the importance of assessing the utilized instrument in a study to decide whether or not it was useful to achieve the target of the research. The instrument assessment reveals the extent of the instrument's appropriateness for the context of the research study, research questions, and the targeted population. The purpose of a pilot study is to test the instruments in a study and assess their appropriateness to the participants in terms of clarity, reliability, and validity to be confident of the study results (Baker, 1994). Therefore, to test the tools of the present study, the researcher piloted the adopted teacher questionnaire by asking a sample of ten experienced STEM teachers to test the teacher questionnaire and ten STEM students to test the developed student questionnaire. Literature states that although ten percent of the entire population is considered a decent number of participants to pilot test an instrument in a study, yet a smaller sample can help the researcher identifying the inapt questions (Baker, 1994). Blumberg (2008) stated that for better results in research under study, the data collection phase has to start with pilot testing to test the various aspects of the exploited tools. Creswell (2009) argued that through testing or piloting an instrument, the researcher can reveal if the instructions are well-defined and clear to the participants, if the wording is simple and coherent, and if the content is comprehensible. Moreover, it indicates how long the questionnaire takes to be completed when applied to the basic study sample (Rattray & Jones, 2007). Teachers and students who participated in instruments' piloting were informed that they are participating in instruments' pilot testing and that their answers will not be encompassed in the research analysis. Nevertheless, their valuable feedback and reflections after completing the questionnaires will help the researcher pinpoint potential problems related to content and wording and to the justification of possible solutions. Ultimately, the two questionnaires were reviewed and

necessary amendments took place for better instrument design and research results. In fact, few improvements took place in the student questionnaire after the pilot test. Based on the ten first students' feedback, the researcher changed the word career into job, as younger students asked the researcher what does the word career mean. Moreover, the word Mathematics was replaced by the word Math as it is easier for the younger students to read it. The general feedback of the students participating in the pilot test came positive. They claimed that the questionnaire was "easy" and they were "happy to complete it". The average time to complete the student questionnaire was two minutes. Nonetheless, based on the feedback of ten STEM experienced teachers, the researcher exchanged few words in the quantitative part of the teacher questionnaire with simpler words to make it easier for the participants to understand the questions, such as exchanging "to leverage collaboration literacy" with "to better collaborate". The researcher then decreased the number of the open-ended questions from seven to five to reduce the time needed to complete the questionnaire and not to exhaust the participants. Lastly, the font and the print size of the words in both questionnaires were upgraded for clearer presentation and better appearance. Yet, the general feedback came positive and encouraging. Participants claimed that "the questionnaire is very interesting, easy for participants to understand and respond to its elements". The average time to complete the teacher questionnaire was six minutes.

To test the trustworthiness of the applied instruments as means of gathering data, the questionnaires were tested for their validity and reliability through the use of multiple tests. Testing the validity and reliability of the research instruments is a procedure that is highly required to warrant the effectiveness and the credibility of research (Fraenkel, Wallen & Hyun, 2012).

Validation is a constant and reiterative process of assembling several distinctive types of evidence to prove that researchers are measuring what they intend to measure (Knekta, Runyon & Eddy, 2019). Validation has "to do with whether a measure of a concept really measures that concept" (Bryman, 2016, p.158). Validity is defined as a quality of the use of a tool in a certain context and not as a quality of a tool. Every time a tool is used in a new context, the researcher has to conduct some measures of validity for that precise context (Knekta, Runyon & Eddy,

2019). Therefore, despite the fact that the Vietnamese adopted a teacher questionnaire which was validated for the Vietnamese context, this does not mean that it must work on the Emirati population; consequently, it has to be validated. The same rule applied on developed student questionnaire.

The validity of the two questionnaires was considered from different perspectives including the translational validity (content and face validity) and construct validity (factor analysis).

The content validity was conducted to determine if the content of the questionnaires were appropriate and relevant to the purpose of the study (Parsian & Dunning, 2009). Usually, the content validity is conducted by seven or more experts to ensure whether the utilized tool was consistent with the conceptual framework of a study or not (DeVon et al., 2007; Parsian & Dunning, 2009). Hence, in the present study, the content validity of the quantitative part of the teacher and the student questionnaires was validated by consulting ten STEM key informants based in the UAE to ensure that the questionnaires were valid in the UAE context and that the researcher's inferred interpretations and conclusions at the end of the study were appropriate, correct, meaningful, and useful (Fraenkel, Wallen & H, 2019). The reviewers were asked to check independently if each item in the teacher questionnaire and the student questionnaire were clear and relevant to the study. Moreover, the STEM key informants were asked to review the open-ended questions which were developed by the researcher in the qualitative part of the teacher questionnaire to ensure their clarity and validity.

The face validity assesses the appearance of the questionnaire in terms of feasibility, readability, consistency of style and formatting, and the clarity of the language used (DeVon et al., 2007; Parsian & Dunning, 2009). It is a form of usability rather than reliability. To conduct the face validity of the teacher and student questionnaires, the researcher asked fifteen elementary students to assess the student questionnaire and ten elementary teachers to assess the teacher questionnaire in terms of the clarity of the wording, the likelihood that the target audience would be able to answer the questions, the layout, and style (Parsian & Dunning, 2009). In both cases, the feedback of the participants came positive by confirming that the questions of the

questionnaires indicate high content and face validity. In other words, the statements reflect the content of the studied concept and the items represent all facets of the concept under study. Additionally, the questionnaires were well-scripted with an appropriate tone, an understandable language, and it needed an acceptable time to be answered.

The construct validity indicates the extent to which the items on an instrument relate to the relevant theoretical construct and the degree to which the answers of the statements accumulate evidence to support the interpretation of what the study reflects (DeVon et al., 2007; Parsian & Dunning, 2009). Construct validity is a quantitative value that is determined by statistical methods, mainly by conducting factor analysis. Factor analysis helps the researchers group items into common factors, interpret each factor according to the items having a high loading on, and summarize the items into a small number of factors (Bryman & Cramer, 1999; Parsian & Dunning, 2009). A factor is a list of items that belong together (Munro, 2005; Parsian & Dunning, 2009).

For the adopted teacher questionnaire, the Vietnamese researchers had to determine first if the data was appropriate for factor analysis and if the sampling is adequate for analysis ($n=186$). This was accomplished by using the KMO Measure of Sampling Adequacy via the IBM SPSS. The KMO value was 0.863 which was acceptable and which indicated that the variables were factorable (Hair Jr. et al., 2009). Moreover, The Bartlett's test of sphericity was statistically highly significant with a value <0.001 (< 0.05), which indicated that the variables were correlated.

Given the above indicators, factor analysis was regarded to be suitable with all the twenty-one items (Gambashidze et al., 2017). The questionnaire involved three parts which addressed queries related to (i) teachers' overall perceptions of STEM education (three items), (ii) teachers' value of STEM competencies (7 items), and (iii) teachers' difficulties in STEM implementation (11 items). It consisted of twenty-one, five-point Likert scale of agreement to disagreement quantitative questions (Strongly agree, agree, neither agree or disagree, disagree, strongly disagree). The exploratory factor analyses results indicated that the range of item factor loadings for the teachers' overall perceptions of STEM education was 0.56 to 0.77, the range of

item factor loadings for teachers' value of STEM competencies was 0.80 to 0.85, and the range of item factor loadings for teachers' difficulties in STEM implementation was 0.63 to 0.78. Therefore, none of the twenty-one items was eliminated because they all met a minimum criterion of having a primary factor loading of 0.55 or above for $n = 186$ (Gambashidze et al., 2017; Thi To Khuyen et al., 2020); accordingly factor analysis yielded reliable findings.

To ensure the construct validity of the developed student questionnaire, the researcher of the present study followed the same procedure. To determine first if the data was appropriate for factor analysis, the researcher had to determine if the sampling ($n = 100$) was adequate for analysis. This was accomplished by using the KMO Measure of Sampling Adequacy via the IBM SPSS (Analyze, Dimension reduction, Factor, Descriptive, KMO and Bartlett's test of sphericity). The KMO value was 0.776 which was acceptable and which indicated that the variables were factorable (Hair Jr. et al., 2009). Moreover, the Bartlett's test of sphericity was statistically highly significant with a p -value 0.001 (< 0.05) (Table 3). Given the above indicators, factor analysis was regarded to be suitable with all the items of the student questionnaire (Gambashidze et al., 2017). The exploratory factor analyses results indicated that the items targeted for assessing student perception of science, math, engineering, technology, and STEM career interests were strongly associated with the intended construct in every case where the range of item factor loadings for the student perceptions of science was (0.70 to 0.88), the range of item factor loadings for the student perceptions of technology was (0.76 to 0.90), the range of item factor loadings for the student perceptions of engineering was (0.80 to 0.88), the range of item factor loadings for the student perceptions of maths was (0.73 to 0.86), and the range of item factor loadings for the student perceptions of STEM career was (0.62 to 0.78). Therefore, none of the items was eliminated because they all met a minimum criterion of having a primary factor loading of 0.55 or above for $n = 100$ (Gambashidze et al., 2017; Keshminder, 2020); accordingly factor analysis yielded reliable findings.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	.776
Bartlett's Test of Sphericity	Approx. Chi-Square
	1858.696
	Df
	300

Table 3: KMO and Bartlett's Test results

Reliability complements validity. Reliability is described as the extent of internal consistency whilst a testing procedure recurred (Knekta, Runyon & Eddy, 2019). Coefficient alpha is considered as a decent estimator of reliability. Cronbach alpha is defined by Bryman (2016) as a “commonly used test of internal reliability” (p. 158). For valid interpretations of the findings collected via a tool in the research under study, the reliability of that tool must be high (Knekta, Runyon & Eddy, 2019). Thus, despite the fact that Thi To Khuyen et al. (2020) calculated alphas of (i) teachers’ overall perceptions of STEM education, (ii) teachers’ value of STEM competencies, and (iii) teachers’ difficulties in STEM implementation which came respectively high and equal to (0.764, 0.919, and 0.774) indicating reliable and very highly reliable scale (as values ≥ 0.70 are considered reliable, and values ≥ 0.90 considered very highly reliable), the reliability of the teacher questionnaire was justified by the researcher via the Cronbach’s alpha test to ensure that the adopted tool fits the contextual, linguistic, and the cultural aspects of the teachers teaching in elementary private schools in Abu Dhabi (Rattray & Jones, 2007; Tavakol & Dennick, 2011).

Once calculated from the answers of the first 50 respondents by exporting the participants’ responses as numerical values to Excel program, the coefficient was compared to 0.7 to accept the internal consistency of each question (Brace, Snelgar & Kemp, 2012). The results of alphas’ values of (i) teachers’ overall perceptions of STEM education, (ii) teachers’ value of STEM competencies, and (iii) teachers’ difficulties in STEM implementation came respectively (0.646, 0.792, and 0.915) indicating adequate, fairly high, and strong values respectively (Van Griethuijsen et al., 2015).

The same procedure was followed to ensure the reliability of the student questionnaire. The researcher calculated the Cronbach’s alpha value to ensure that the developed tool fits the contextual, linguistic, and the cultural aspects of the students’ learning in elementary private schools in Abu Dhabi. Once calculated from the answers of the first 50 respondents by exporting the participants’ responses as numerical values to Excel program, the coefficient was compared to 0.7 to accept the internal consistency of each question (Brace, Snelgar & Kemp, 2012). The

alpha values for Science, Technology, Engineering, Maths, and STEM Career STEM perceptions' related questions came respectively (0.77, 0.93, 0.93, 0.77, and 0.71), indicating relatively high, excellent, excellent, relatively high, and good values respectively (Van Griethuijsen et al., 2015).

3.3 Data Analysis Plan

This study adopted an exploratory sequential mixed methods design to explore the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools and to investigate the elementary teachers' and students' perceptions of STEM education in private elementary schools in Abu Dhabi. In an exploratory sequential study, each set of data is suggested to be analyzed independently as it is collected for dissimilar purposes and at different times.

In the first qualitative phase, the researcher adopted the Braun and Clarke (2006) thematic analysis strategy. This strategy involves six phases including familiarization with the data, coding, searching for themes, reviewing themes, defining and naming the themes, and writing up. The Braun and Clarke (2006)'s thematic analysis strategy helped the researcher to decipher the content, to report, and to interpret the qualitative data of the collected and related documents to elementary STEM education in private schools in Abu Dhabi in order to evaluate and reveal the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools.

Subsequently, the researcher disseminated the quantitative teachers' and students' surveys to teachers and students allocated in STEM private elementary schools in Abu Dhabi via a SurveyMonkey tool. The valid and reliable teacher survey was voluntary and anonymous. It took the teachers around six minutes to complete it. Likewise, the valid and reliable student survey was voluntary and anonymous. It took the students around two minutes to complete it.

The anonymous quantitative data was collected and encrypted by the researcher. The collected data was retrieved for the study analysis only. The IBM Statistical Package for the Social Science Statistics (SPSS) software version 24 was utilized to analyze the gathered data from the teachers' questionnaire after coding it in a codebook (Johnson & Christensen, 2016). The researcher conducted descriptive statistics and inferential statistical tests to analyze the

disclosed quantitative primary data of the teacher questionnaire to reveal the significant factors associated to the teachers' perceptions of STEM education in private elementary schools in Abu Dhabi. The analysis was done to assess the influence of each of the demographic factors on teachers' perceptions of STEM education especially that few studies had investigated discrepancies of teachers' perceptions and practices of STEM education based on their demographics (Park et al. 2016). The same procedure and tests were utilized to analyze the student's questionnaire responses. However, the teachers' answers of five open-ended questions at the end of the teacher questionnaire were analyzed via the Krathwohl (2009)'s three main stages which consisted of: 1) familiarization and organization of the participants' answers, 2) coding and recoding of the findings, and 3) summarization and interpretation of the findings to explore their perceptions of STEM education in a qualitative method. Similarly, the researcher analyzed the qualitative data from the classrooms' observation checklist to explore the students' and teachers' practices of STEM education in private elementary schools in Abu Dhabi.

3.4 Ethical Considerations

Research ethics includes three areas which are: the scientific research-society relationship, the researcher-participants relationship, and the professional issues (Johnson & Christensen, 2008). In the present study, the scientific research-society relationship is met as the purpose of this study is allied with the UAE's needs and priorities as it was mentioned in the introduction of this study. Additionally, the ethical considerations were checked by the researcher at each stage of the study. Therefore, while conducting the present proposed study, the researcher first sought approval from the BUiD's Research Ethics Committee (Appendix 5) to contact and access the required private elementary schools in Abu Dhabi after fulfilling the research ethics self-assessment form, the research ethics checklist, and after uploading the intended consent letter (Appendix 6) to be delivered to the schools' principals. The research ethics form which was submitted to the Research Ethics Committee for review included several information related to the research under study, such as the aim of the study, the study design, the participants, the methods of data collection and analysis, the risks to participants and researchers, the methods to secure the collected data and to ensure its confidentiality and protection during and beyond the

end of the study, and how to deal with potential conflicts of interests with researchers or participants.

A consent letter is a letter that denotes that potential “research participants should be given as much information as might be needed to make an informed decision about whether or not they wish to participate in a study” (Bryman, 2016, p.691). So, in the consent letter which was sent to the elementary principals via personalized emails, the researcher explained in details the purpose of the study, the significance of implementing STEM education at the elementary level, the role of the teacher in implementing STEM education, the data collection methods, the ethical considerations, and the significance of the research under study. Moreover, the researcher elucidated that the elementary teachers’ and students’ participations are totally voluntary and there are no identified physical, psychological, or social threats related to this study. Hence, the researcher confirmed to the principals that the questionnaires’ results will remain completely confidential and anonymous and will be retrieved after being encrypted for the study analysis only, and if the study is published, only emerging results will be documented.

The present research encompassed minimal risk. It entailed disseminating an online teacher survey and an online student survey for a number of teachers and students enrolled in STEM private elementary schools in Abu Dhabi. In that sense, the research did not expose the teachers, nor the students to any possible hurtful or illegal behavior, nor the opposite was probable. Also, the researcher had no connections or aforementioned history with the target schools which reduce the chances of any conflicts of interest (Yin, 2015).

In all stages of the research, the researcher adhered to the ethical code of conduct of the BUiD which states that the primary responsibility for the conduct of ethical research lies with the researcher who had to act ethically by following the six key principles of ethical research which mainly highlight 1) the researcher respect, the rights, and the autonomy of the participants beside the mitigation of any potential risk that might harm the participants by robust precautions; 2) the expansion of the research benefits and value; 3) the delivery and the explanation of all the research related information to all the participants by avoiding any deception in providing misleading information or withholding any information about the nature and/or purpose of the study; 4) the respect, the privacy, and the protection of any collected personal data; 5) the

assurance of the transparency; 6) and the recognition of the personal bias and the conflict of interest, if any.

In addition, the ethical standards of the American Educational Research Association (AERA, 2011) and the five AERA ethical principles which consist of the professional competence, the researcher integrity, the professional, scientific, and scholarly responsibility, the respect for people's rights, dignity, and diversity, and the social responsibility were revisited throughout the whole study.

Regarding the approach towards the research participants, the researcher contacted the target principals, one by one, via a personalized e-mail in a way to ensure anonymity and reduce possible coercion that may result from participant knowledge of other elementary principals being contacted (Yin, 2009). The personalized e-mail entailed a consent letter that explained in details the purpose and the significance of the study as well as the means of data collection and the role of the participating teachers and students in the study. Moreover, the researcher adhered to the plan in which participants were not offered any monetary and/or other incentives that would encourage them to participate in the study. Furthermore, succeeding the official consents from schools' principals for research administration, all the participants were informed via an introductive letter, on the top of the teacher survey, about the purpose, the benefits, and the risks of the present study as well as their roles in the study. The agreement of participating in the teacher survey was required from the participants in the first question of the survey after assuring them that the survey was totally anonymous and that their participation was entirely voluntary and deciding not to participate or to withdraw from participating at any time would not result in any harmful consequences and there were no identified physical, psychological, or social risks allied with the present study. The collected data was confidential. The researcher was the only one who had access to it to code it, analyze it, interpret it, and to draw conclusions.

The primary students, as minor participants present problems for academics. They were dissimilar from the adult subjects as they may have not comprehended the language of informed consent. Thus, the researcher considered an informed consent from the elementary principals on the behalf of their students to participate in the present study. Moreover, the researcher asked the principals to demand the teachers to ensure the students that none of them was pressurized into participating in the present study (Fraenkel, Wallen & Hyun, 2015). However, the first question

in the student survey asked for the student agreement in participating in the study after a short introductive sentence about the purpose of the study.

Summary of the Chapter

Chapter 3 delineated the research approach and methods selected by the researcher to meet the purpose of this study. In the research approach section, the adoption of the pragmatic paradigm that guided the research design of the research under study was identified. Moreover, the selection of the mixed methods approach and the adoption of the exploratory mixed methods design to collect and analyze data to meet the purpose of the study were justified. In the research methods section, the context of the study, the site selection, the population, sampling and participant selection, the instrumentation including the document analysis protocol, the teacher questionnaire, and the student questionnaire were described in details. The distribution protocol of the teacher and the student surveys was also clarified and the pilot test was described. Then, the validity and the reliability of the research instruments were discussed to warrant the effectiveness and the credibility of the research. Furthermore, the data analysis plan clarified how each set of data is analyzed independently in this exploratory sequential study. Additionally, the ethical considerations including the scientific research and the society relationship, the researcher and the participants relationship, and the professional issues in addition to the role of the researcher were considered at the end of this chapter.

CHAPTER 4: DATA ANALYSIS AND RESULTS

Overview of the Chapter

Chapter 3 outlined the exploratory sequential method that was utilized in this study to explore the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools and to investigate the teachers' and students' perceptions of STEM education in private elementary schools in Abu Dhabi. Chapter 4 presents the data analysis and findings of each research question. First, in order to explore the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools and to answer the first question of the study which is, "What are the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools?" the researcher conducted a document analysis. It was done by selecting and critically analyzing authentic, credible, and representative primary documents from different resources related to STEM education in private elementary schools in Abu Dhabi. The researcher followed the thematic analysis method offered by Braun and Clarke (2006) which depicts six phases: "1) Familiarizing oneself with the data, 2) Generating initial codes, 3) Searching for themes, 4) Reviewing themes, 5) Defining and naming themes, and 6) Producing the report" (p. 87) to analyze the data of the selected documents and to draw frequent themes related to STEM provisions in private elementary schools in Abu Dhabi. Next, the researcher presented and analyzed the responses of seventy-five elementary teachers from the teacher questionnaire to investigate their perceptions of STEM education and to examine demographic factors associated with their overall perceptions of STEM education in private STEM schools in Abu Dhabi. Similarly, the teachers' answers of five open-ended questions at the end of the teacher questionnaire were analyzed via the Krathwohl (2009)'s three main stages which consisted of: 1) familiarization and organization of the participants' answers, 2) coding and recoding of the findings, and 3) summarization and interpretation of the findings to explore their perceptions of STEM education in a qualitative method. Likewise, findings from one hundred student questionnaires were presented and analyzed in order to examine the elementary students' perceptions of STEM education and their interest in STEM careers as well as to examine demographic factors associated with their overall perceptions of STEM education

in private STEM schools in Abu Dhabi. The researcher applied descriptive and inferential statistics via the IBM SPSS software to analyze the collected quantitative data and to draw conclusions related to teachers' and students' perceptions of STEM education in order to address the Research Questions 2 and 3 of this study which are : “What are the elementary teachers' and students' perceptions of STEM education in private schools in Abu Dhabi?”, and “Are there any demographic differences in elementary teachers' and students' perceptions of STEM education in private schools in Abu Dhabi?”.

4.1 Document Analysis and Results

In social sciences, numerous definitions depicted the word “document”. The definition of Scott (1990) came broad. Scott defined a document as “an artifact that has as its central feature an inscribed text” (p. 5). Yet, Altheide and Schneider (1996) described a document from a different perspective. Altheide explicitly introduced the media-neutral concept in his definition where he argued that a document is “any symbolic representation that can be recorded or retrieved for analysis” (p. 2). Likewise, the two researchers Karppinen and Moe (2012) claimed that a document is any written or audio-visual remainders that the researcher did not interfere in their generation or production.

In document analysis, documents are collected by the researcher to be analyzed. Documents are acknowledged as primary sources that represent factual information. They can be any public or official document generated by any state or organization (Karppinen & Moe, 2012; Syversen, 2004). They epitomize the main objects and focus in a study. They are reliable in authentically revealing reality with no mediation; whereas, academic literature is categorized as secondary material that suggests interpretations of primary resources. The secondary resources, such as books and journals, are less accurate than the primary documents as they can encompass biased interpretations or records of the original documents (Altheide & Schneider, 1996; Karppinen & Moe, 2012; Scott, 1990).

The distinction between primary and secondary resources is obvious and commonsensical. Yet, it is to be noted that sometimes document analysis might be problematic as the documents which are used as original resources in a study are created for the purpose of action and not penned for the sake of the researchers' studies (Scott, 1990). Moreover, analyzing

a document requires a methodological awareness. In practice, researchers are guided by their assumptions, interests, and values. Hence, documents can be reactive. Researchers can interact with the chosen material to select definite statements in a setting for analysis. Consequently, documentary materials might not be protected from the researcher's intervention in the field. The researcher has to safeguard the unobtrusive and naturalistic nature and condition of a document. Theoretically, data are found out there for assembly and analysis, and not produced by the researcher in document analysis (Bryman, 2016; Jensen, 2002; Karppinen & Moe, 2012).

In selecting documents as sources for document analysis, the researcher has to reflect on selection criteria to choose significant and relevant documents to the aim of the research under study or to the objectives of the question to be answered (Karppinen & Moe, 2012).

The researcher conveniently selected the significant and related written documents that helped in meeting the first objective of the study among the various and available primary written documents published online. The selected documents were identified based on specific criteria, such as being published, clear, up-to-date, and insightful to the STEM provisions in private elementary schools in Abu Dhabi (Bowen, 2009).

The selected documents came dissimilar and of different forms. The selected documents were collected from at least two different resources by using different methods and data sources to seek corroboration and convergence (Bowen, 2009). The assigned number of the selected documents was determined based on their availability, their quality, and their relativity to the research topic which is the elementary STEM education (Bowen, 2009). A document analysis protocol was adopted to collect data from the selected documents related to STEM education implementation and integration in the UAE (Al Quraan, 2017). The protocol involved key elements such as the type, the title, the source, and the rationale of each relevant document to elementary STEM education utilized in the document analysis.

4.1.1 Thematic Analysis

The researcher utilized the document analysis to explore the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools. Document analysis is portrayed as a practice in which the researcher interprets and analyzes a document to generate themes that share mutual features (Al Quraan & Forawi, 2019). In the research under study, the

thematic analysis method is followed to analyze data of selected documents or data items.

Thematic analysis is a flexible and accessible analysis method that does not require sophisticated theoretical and technological knowledge of qualitative approaches, but it allows the researcher to “identify, analyse, and report patterns within the data” (Braun & Clarke, 2006, p.41). A data item refers “to each individual piece of data collected, which together make up the data set or corpus” (Braun & Clarke, 2006, p.79). In the present case, a data item can be any written or audio-visual document related to STEM education, or any physical arrangement relating to media such as a STEM student artifact.

For a robust thematic analysis, the researcher needed to apply an analytic eye to analyze and interpret the collected data in light of what is already known about the offered provisions of STEM education in the private schools in Abu Dhabi. To achieve a thematic data analysis, the researcher had to follow a procedure of six steps offered by Braun and Clarke (2006). Braun and Clarke (2006)’s qualitative thematic analysis method depicts six phases as the following: “1) Familiarising oneself with the data, 2) Generate initial codes, 3) Searching for themes, 4) Reviewing themes, 5) Defining and naming themes, and 6) Producing the report” (p. 87). However, the suggested procedure is not a fast and linear method. Instead, it is a slow procedure that develops over time. Moreover, it is a recursive method that allows the researcher to move back and forth as needed via the different phases of the thematic analysis (Braun & Clarke, 2006). Therefore, initially, the researcher had to read the data several times to familiarize oneself with the raw data and to note initial ideas. Then, the researcher had to generate initial codes. Following this, the researcher had to collate the codes and generate potential themes. Hereafter, the researcher had to review the generated themes. Next, the researcher had to define and name the themes. Lastly, the researcher had to produce the final report of the analysis.

Thematic analysis is a method that provides clarity about meanings of the raw data by searching across a data set to reveal repeated themes of meaning (Braun & Clarke, 2006). “A theme captures something important about the data in relation to the research question, and represents some level of patterned response or meaning within the data set” (Braun & Clarke, 2006, p.82). In the current case, the thematic analysis helped the researcher to delve into the selected raw data for more clarification and to inaugurate inquiry for the understanding of the current provisions that are on offer in relation to STEM education in Abu Dhabi private

elementary schools via the analysis of the collected documents or data items. Moreover, the thematic analysis helped the researcher to reflect on and to generate a thick and rich description of the STEM provisions in private schools in Abu Dhabi. Table 4 illustrates the six steps suggested by Braun and Clarke (2006) to pursue thematic data analysis.

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

Table 4: Phases of thematic analysis (adopted from Braun and Clarke, 2006)

4.1.2 Data Collection

In the research under study, the researcher was keen to explicitly explain the methodological choice or the process, from data collection through data analysis and interpretation, to strengthen the validity of the document analysis findings (Karppinen & Moe, 2012). To collect the required data for document analysis, the researcher investigated numerous documents. The main sources of the collected data were the STEM schools’ websites. The researcher surfed every single website to pull out documents and curricula related to STEM integration and implementation. Moreover, the researcher surfed the Which School Advisor (WSA) website to retrieve ADEK schools’ inspection reports to reveal the schools’ STEM implementation back to ADEK standards. To corroborate the data, the researcher had to select

data from different sources. Hence, the researcher followed on YouTube, Instagram, Facebook, and LinkedIn page of every STEM school to identify posts such as videos or pictures related to STEM education practices. Every video or picture related to STEM classes was identified, selected, and saved for analysis, whether it was a video or a picture for students in a STEM lab, or a STEM competition announcement. Hence, the researcher tried to collect resources related to STEM practices from the mentioned schools by asking their principals' assistants or STEM teachers to provide any material related to STEM practices by email for further understanding of the offered STEM provisions in Abu Dhabi. The data was gathered in a document analysis protocol (Table 2) which involved key elements of each document, such as the type, the title, the source, and the rationale of choosing it. After an extensive search, the researcher arrived to collect several documents comprising primary data. Eight STEM based curricula were collected from different schools' websites. The selected schools follow different systems: the American and the British systems. Moreover, eight ADEK inspection reports for the same schools were retrieved from Which School Advisor (WSA) website to be analyzed and to triangulate the findings of the schools' websites. Additionally, the analyst was able to acquire a math study plan for 20 math lessons to be explored from a teacher in a STEM elementary school in Abu Dhabi. Furthermore, an intensive and time-consuming search via the social media platforms allowed the researcher to collect visual and audio-visual primary data. A series of pictures of elementary students performing STEM activities in STEM labs, in natural contexts, and outdoor environments was selected and saved for further analysis. In addition, two YouTube videos of two elementary classrooms performing in STEM labs were collected for analysis. Table 2 illustrates the summary of the documents selected in the research under study for document analysis.

4.1.3 Six Steps of Thematic Analysis

In the research under study, the researcher utilized the Braun and Clarke (2006) model of thematic analysis to answer the first question. The six phases of the model were followed by the researcher to analyze the collected data in a proper way and to reflect on the findings in an accurate way. The collected data, as illustrated in Table 2 comprises implemented STEM curricula retrieved from the STEM schools' websites, ADEK inspection reports retrieved from

the Which School Advisor website, Math study plan for several lessons collected from Math teachers in the schools, and several pictures retrieved from the schools' Instagram and Facebook pages in addition to two YouTube video of elementary class students who were learning coding lessons collaboratively in STEM labs.

The researcher followed the following steps to analyze the collected documents: “1) Familiarizing oneself with the data, 2) Generating initial codes, 3) Searching for themes, 4) Reviewing themes, 5) Defining and naming themes, and 6) Producing the report” (Braun & Clarke, 2006, p.87).

Step 1: Once gathered, the researcher followed the flexible Braun and Clarke (2006) strategy to familiarize oneself with the content and all aspects of the selected data, to code it, and to generate potential themes related to STEM provisions in Abu Dhabi. The researcher took the necessary time to identify, read, and listen to the collected data. Although it was time-consuming, familiarizing oneself with the data was required as it provides the bedrock for valid analysis. During this step, the researcher took notes and highlighted ideas on the black and white printed written documents to get ready for the formal coding process. Regarding the audio-visual documents or verbal data such as the collected videos of elementary students working in STEM labs, the data were transcribed into a written form and printed out. The researcher made sure that the transcripts were accurate and retained all the needed information in a way that is true to its original nature (Braun & Clarke, 2006). This step is a key phase in qualitative methodology for a better understanding of the data. Moreover, it helped in enhancing the researcher's interpretative skills to analyze the data, interpret it, and generate meanings and themes for document analysis (Bird, 2005; Riessman, 1993). Furthermore, while reading and re-reading the different collected data, the researcher made sure to take notes on a notebook for each document under its specific title. This specific act helped the researcher better understand the data by being attentive to specific content. It also assisted in generating common codes or themes that might occur during the analysis stage.

Step 2: Once the researcher was familiarized with the data, step two began. This phase involved the production of initial codes from the collected data. A code refers to “the most basic

segment, or element, of the raw data or information that can be assessed in a meaningful way regarding the phenomenon” (Boyatzis, 1998, p.63). Coding is part of the analysis; it helps the researcher develop the themes in a study. The researcher approached the data from the participants’ experiences and voices to code data and to develop code structures to accommodate new ideas. In this case, coding was inductive and data-driven. The researcher performed the initial coding phase manually and line by line by taking notes on the printed written and transcribed documents, and by utilizing highlighters to identify potential patterns throughout the data corpus. The researcher utilized a pink highlighter to mark keywords related to STEM provisions and an orange color to highlight lines that illustrate data related to the addressed research question. At the same time, the researcher wrote with a blue pen initial thoughts on potential codes or patterns in the margins of each document (Appendix 7). The data extracts were collected and the list of initial codes was generated. The researcher, afterwards, started refining the codes by utilizing axial coding in order to consolidate, merge, and then collate the open codes within each identified code. Sometimes one data extract was coded many times as relevant to STEM status. Additionally, the distinguished anomalies were removed (Yin, 2009). For example, the open codes “teachers promote the group activities”, “students work together”, and “collaborating in STEM labs” were collated to identify the “collaboration in STEM activities” code. Another example was the consolidation of the “Raytheon Emirates”, “Exxon Mobil” and “CITI Innovation” open codes into “STEM partners” code. From the collected documents, the researcher initially identified 120 open codes which were merged and condensed by axial coding into 40 codes related to the STEM provisions in private elementary schools in Abu Dhabi (Appendix 8). The codes were transferred into a Microsoft Word table to be grouped under themes and to help the researcher reconnoiter the most frequently encountered codes related to STEM provisions in private schools in Abu Dhabi. Based on their frequency in the analyzed documents, seven dominant codes were identified by the researcher, including interdisciplinary curriculum, problem-solving, collaboration, creativity, critical thinking, technology, and student support.

Step 3: After coding the collected data, the researcher was ready for the “searching themes” phase, which is phase 3 in Braun and Clarke (2006)’s model. This phase focuses on

generating potential themes from the different collated codes. The elementary process of generating themes embraces the clustering of codes that seem to share some unifying feature together to mirror and describe a consistent and meaningful pattern in the data (Braun & Clarke, 2006). As such, the researcher started thinking about the relationship between the different codes by analyzing them in order to combine them under potential themes. The researcher utilized the codes as a guide to generate potential themes related to STEM provisions in private schools in Abu Dhabi. Highlighters and notes were utilized to infer connections between the different codes and data. Twenty generated potential themes related to the STEM provisions in private schools in Abu Dhabi were initially identified by the researcher (Appendix 8). An example of a potential generated theme was “STEM professional development” deriving from the combination of the two connected codes “teachers’ STEM workshops” and “students’ STEM workshops”. Another example was the connection of the two codes “hands-on activities” and “real-world projects” into “project-based learning” potential theme.

Step 4: Reviewing preliminary themes which were identified in phase 3 is the fourth phase in Braun and Clarke (2006)’s model. It involves the refinement of the preliminary themes generated in the third phase. It is basically about quality checking. In this phase, the researcher reviewed the established preliminary themes by making sure that codes within them cohere significantly. If not, new themes had to be generated to contain the data that did not fit (Patton, 1990). Therefore, while reading and re-reading the data, the codes, and the generated preliminary themes, the researcher re-coded the data that had been missed in earlier stages and collated it under the suitable theme. Braun and Clarke (2006)’s posited that the re-coding stage is essential in document analysis as “coding is an ongoing organic process” (p. 91). After an extensive review and analysis of the original data, the established codes, and the preliminary themes, the researcher refined the potential themes by making sure that the data associated with each theme did really support it.

Step 5: Defining and naming themes is the fifth phase in Braun and Clarke (2006)’s model. It involves the definition and the further refinement, organization, and clustering of the preliminary themes to be ready for final analysis. Moreover, it involves the identification of the

core of each theme besides the determination of the coherent data aspect that it apprehends. In this phase, a final review of all preceding phases was pursued by the researcher to check for completion, quality, and accurateness. The researcher identified the connections between the codes and the themes. Moreover, an extensive review was made to ascertain how the data and the codes support the themes. Any missing data item was, then, added and any incorrectly placed data item was rearranged. At this point, the eight themes of this study which are (1) Integrated STEM-based curriculum, (2) Project-based learning, (3) Technology and engineering integration, (4) Teacher willingness to implement STEM, (5) 21st century skills and STEM, (6) Authentic STEM classroom environment, (7) Authentic STEM assessment, and (8) School administration support of STEM integration, were defined and they were ready for the final analysis. Table 5 depicts an example of the coding of the generated theme “Authentic STEM Assessment”.

Open Codes	Codes	Potential Themes	Themes
Students are skilled in peer assessment	Students’ abilities to assess their work in STEM and their peers’ works in STEM	Ongoing STEM assessment	Authentic STEM Assessment
Students are skilled in self-assessment			
Students receive regular feedback on their work	Authentic STEM formative assessment		
The assessment procedure is rigorous and consistently applied via international benchmarks and standards. Robust external testing provides information about student achievement	Authentic STEM summative assessment		
Robust link between the assessments’ results and lesson plans	STEM Study plans based assessments’ results	Ongoing STEM curriculum reform	
Teachers use the test information to plan lessons and identify areas of improvement			
Teachers use the assessments’ results to adapt the curriculum and meet the learning needs of the students			
	STEM curriculum-reform based assessments’ results		

Table 5: An example of open codes, codes, sub-themes, and themes from document analysis

Step 6: Producing the report is the sixth and final phase in Braun and Clarke (2006)'s model of thematic analysis. It involves a final analysis of the fully worked-out themes and a report production. The report production has to tell the story of the collected data, accurately, to prove the validity and the value of the pursued thematic analysis. Hence, the thematic analysis has to be succinct, clear, and interesting. Moreover, it has to be non-repetitive in telling the data story across and within the themes, not in a descriptive way, but in an analytic narrative way in making arguments related to the research question (Braun & Clarke, 2006). At this point, the researcher commenced with the last step of the thematic analysis which involved the themes analysis and the write-up of the final report. Appendix 8 depicts the complete list of the identified open codes, codes, preliminary themes, and the themes generated by the researcher throughout the examination of the collected documents related to the STEM provisions in private schools in Abu Dhabi.

4.1.4 Interpretative Analysis

The thematic analysis emphasizes the understanding of the STEM provisions and the level of its integration in private schools in Abu Dhabi by exploring the qualitative data collected from related documents. Eight themes were reported after reviewing and coding the gathered data: (1) Integrated STEM-based curriculum, (2) Project-based learning, (3) Technology and engineering integration, (4) Teacher willingness to implement STEM, (5) 21st century skills and STEM, (6) Authentic STEM classroom environment, (7) Authentic STEM assessment, and (8) School Administration support of STEM integration. The themes came out dissimilar, but each theme was obviously related back to the research question which is: "What are the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools". The thematic analysis comprised a descriptive and an interpretative analysis of the generated themes to provide a rich sense of the scope and the miscellany of each of them. In this case, the analyst had to tell the reader a coherent and a persuasive story of the identified themes by relating the identified meanings to the literature review and the conceptual framework of the study or to any other academic analysis related to STEM education in order to generate analytic statements about the STEM provisions and its level of integration in private schools in Abu Dhabi and to contribute to the literature related to STEM education in the UAE. The analytic

claims had to be grounded in the collected qualitative data although they had to go beyond it to reveal the approximate reality (Braun & Clarke, 2006, 2013).

4.1.4.1 Theme 1: Integrated STEM-Based Curriculum

The first highlighted global theme in study was “Integrated STEM-based curriculum”. This theme appeared in all the written documents. All the explored curricula of the different school systems mentioned the integrated curriculum by focusing on interdisciplinary approaches to learning STEM, subjects’ integration, projects-based learning, and technology integration. For instance, *“cross-cutting concepts”*, *“innovative and interdisciplinary approaches to learning science and technology”*, *“cross-functional activities and challenges”*, *“developing and using models”*, *“tackling real-world challenges across the subjects of science, technology engineering, and math”*, *“student-centered approach”* were the statements that were repeated in most of the curricula demonstrating that the schools were keen to indicate that they are clearly implementing STEM curricula. Additionally, all the examined ADEK inspection reports of the different STEM inspected schools performing between very good and outstanding mentioned the efficiency of the schools’ integrated curriculum by focusing on relevant learning experiences and technology integration. *“Cross-curricular links are meaningful and students’ skills in ICT are fully integrated in planning across most subjects”*, *“the school offers an integrative curriculum and an extensive range of relevant learning experiences that develop students’ talents and interests”*, *“the curriculum had been designed imaginatively in all phases to engage students in captivating learning experiences which link curriculum areas very successfully”*, *“the focus on students’ learning via student-centered approach”* were the reported claims by ADEK regarding the integrated curricula. Moreover, all the examined pictures which were retrieved from the STEM schools’ social media platforms showed students collaborating to construct integrated models by using their engineering and mathematical skills (Appendix 9), or to code programs by using their mathematical and technological skills (Appendix 10), or to explore scientific phenomena by using their scientific and engineering skills in natural contexts (Appendix 11). The analysis of the pictures reflected an integrated curriculum based on hands-on activities and real-world problems that enhance the students’ scientific and soft skills. Consequently, the data showed that the global theme of integrated STEM-based curriculum was tightly interrelated to the “Project-based

learning” and “Technology and engineering integration” global themes. Additionally, a relationship was obviously shown amid the integrated STEM-based curriculum theme and the “21st century skills and STEM”, “Authentic STEM classroom environment”, and “Authentic STEM Assessment” themes. For instance, one document suggested, “... *by tackling real-world problems across the STEM subjects, the student will develop 21st century skills such as creativity and communication*”, while another document suggested that, “*our teachers encourage students to work together to find innovative and creative solutions to real-world and complex problems*”. An inspection report also stated that, “*the teachers make full use of the assessment information to plan STEM lessons and identify areas of performance that need improving*”. Additionally, the STEM-based curriculum theme was strongly tied to the theoretical framework, conceptual framework, and the literature review of the study, which accentuated its relevance and importance to the study. Subsequently, the presence of the integrated STEM-based curriculum theme in all the collected written data is key to answer the first question of the study. It highlights the implementation of interdisciplinary STEM practices in STEM schools in Abu Dhabi. Besides, it is an indicator of a quality STEM implementation which reflected a substantial quality of STEM provisions in the mentioned schools. Kelley and Knowles (2016) posited that if implemented efficiently, integrated STEM education can benefit the student’s educational performance and achievement significantly. Besides, it improves the students’ engagement and aspiration levels in learning by improving their scientific knowledge and by enhancing their abilities during problem-solving.

4.1.4.2 Theme 2: Project-Based Learning

The second highlighted global theme in this study was “Project-based learning”. This theme appeared in almost all the data items. All the collected STEM curricula and inspection reports highlighted the efficient role of projects-based learning in implementing very good and outstanding curricula in STEM schools. Moreover, most of the collected media items reflected students collaborating to solve problems by using hands-on activities and integrating skills from different subjects (Appendices 11,12). The global theme of Project-based learning was strongly tied to the “integrated STEM based curriculum” and “technology and engineering integration” themes. All the explored curricula mentioned that integrated curricula must have a project-based

learning approach to solve real-world problems. For instance, *“developing models to explain real-world events”*, *“designing solutions using engineering and technology”*, *“demonstrating by using evidences for ideas”*, *“students are encouraged to experiment rather than wait for instructions”*, *“by collaborating and thinking critically, students solve trickiest problems related to real-world situations via hands-on activities”*, *“opportunities for innovation and creativity via hands-on activities are embedded in the curriculum”* were statements which appeared all over the explored documents. Moreover, an obvious relationship was also depicted between the project-based learning theme and the identified teacher willingness to implement STEM/ 21st century skills and STEM/ authentic STEM classroom environment/ authentic STEM Assessment/ and school administration support of STEM integration. For instance, *“students collaborate in STEM lab to find innovative solutions for real-world projects”*, *“teachers empower the students to meet STEM challenging real-world activities’ targets”*, *“Teachers plan innovative projects that stimulate student interest and engagement in inspiring learning environment throughout the use of technology and needed STEM resources”* were claims which appeared in the explored STEM curricula and ADEK inspection reports. Successively, the presence of the project-based learning theme in all the collected written data helped the analyst in answering the first question of the study by highlighting the practices of the STEM students and teachers in STEM schools in Abu Dhabi. This specific theme was strongly tied to the theoretical framework, conceptual framework, and the literature review of the study. In fact, it was an indicator that reflected a superior quality of STEM provisions and effective STEM practices in the mentioned schools. Gullapyan (2020) reported that applying student-centered educational approaches such as PBL is considered the most successful practice for effective STEM education. In fact, it is considered one of the best pedagogical practices for integrated STEM in elementary and secondary levels (Lamberg & Trzynadlowski, 2015).

4.1.4.3 Theme 3: Technology and Engineering Integration

The third highlighted global theme in this study was “Technology and Engineering Integration”. This theme appeared in most of the collected data items, especially in the collected curricula and media items. Yet, it showed up much less in ADEK inspection reports. Statements, such as *“computational thinking”*, *“clear expectations for students to learn problem solving that*

includes coding”, “*constructing explanation and designing solutions*”, “*throughout the technological tools and the support of teachers the students learn how to be digital citizens, innovative designers, and global collaborators*”, “*the role of technology in enhancing the students’ skills is unmeasurable*”, “*science and technology are usually taught separately, but in our school we use them together as tools for cracking some of the world’s greatest puzzles*”, and “*our students participate in activities including robotics, bioengineering, and coding*” appeared in most of the collected curricula. The third global theme of technology and engineering integration was strongly tied to the “integrated STEM based curriculum” and the “Projects- based learning” themes. Moreover, it was strongly tied to the literature review and the conceptual framework of the study. Hwang and Taylor (2016) suggested that for students to be granted increased access to STEM success, they have to acquire STEM knowledge in an integrative manner which allows them to learn problem-solving skills within science contexts while they engage in hands-on activities promoting their engineering skills and use various types of technology whenever possible. Furthermore, the technology and engineering integration theme appeared to be strongly tied to the school administration support theme. For instance, most of the media items depicted students who were immersed in robotics activities and engineering projects in STEM labs. Hence, several pictures highlighted the partnership of the schools with international technology and innovation partners such as CITI, Raytheon Emirates, and Exxon Mobil (Appendices 13-15). This reflected the availability of funding, outside support, high-quality resources, and technology tools which are considered main factors for an effective STEM implementation. They also serve as main factors for the high interest of the STEM schools in implementing and empowering the technology and engineering disciplines in an effective and professional way. Malaka (2018) stated that funding for the resources of STEM education is a must for supporting and executing an effective STEM practice. Additionally, the various claims, such as “*our STEM teachers participate in workshops that expose them to the forefront of STEM research and thinking*”, “*our teachers receive hands-on trainings from renowned academics*”, and “*we have teamed up with one of the most influential universities in the world to help guide the way on STEM learning*” which appeared in the collected curricula corroborated the data and the findings revealed in the media items, and they reflected advisory services and outside support from innovative STEM institutions for better STEM implementation.

4.1.4.4 Theme 4: Teacher Willingness to Implement STEM

The fourth highlighted global theme in this study was “Teacher willingness to implement STEM”. This theme was considered by Khadri (2014) as a key implementation factor for integrated STEM education. The theme was evident throughout all the collected curricula and ADEK inspection reports. However, the researcher was not able to collect data related to the teachers’ practices and willingness to implement STEM via media items as the focus was always on students’ practices. For instance, claims such as *“teachers support and empower the students to meet the challenging STEM activities’ targets “, teachers provide opportunities for students to critically analyse and use learning for problem solving”, “teachers provide inspiring learning environment throughout the use of technology and needed resources, and “teachers use a lot of STEM resources to enhance students learning and stimulate student interest and engagement”* were evident through the thematic analysis. Accordingly, teachers’ motivation and desire to practice STEM curricula were obvious in STEM schools. Toto, Yulisma and Amam (2021) posited that teachers’ willingness to implement STEM reflects their motivation to practice it. Moreover, the teacher’s willingness to implement STEM global theme was connected to all the other themes, especially to the STEM authentic learning environment, 21st century skills, and STEM themes where the teachers play a fundamental role in providing engaging STEM learning environments and in enhancing the 21st century skills of the students. *“Teachers using open-ended questions extremely well to extend students’ critical thinking and problem-solving skills to solve real-world problems in authentic learning environments”*, and *“teachers have curriculum knowledge... and provide inspiring learning environments through their use of displays, technology and carefully chosen resources”* were claims that reflected teachers’ pedagogical knowledge, motivation, and desire to enhance students’ skills and implement STEM in authentic learning environments via authentic and real-world projects in the STEM schools.

4.1.4.5 Theme 5: 21st Century Skills and STEM

The fifth highlighted global theme in this study was “21st Century Skills and STEM”. 21st century skills are identified as learning dispositions, skills, or abilities which are compulsory for success in the 21st century digital society. These skills are not content-knowledge based. Thus,

they are related to a deeper learning which is founded on problem-solving and analytical reasoning (Cuban, 2015; Stedman, 2015). This theme was evident throughout the entire thematic analysis with a focus on collaboration. Collaboration was strongly tied to the theoretical framework, conceptual framework, and literature review of the study. Collaboration is defined as a process or outcome of joint activity portrayed by both teachers and students (Evans, 2020). Roche et al. (2021) posited that students' collaboration and communication are keys to effective STEM lessons. The global theme 21st century skills was closely interconnected with other identified global themes. The data analysis via the thematic analysis showed that the integrated STEM-based curriculum, the project-based learning, the authentic STEM learning environment, the teacher willingness to implement STEM, and the school administration support of STEM integration themes were highly intertwined with the 21st century skills themes. For instance, *"teachers promote group activities"*, *"opportunities for innovation and creativity are embedded in all curricular areas"*, *"teachers using open-ended questions to extend students' critical thinking and problem-solving skills"*, *"students work together to develop models, construct explanations, and design solutions"* were claims found in written data. Additionally, most of the collected media items showed students collaborating in natural contexts to solve real-world problems. Accordingly, it is clear that STEM schools in Abu Dhabi are implementing learner-centered approaches that promote the students' twenty-first-century skills to help them address open questions, accomplish realistic projects, and solve real-world problems.

4.1.4.6 Theme 6: Authentic STEM Classroom Environment

The sixth highlighted theme in this study was "Authentic STEM classroom environment". This theme surfaced in most of the collected data items and it was closely intertwined with the other global themes, especially with the teacher willingness to implement STEM, project-based-learning, 21st century skills and STEM, and the School administration support of STEM integration themes. Statements such as *"Teachers plan innovative projects that stimulate student interest and engagement in inspiring learning environment throughout the use of technology and needed STEM resources"*, *"students are interested in, engaged in, and enjoying STEM activities within authentic learning environments"*, and *"Teachers receive hands-on trainings and workshops with leading engineers and scientists and a lot of STEM resources to enhance*

students' learning and critical thinking via the authentic learning experiences in authentic learning environments” were clear all over the written data and obvious via the collected media data. Moreover, the Authentic STEM classroom environment theme was strongly connected to the theoretical and conceptual frameworks of the study as well as to its literature review. Gullapyan (2020) stated that providing students with authentic learning environments is considered an effective practice in STEM education. Beier et al. (2019) posited that the students' enjoyment, interest, and career aspiration in STEM areas improve once they participate in authentic learning experiences within authentic learning environments. Subsequently, thematic analysis showed that meaningful experiences within authentic environments were part of STEM implementation and integration in the STEM schools in Abu Dhabi which revealed the stakeholders' efforts and insistence in encouraging students' and teachers' creativity, critical thinking, self-confidence, and self-efficacy (Forawi, 2016; Jacobs & Shahbazi, 2019).

4.1.4.7 Theme 7: Authentic STEM Assessment

The seventh highlighted theme in this study was “Authentic STEM assessment”. This theme was stated in almost all the reviewed written data items with a focus on teachers' constructive feedback on students' learning processes and formative assessment tasks. On the other hand, summative assessment procedures which were consistently applied via international benchmarks and standards were also obvious throughout the reviewed curricula and inspection reports. All the collected STEM curricula and inspection reports highlighted the importance of authentic assessment in enhancing the quality of students' learning and in improving the teachers' teaching approaches and curricula. Statements such as “*teachers make extreme use of the outcomes of the assessments to influence their teaching and adapt the curriculum to meet the learning needs of the students*”, and “*teachers provide students with constructive feedback that strongly supports their learning processes in authentic contexts*” were evident all over the thematic analysis. Moreover, this theme was closely intertwined with other themes identified in this study, especially the teacher willingness to implement STEM, the integrated STEM-based curriculum, and the school administration support of STEM integration themes. In fact, for teachers to know how to assess students authentically, they must be knowledgeable of the curriculum and they have to be instructed and supported by specialists of the different assessment

types via trainings, which reflect the school support. Furthermore, the identified theme was tied to the conceptual framework and literature review of the study. Harks et al. (2014) stated that teachers' authentic assessments and continuous feedback which focuses on students' learning processes motivate the students and support their growth mindset development. The authentic STEM assessment theme reflected a main practice of teachers in STEM schools in Abu Dhabi. However, the assessments' methods of integrated STEM projects which are of non-traditional nature (Al Quraan & Forawi, 2019) were not very clear in the collected data. Investigating the STEM-non-traditional nature assessment in the STEM schools in Abu Dhabi is an area to be considered in future research.

4.1.4.8 Theme 8: School Administration Support of STEM Integration

The eighth and last highlighted theme in this study was "School Administration Support of STEM Integration". The school support is a key element for successful STEM education integration (Al Quraan & Forawi, 2019). It might have many facets. An interpersonal facet illustrated by providing continuous professional development in STEM education, such as trainings for STEM teachers, workshops for students, and a structural facet illustrated by cooperating with outside organizations and science centers or even partnering with global STEM partners to provide the STEM stakeholders the technology tools and resources which are crucial elements for successful STEM integration. The school administration support theme surfaced in all the written and media items with a focus on partnership with global STEM partners. For instance, *"we salute our innovation partner @CITI, @ Raytheon Emirates, @Exxon Mobil... for powering technology education for our elementary students in our elementary school innovation lab"*, *"our teachers participate in workshops @ MIT that expose them to the forefront of STEM research and thinking"*, *"our students meet leading scientists, build and experiment in workshops, and learn about new discoveries that will shape their future. Activities during STEM workshops include robots, bioengineering, and coding"* were statements that surfaced in most of the collected curricula and media items. Moreover, it was intertwined with all the other themes especially with the technology and engineering integration, teacher willingness to implement STEM, authentic STEM learning environment, and authentic STEM assessment themes. Furthermore, it was strongly tied to the theoretical framework, conceptual framework, and

literature review of the study. Accordingly, it was evident that the STEM schools in Abu Dhabi were supporting their teachers and students, on both structural and interpersonal levels, for better STEM education integration.

4.2 Quantitative Data Analysis and Results

This section presents the analyses and the results related to the second and third questions of this study which are “What are the elementary teachers’ and students’ perceptions of STEM education in private schools in Abu Dhabi?” and “Are there any demographic differences in elementary teachers’ and students’ perceptions of STEM education in private schools in Abu Dhabi?”. In this regard, an online teacher questionnaire and an online student questionnaire were utilised to collect quantitative data from the elementary teachers and students in STEM schools in Abu Dhabi to examine their demographic differences and their perceptions related to factors associated with STEM education. Therefore, this section is divided into two sub-sections. The first sub-section presents the analyses and the results related to demographic differences and factors associated with elementary teachers’ perceptions of STEM education such as understanding of STEM education, value of STEM competencies, and STEM difficulties. On the other hand, the second sub-section presents the analyses and the results related to demographic differences and factors associated with the elementary students’ perceptions of STEM education such as the examination of their perceptions related to Science, Technology, Engineering, and Maths disciplines along with their interest in STEM careers. In both sections, descriptive and inferential statistical analyses were conducted and the results were revealed and explained.

4.2.1 Results and Analyses of the Teacher Questionnaire

LeCompte and Schensul (1999) claimed that data analysis is a process that is utilized by the researcher to reduce data to a story and to interpret it in order to derive insights. Marshall and Rossman (2014) stated that data analysis is a messy and time-consuming yet a creative procedure in which a large chunk of data is reduced to smaller fragments, categorized, and identified to generate meanings. This section presents analyses and results of the teacher questionnaire that examines the teachers’ perceptions of STEM education in STEM private elementary schools in Abu Dhabi. The teacher questionnaire of this study is adopted from the valid and reliable cross-

sectional Vietnamese survey of Thi To Khuyen et al. (2020) which measures teachers' perceptions of STEM education following three components: (1) The understanding of STEM education, (2) The value of STEM competencies, and (3) STEM difficulties. The questionnaire helped the researcher in answering the second question related to the elementary STEM teachers' perceptions of STEM education in private schools in Abu Dhabi and the third question related to the demographic differences in elementary teachers' perceptions of STEM education in private schools in Abu Dhabi. The questionnaire was divided into two clusters. A quantitative cluster and a qualitative cluster. The quantitative cluster was divided into three sections. The first section consisted of several categorical-type questions related to teachers' demographics, such as gender, age, education background, the level of education, the overall teaching experience, the teaching experience in STEM, the major, the grade level they teach, and the frequency, and the way they integrate STEM in their classrooms. The second section involved three parts which addressed queries related to (i) teachers' overall perceptions of STEM education (3 questions), (ii) teachers' value of STEM competencies (7 questions), and (iii) teachers' difficulties in STEM implementation (11 questions). It consisted of twenty-one, five-point Likert scale of agreement to disagreement quantitative questions (Strongly agree, agree, neither agree or disagree, disagree, strongly disagree). The second qualitative cluster of the teacher questionnaire consisted of a set of five structured open-ended qualitative questions which required the teachers to reflect on their perceptions of STEM education by typing their answers using their own words in a comment box to help the researcher explore new areas and understand the participants' issues.

In this study, a total of seventy-eight teacher questionnaires was completed by elementary teachers in STEM schools in Abu Dhabi. Out of the seventy-eight completed questionnaires, three cases were overlooked due to incomplete responses. As a result, seventy-five teachers completed the full survey and therefore seventy-five teacher questionnaires were analyzed with a completion ratio of one-hundred percent. The typical time spent to complete the questionnaire was six minutes.

4.2.1.1 Descriptive Statistics Among Demographic Groups

The researcher conducted first descriptive statistics to present the data. The descriptive statistics allow the researcher to gather mixed information and to describe the characteristics of

the population by focusing not on the “why”, but on the “what” of the research subject. Demographic data delineated the first section in the teacher questionnaire. Statistics related to teachers’ demographic characteristics such as gender, age, education background, the level of education, the overall teaching experience, the teaching experience in STEM, the major, the instructional grade level they teach, and the frequency and the way they integrate STEM in their classrooms were analyzed first by utilizing the basic statistics of the SurveyMonkey which were automatically computed and displayed via the SurveyMonkey software or via the frequencies statistics of the SPSS software. The succeeding pie charts (Figures 6-12) present the graphical representations of individual results of the participating elementary teachers’ demographics in this study (gender, age, level of education, education background, teaching experience, and teaching experience in STEM). The pie chart which is a useful visual aid allowed the researcher to better understand the data distribution of the closed-ended questions with a single response via the observation of the spread and dispersion of data by showing percentage values of data as slices of pie. On the other hand, the remaining demographics related to instructional grade level, teaching subject, the curriculum in which STEM is taught, and the approaches to STEM, they were presented in bar graphs. The bar graphs (Figures 13-17) were utilized as visual aids to help the researcher better understand the data distribution of the closed-ended questions with multiple answers in forms of rectangular bars with lengths, proportional to the values that they represent.

Figure 6 presents the frequency distribution of the teachers by their gender. The ratio of both males and females was dissimilar with participating female teachers (68%) being higher compared to that of the male teachers (32%).

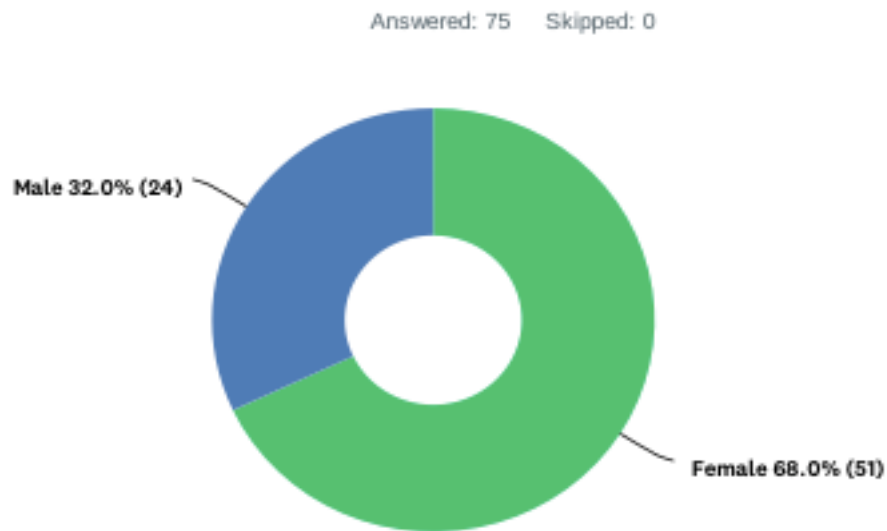


Figure 6: Gender of teachers

Figure 7 presents the frequency distribution of the teachers by their age group. The findings revealed that among 75 participants, around 70% of the teachers belonged to the 35-44 years age group, whereas 21% belonged to the 25-34 years age group. Only 9% of participants were above 45 years old.

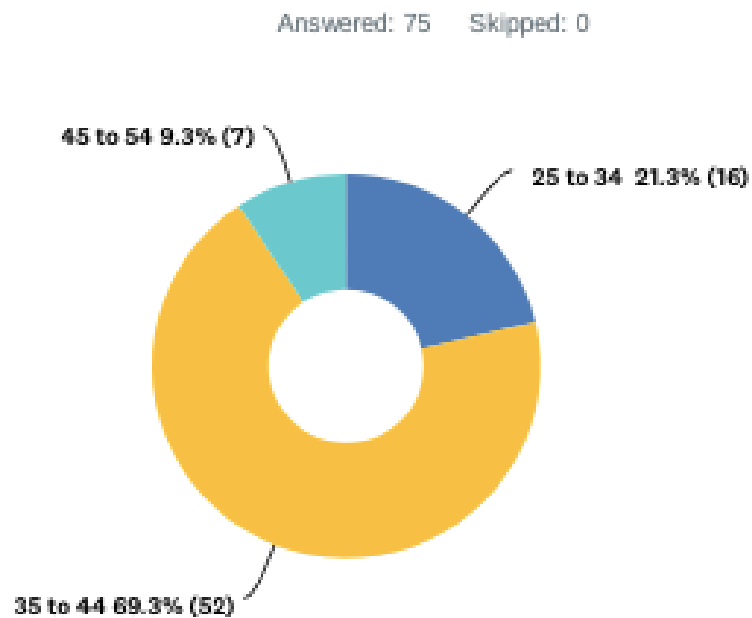


Figure 7: Age of teachers

Figure 8 presents the frequency distribution of the teachers by education background. The majority of teachers who completed the questionnaire in this study had completed their education in the Science major (46.7%), followed by teachers who had completed their education in Math (28%) and Technology (5.3%), and (20%) of the participants had completed their education in other majors.

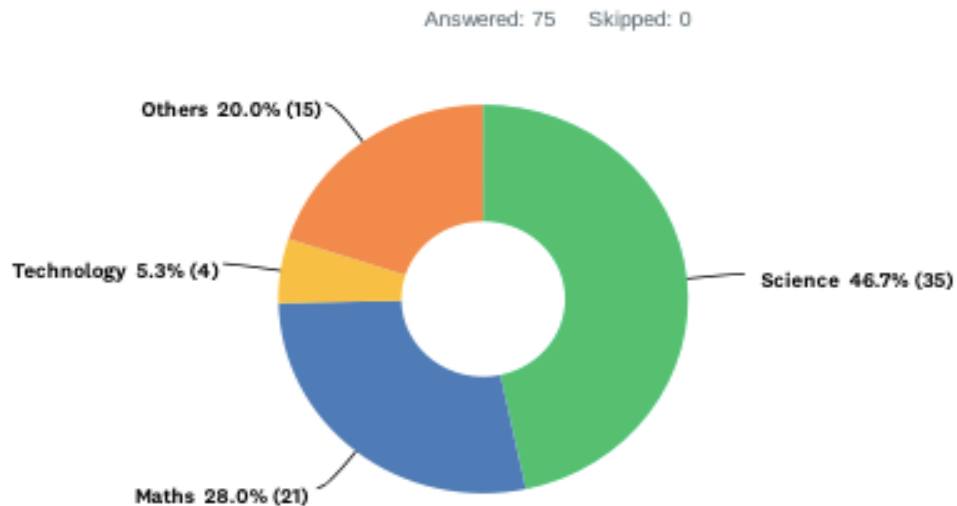


Figure 8: Education background of teachers

Figure 9 presents the frequency distribution of the teachers by education level. The largest group of respondents who participated in this study had a master's degree (60%) while (40%) had a bachelor's degree.

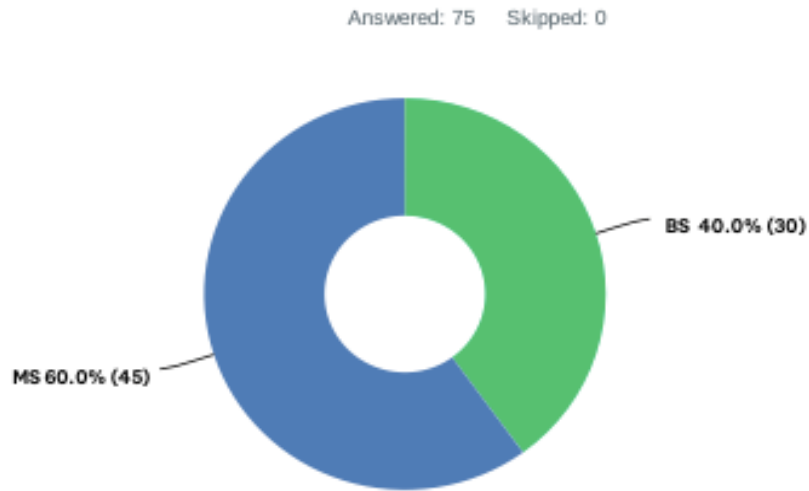


Figure 9: Education level of teachers

Figure 10 presents the frequency distribution of the teachers by years of teaching experience. The majority of the participants had more than 10 years of experience (53.3%), followed by teachers who had 1 to 5 years of experience (25.3%), and the remaining 21.3 % of the participating teachers had 6 to 10 years of teaching experience.

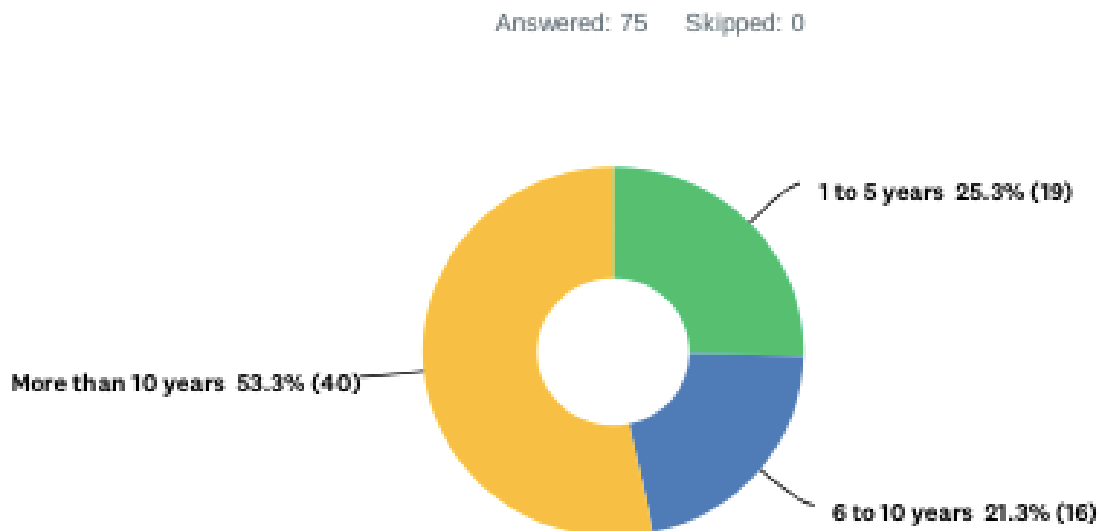


Figure 10: Teaching experience of teachers

Figure 11 presents the frequency distribution of the teachers by years of teaching experience in STEM. The majority of the participants had more than 3 years of experience in

STEM (41.3%) followed by teachers who had 1 year of experience (29.3%). The remaining participants had between 2 to 3 years of experience in STEM.

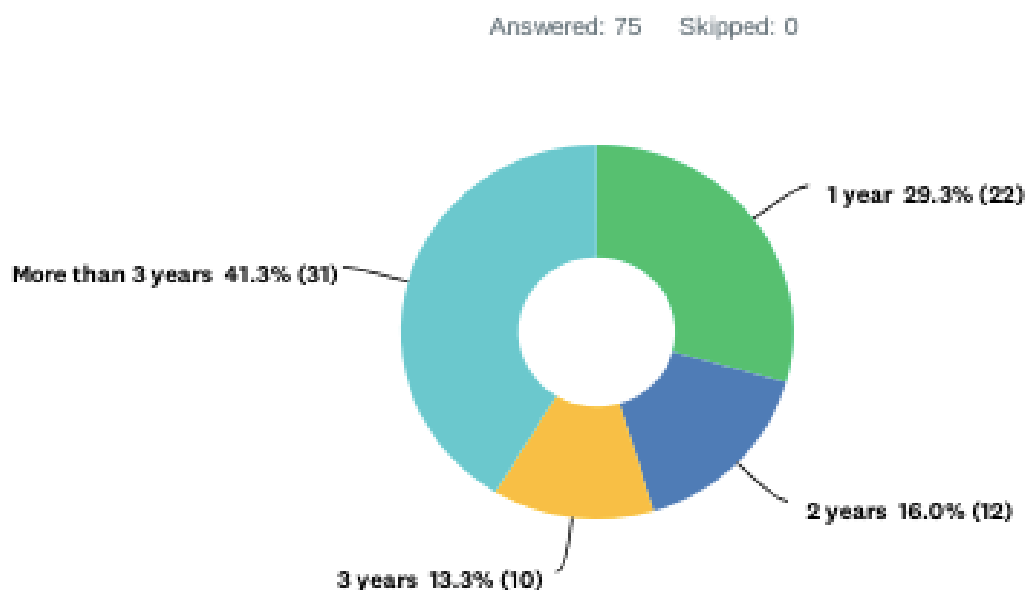


Figure 11: Teaching experience in STEM of teachers

Figure 12 presents the frequency of STEM implementation in STEM schools in Abu Dhabi. Results show that only 33.3% of the participants implement STEM in every lesson in their elementary classes, whereas 25.3% of teachers implement STEM three times per month and 21.3% implement it twice per month. 10.7 % of the teachers implement STEM once per month and 4% implement it once per term. 5.3 % of the teachers claimed that they integrated math and technology almost every day. Yet, engineering mindset and science are incorporated when the need arises in the daily life in addition to the curricular lessons.

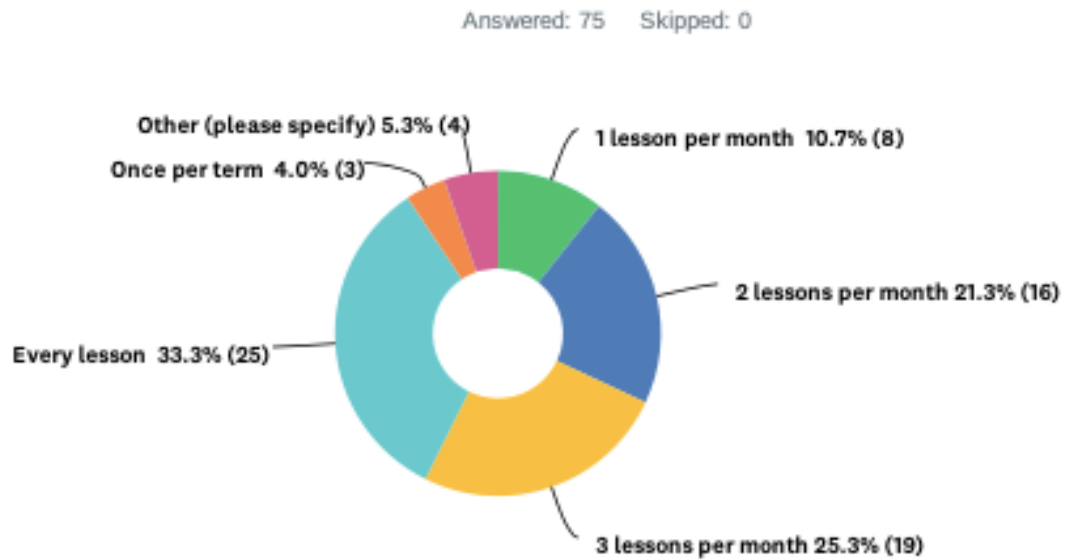


Figure 12: Frequency of STEM implementation

Figure 13 presents the grade level in which the participants are currently teaching. Results revealed that the majority of teachers teach grade 5 (26.7%) and grade 4 (22.7%), followed by teachers who teach grade 2 (17.3%), grade 1 (13.3%), and grade 3 (10.7%) level. Few participating teachers teach grade 1 to grade 5 (9.3%).

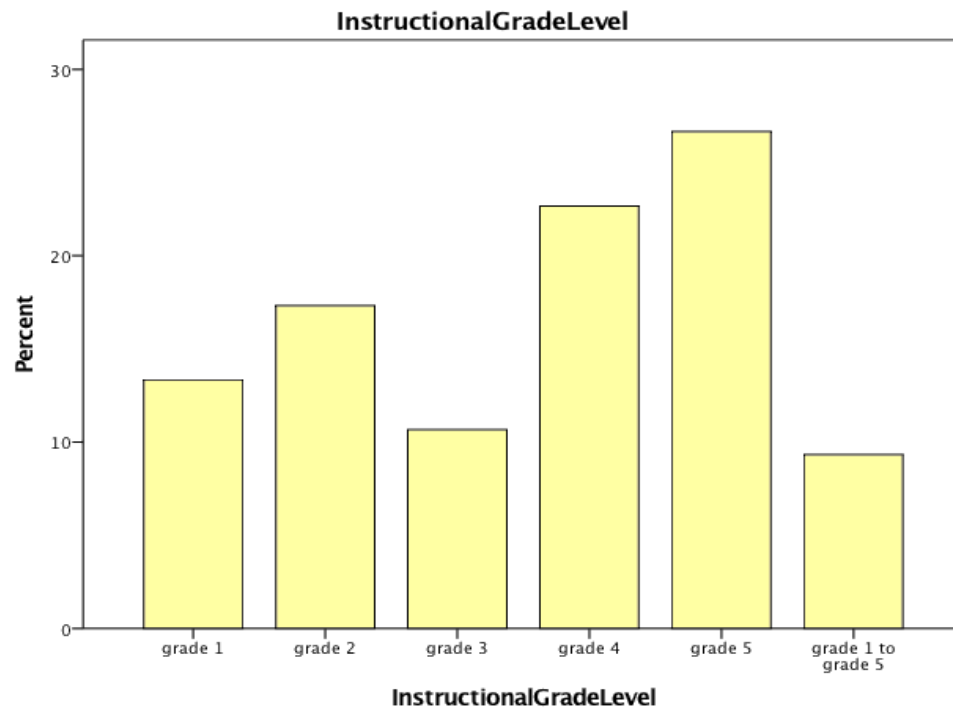


Figure 13: Instructional grade level of teachers

Figure 14 presents the teaching subjects that the participants are currently teaching and within which they are implementing STEM. Results revealed that the majority of teachers who participated in this study were homeroom teachers who teach Science, Math, and ICT subjects at the same time (49.3%), whereas the other participants were Science teachers (28%), Math teachers (14.7%), and ICT teachers (8%).

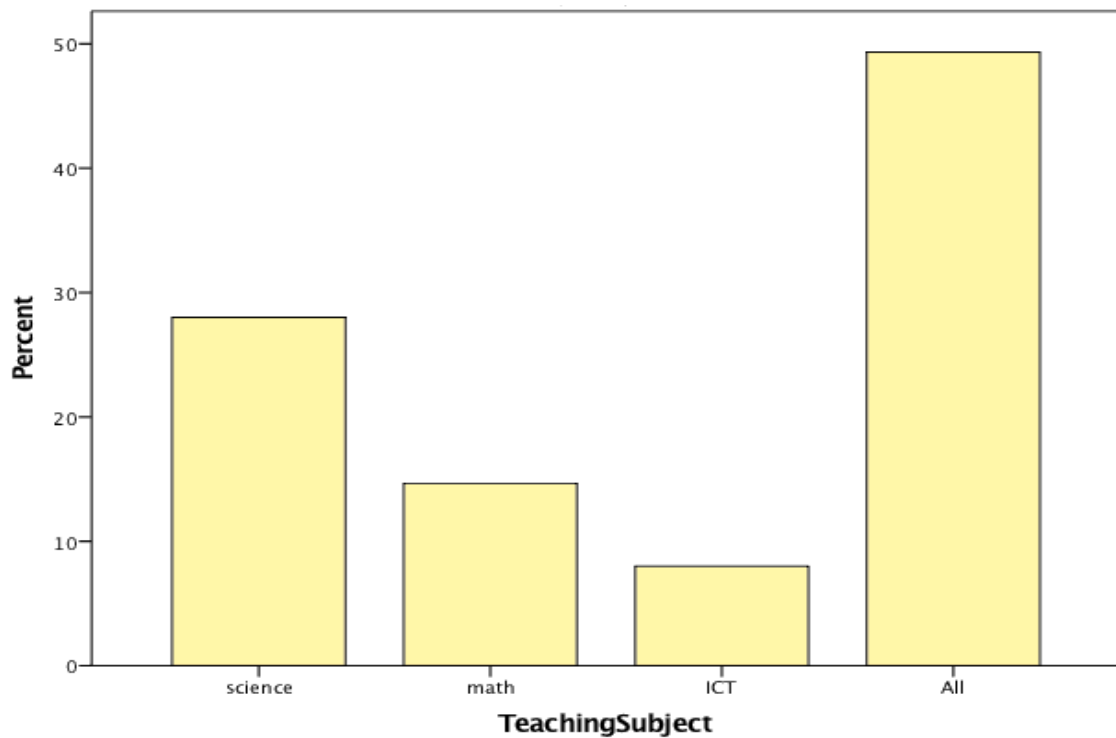


Figure 14: Teaching subjects of teachers

Figures 15 and 16 present data about curricula related to STEM education in private elementary schools in Abu Dhabi. Results revealed that the majority of teachers who participated in this study teach in American schools (73.3%) followed by teachers from British schools (26.7%). Moreover, findings show that in most schools STEM is integrated in the regular curriculum (86.7%). Whereas, 13.3% of the schools integrate STEM in their extra-curricular activities.

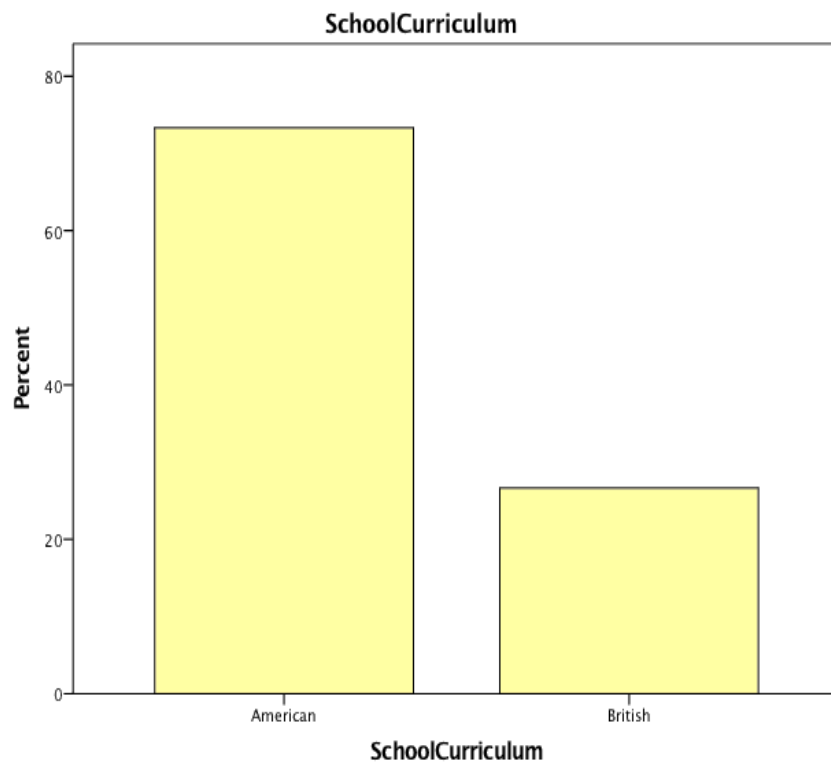


Figure 15: School curricula

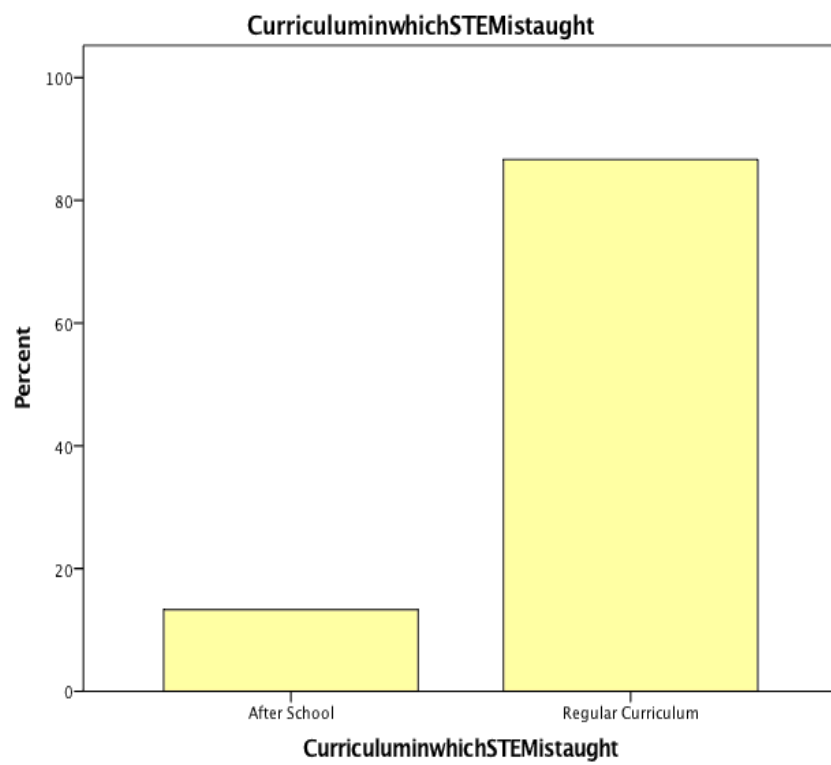


Figure 16: Curricula related to STEM implementation

Figure 17 revealed that 28.6% of the elementary teachers in STEM schools in Abu Dhabi approach STEM in an interdisciplinary way by integrating the four STEM disciplines (33.3%) or by integrating math, science, and technology in their lessons (36.0%). Whereas 21.4% of the participants approach STEM in a multidisciplinary way by connecting science and technology (16.0%) or by connecting math and science (12%).

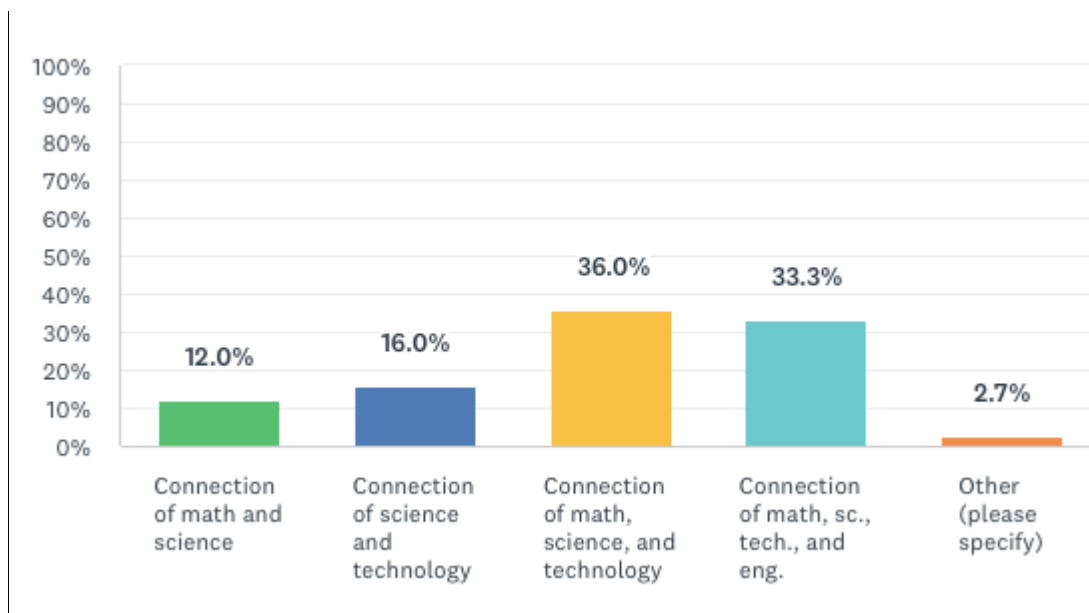


Figure 17: Teachers' approaches of STEM integration

The descriptive statistics of the elementary teachers' demographics in STEM schools in Abu Dhabi revealed that the participants were mostly females with diverse degree majors and teaching experiences. The participants were from different schools which implement different curricula that approach STEM in different approaches. This diversity in participants' demographics indicated that there would be diversity in their responses related to their perceptions of STEM education. Nevertheless, it was critical to determine if there were significant differences in the teachers' perceptions of STEM education components (teachers' value of STEM competencies, teachers' value of STEM competencies, and teachers' difficulties in STEM implementation) based on their demographics' differences in order to determine which group has more positive perceptions towards each of the STEM education component identified from the questionnaire to be able to answer question 3 of the study (Table 6).

Gender	Age	Education Background	Education Level	Years of Teaching Experience	Years of Experience in STEM	Teaching Subject	Instructional Grade Level	Implemented Curriculum
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Teachers' Perceptions of STEM		
STEM education	STEM competencies	STEM difficulties

Table 6: Variables affecting teachers' perceptions components

4.2.1.2 Teachers' Perceptions of STEM Education: Quantitative Results

Descriptive statistics were utilized to summarize and organize the quantitative data set related to the teachers' perceptions of STEM education in STEM schools in Abu Dhabi and to address question 2 of the current study. The statistical package for social sciences (SPSS) version 22.0 was utilized to describe and analyze the teachers' perceptions of STEM education after creating a codebook to code the collected data. Measures of central tendency were calculated through mean scores and standard deviations to examine and interpret the overall teachers' perceptions among the three STEM domains (Table 7) which are the general understanding of STEM education ($M= 1.67$, $SD=0.616$), the values of STEM competencies ($M= 1.36$, $SD= 0.381$), and the difficulties in STEM implementation ($M= 2.36$, $SD=0.703$).

			Statistic	Std. Error
STEM	Mean		1.6711	.07117
Understanding Total	95% Confidence	Lower Bound	1.5293	
Mean	Interval for Mean	Upper Bound	1.8129	
	5% Trimmed Mean		1.6531	
	Median		1.6667	
	Variance		.380	
	Std. Deviation		.61633	
	Minimum		1.00	
	Maximum		2.67	
	Range		1.67	
	Interquartile Range		1.00	
STEM Value of	Mean		1.3600	.04409
Competencies Total	95% Confidence	Lower Bound	1.2721	
Mean	Interval for Mean	Upper Bound	1.4479	
	5% Trimmed Mean		1.3233	
	Median		1.2857	
	Variance		.146	
	Std. Deviation		.38186	
	Minimum		1.00	
	Maximum		2.71	
	Range		1.71	
	Interquartile Range		.57	
STEM Difficulty	Mean		2.3648	.08119
Total Mean	95% Confidence	Lower Bound	2.2031	
	Interval for Mean	Upper Bound	2.5266	
	5% Trimmed Mean		2.3465	
	Median		2.2727	
	Variance		.494	
	Std. Deviation		.70315	
	Minimum		1.18	
	Maximum		4.09	
	Range		2.91	
	Interquartile Range		1.27	

Table 7: Descriptive statistics of STEM domains

Figure 18 elucidates the boxplots which illustrate the distribution of the three STEM domains. The general observation revealed that the box plots of the first and the second domain were comparatively short while the box plot of the third domain was comparatively tall. This means that overall teachers had a high level of agreement of the definition and the values of STEM competencies. Whereas, they held quite different opinions regarding the STEM difficulties. Additionally, the first domain which was STEM understanding had a median of 1.666, a minimum of 1.00 (lower whisker), and a maximum of 2.67 (upper whisker). The lower bound was 1.529 (Q1) and the upper bound was 1.812(Q3). The second domain which was values of STEM competencies had a median of 1.285, a minimum of 1.00 (lower whisker), and a

maximum of 2.76 (upper whisker). The lower bound was 1.272 (Q1) and the upper bound was 1.447 (Q3). The third domain which was difficulties in STEM implementation had a median of 2.272, a minimum of 1.18 (lower whisker), and a maximum of 4.09 (upper whisker). The lower bound was 2.203 (Q1) and the upper bound was 2.526 (Q3). Therefore, the researcher concluded that 75% of the elementary teachers in STEM private schools in Abu Dhabi strongly understand what STEM education is (upper bound= 1.812) and they strongly agree that STEM competencies are extremely important (upper bound = 1.447). Yet, 50% of the teachers agree that they find difficulties in implementing STEM education (Interquartile ranges between 2.203 and 2.526).

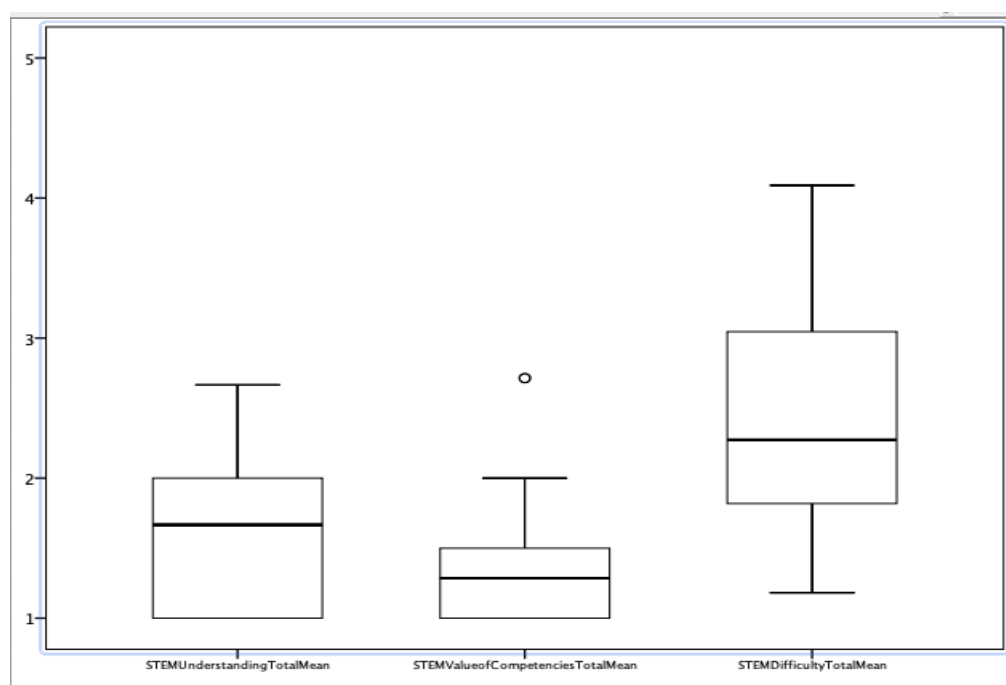


Figure 18: Distribution of STEM domains: STEM general understanding; Value of STEM competencies; Difficulty in STEM implementation

In the second section of the teacher questionnaire, there were seven questions related to the teachers' value of STEM competencies such as “STEM education can help students acquire critical thinking that is usually conducted by scientists, technologists, engineers, and mathematicians” and “STEM education can help students leverage collaboration literacy with others to execute STEM learning projects”, in addition to eleven questions related to the teachers' difficulties in STEM implementation such as “Difficulty to implement an inquiry-based

curriculum” and “Difficulty to authentically assess students’ achievement (formative and summative assessments)”. Teachers were asked to assess the value of each STEM competency and level of STEM implementation difficulty based on five-point Likert scale of agreement to disagreement quantitative questions (1) Strongly agree, (2) agree, (3) neither agree or disagree, (4) disagree, (5) strongly disagree. Tables 8 and 9 present the measures of central tendency via the mean scores and standard deviations of each item of STEM competencies and STEM difficulties.

	N	Minimum	Maximum	Mean	Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error
D-STEM education can help students acquire skills related directly to STEM careers.	75	1.00	4.00	1.6400	.09032
E-STEM education can help students develop scientific literacy	75	1.00	4.00	1.3067	.07096
F-STEM education can help students develop technological skills	75	1.00	3.00	1.3333	.06102
G-STEM education can help students acquire critical thinking that is usually conducted by scientists, technologists, engineers, and mathematicians.	75	1.00	3.00	1.3467	.06149
H-STEM education can help students acquire authentic problem-solving skills to make a decision in the real world.	75	1.00	4.00	1.3067	.07096
I-STEM education can help students to better collaborate with each other's to execute STEM learning projects.	75	1.00	2.00	1.3733	.05623
J-STEM education can help students acquire engineering abilities to make meaningful products (define the needs, design, and make a certain product).	75	1.00	2.00	1.2133	.04762

Table 8: Measures of central tendency of each item of STEM competencies

	N	Minimum	Maximum	Mean	Std. Deviation	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
K-Need to enhance knowledge beyond your major, related to STEM subfields (Technological, pedagogical, and content knowledge)	75	1.00	4.00	2.3200	.11095	.96086
L-Difficulty to implement an inquiry-based curriculum	75	1.00	5.00	2.6933	.10734	.92959
M-Difficulty to authentically assess students' achievement (formative and summative assessments)	75	1.00	5.00	2.6533	.10821	.93712
N-Difficulty to plan STEM activities	75	1.00	5.00	2.6933	.13816	1.19654
O-Difficulty to manage STEM activities	75	1.00	5.00	2.7200	.12529	1.08503
P-Difficulty to evaluate the suitable approach for each STEM activity	75	1.00	5.00	2.4667	.10960	.94916
Q-Insufficient time for students to conduct STEM lessons	75	1.00	5.00	1.9467	.11373	.98493
R-Need an extra support from school administration, scientists, and advisors.	75	1.00	4.00	2.0667	.12496	1.08221
S-Need to collaborate more with other STEM teachers	75	1.00	4.00	2.2267	.11790	1.02104
T-Need for Professional Development	75	1.00	4.00	1.9333	.10960	.94916
U-Difficulty in preparing students for national and international STEM competitions (Robotics, Coding, Innovation competition)	75	1.00	4.00	2.2933	.10183	.88185

Table 9: Measures of central tendency of each item of STEM difficulties

Findings revealed that “STEM can help students acquire engineering abilities to make meaningful products” was perceived as the least important STEM competency ($M= 1.21$, $SD=0.412$) while “STEM can help students acquire skills related directly to STEM careers” ($M= 1.64$, $SD= 0.782$) was perceived as the most important STEM competency by the elementary teachers

in STEM schools in Abu Dhabi. Regarding STEM difficulties, the two items: to manage STEM activities ($M= 2.73$, $SD=1.085$) and to implement an inquiry-based curriculum ($M= 2.69$, $SD=0.929$) were perceived as the main difficulties in implementing STEM education. Whereas, the need for Professional Development ($M=1.93$, $SD=0.949$) and the insufficient time for students to conduct STEM lessons ($M= 1.94$, $SD=0.984$) were perceived as the most tolerated difficulties in comparison with all the other difficulties when implementing STEM education.

4.2.1.3 Results from Significant Testing Among Demographic Groups

The teacher perception section in the teacher questionnaire was divided into three subsamples which were (1) the teacher understanding of STEM education, (2) the teacher value of STEM competencies, and (3) the teacher difficulties to implement STEM. The researcher aimed at examining and analyze if there were differences in teachers' subsamples' perceptions of STEM education between their demographic characteristics. The succeeding findings and tables present the independent t-test results (when comparing 2 groups) and the one-way variance analysis (independent-between groups ANOVA) test results (when comparing more than 2 groups) for the subsamples' perceptions of STEM education. The independent-samples t-test for Equality of Means is an inferential statistics test that demonstrates if there is any significant difference among the means of two different groups. The independent-samples t-test which is usually supported by Levene's test for Equality of Variance was applied to test influences of demographical variables with two independent groups such as gender and educational level on subsamples' perceptions of STEM education. Whereas, the one-way ANOVA test was applied to test the influences of demographical variables which had more than two independent groups such as age group, education background, years of experience, teaching subject, instructional grade level, and the implemented curriculum on the study variables which are the subsamples' perceptions of STEM education. The one-way ANOVA test revealed to the researcher whether there were significant differences between the means of two or more groups. .05 level of significance was adopted to interpret the results. The outcomes obtained from the collected data in accord with the purpose of the study were displayed in tables. Interpretations based on collected data were revealed.

Table 10 shows the differences in teachers' perceptions of STEM education based on gender. The t-test results of the male and female teachers' perceptions of STEM subsamples which were (1) the teacher understanding of STEM education, (2) the teacher value of STEM competencies, and (3) the teacher difficulties to implement STEM revealed that female teachers had the highest mean scores in the first domain (M=2.05, SD=0.642) and the second domain (M=1.36, SD=0.424), indicating that they had a more general understanding of STEM education and they value STEM competencies the most. On the other hand, male teachers scored the highest (M=2.51, SD=0.500) in the third domain indicating that they faced the most difficulties in implementing STEM. Moreover, the outcomes in Table 10 revealed that there was a statistically significant difference in the teacher understanding of STEM education between the male (M= 2.05, SD=0.642) and female (M=1.49, SD=0.517) teachers with $t(73) = -4.08$ and p-value was less than the standard alpha level of 0.05 ($p = .000 < .05$). Yet, dissimilar conclusions were identified regarding the influence of gender on the teacher value of STEM competencies (male (M= 1.34, SD=0.279) female (M= 1.36, SD=0.424), $t(73) = 0.228$ and $p = .820 > .05$) and the teacher difficulties to implement STEM (male (M= 2.51, SD=0.500) female (M=2.29, SD=0.775), $t(73) = -1.242$ and $p = .218 > .05$). Therefore, the researcher concluded that there was no significant relationship between the independent variable gender and the teachers' perceptions of the value of STEM competencies and STEM difficulties. However, there was a relation of statistical significance between gender and general understanding of STEM education.

	Group Statistics				
	Gender	N	Mean	Std. Deviation	Std. Error Mean
STEM Understanding Total	Female	51	1.4902	.51791	.07252
Mean	Male	24	2.0556	.64206	.13106
STEM Value of Competencies	Female	51	1.3669	.42403	.05938
Total Mean	Male	24	1.3452	.27917	.05699
STEM Difficulty Total Mean	Female	51	2.2959	.77542	.10858
	Male	24	2.5114	.50067	.10220

		Independent Samples Test								
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2- tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
STEM Understanding Total Mean	Equal variances assumed	1.453	.232	-4.078	73	.000	-.56536	.13862	-	-.28909
	Equal variances not assumed			-3.774	37.619	.001	-.56536	.14979	-	-.26203
STEM Value of Competencies Total Mean	Equal variances assumed	2.655	.108	.228	73	.820	.02171	.09513	-	.21131
	Equal variances not assumed			.264	64.875	.793	.02171	.08230	-	.18607
STEM Difficulties Total Mean	Equal variances assumed	5.940	.017	-1.242	73	.218	-.21546	.17342	-	.13016
	Equal variances not assumed			-1.445	65.714	.153	-.21546	.14911	-	.08227

Table 10: Independent-samples t-test between variables gender and teachers' perceptions of STEM subsamples

Table 11 shows the differences in teachers' perceptions of STEM education based on age group. The one-way ANOVA test was applied to test the influence of age group on the study variables which were (1) the teacher understanding of STEM education, (2) the teacher value of STEM competencies, and (3) the teacher difficulties to implement STEM. Results revealed that teachers who aged between 35 and 44 years old had the highest mean scores ($M=1.698$, $SD=0.680$) in the first domain indicating that they have a more general understanding of STEM education, while teachers who aged between 25 and 34 years old scored the highest ($M=1.598$, $SD=0.555$) in the second domain indicating that they value STEM competencies the most. Teachers who aged between 45 and 54 years scored the highest ($M=2.831$, $SD=0.761$) in the third domain indicating that they face the most difficulties in implementing STEM. Moreover, the between-groups ANOVA test results revealed that there were no significant differences among the groups for the teacher understanding of STEM education ($F(2,72)=0.260$, $p=.772$) and the teacher difficulty in implementing STEM ($F(2,72)=2.303$, $p=.107$). Yet, findings revealed that there were significant differences between the teachers' age subgroups for the value of competencies of STEM education. The one-way ANOVA test showed that $F(2,72) = 4.315$, $p=.0017 < .05$. In this case, the teachers' age group was not considered a significant contributor to the teacher understanding of STEM education nor a significant contributor to the level of difficulties the teachers faced when implementing STEM; however, it was considered an influencer of the teacher's value of STEM competencies. F statistics do not point out the

teachers' age subgroups within which there was a significant difference in the teachers' perceptions of value of STEM competencies. To point out the subgroups among which there were significant differences in the teachers' perceptions towards the value of STEM competencies, the researcher conducted the Post Hoc analysis, Tukey HSD (Honestly Significant Difference) test. The results of Tukey test for teachers' perceptions of value of STEM competencies and teachers' age group revealed that there were statistically significant differences between teachers who aged between 25 to 34 years old ($M= 1.598$, $SD= 0.555$) and the teachers who aged between 35 and 44 years old ($M= 1.296$, $SD= 0.297$). Accordingly, the mean scores of teachers (25-34 years old) were statistically significantly higher than the means scores of the teachers (35-44 years old), indicating that the youngest teachers value the STEM competencies the most and that the teachers' age group is considered a significant contributor to the teachers' perceptions of value of STEM competencies.

Descriptive									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
STEM Understanding Total Mean	25 to 34 YO	16	1.6458	.44670	.11167	1.4078	1.8839	1.00	2.33
	35-44 YO	52	1.6987	.68044	.09436	1.5093	1.8882	1.00	2.67
	45-54 YO	7	1.5238	.46576	.17604	1.0931	1.9546	1.00	2.33
	Total	75	1.6711	.61633	.07117	1.5293	1.8129	1.00	2.67
STEM Value of Competencies Total Mean	25 to 34 YO	16	1.5982	.55505	.13876	1.3025	1.8940	1.00	2.71
	35-44 YO	52	1.2967	.29785	.04130	1.2138	1.3796	1.00	2.00
	45-54 YO	7	1.2857	.28571	.10799	1.0215	1.5500	1.00	1.57
	Total	75	1.3600	.38186	.04409	1.2721	1.4479	1.00	2.71
STEM Difficulty Total Mean	25 to 34 YO	16	2.1591	.67010	.16753	1.8020	2.5162	1.18	3.45
	35-44 YO	52	2.3654	.68847	.09547	2.1737	2.5571	1.27	4.00
	45-54 YO	7	2.8312	.76138	.28777	2.1270	3.5353	1.82	4.09
	Total	75	2.3648	.70315	.08119	2.2031	2.5266	1.18	4.09

		ANOVA					
		Sum of Squares	df	Mean Square	F	Sig.	
STEM Understanding Total Mean	Between Groups	.202	2	.101	.260	.772	
	Within Groups	27.908	72	.388			
	Total	28.110	74				
STEM Value of Competencies Total Mean	Between Groups	1.155	2	.577	4.315	.017	
	Within Groups	9.635	72	.134			
	Total	10.790	74				
STEM Difficulty Total Mean	Between Groups	2.200	2	1.100	2.303	.107	
	Within Groups	34.387	72	.478			
	Total	36.587	74				

Post Hoc Tests

Multiple Comparisons							
Tukey HSD							
Dependent Variable	(I) Age Group	(J) Age Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
STEM Value of Competencies Total Mean	25 to 34 YO	35-44 YO	.30151	.10458	.014	.0512	.5518
		45-54 YO	.31250	.16578	.150	-.0842	.7092
	35-44 YO	25 to 34 YO	-.30151	.10458	.014	-.5518	-.0512
		45-54 YO	.01099	.14728	.997	-.3415	.3634
		25 to 34 YO	-.31250	.16578	.150	-.7092	.0842
		35-44 YO	-.01099	.14728	.997	-.3634	.3415

Table 11: One-Way ANOVA test between variables age group and teachers' perceptions of STEM subsamples

Table 12 shows the differences in teachers' perceptions of STEM education based on education background. The researcher conducted One-way ANOVA test in order to examine educational background differences (science, math, engineering, technology, and other subjects) on the teachers' perceptions of STEM subsamples. Results revealed that teachers who had math background ($M=1.936$, $SD=0.646$) had the highest mean scores in the first domain indicating that they have a more general understanding of STEM education. On the other hand, teachers who had technology background scored the highest ($M= 1.500$, $SD= 0.377$) in the second domain indicating that they value STEM competencies the most. Teachers who had technology background scored the least in the third domain ($M=2.136$, $SD=1.097$); whereas teachers who had "other subjects" background scored the highest ($M= 2.800$, $SD= 0.774$). This indicated that teachers with technology background face the least difficulties in implementing STEM while teachers who had different background other than science, math, or technology faced the most difficulties in implementing STEM. Moreover, Table 12 revealed that there were no significant

differences between groups for the teacher understanding of STEM education ($F(3,71) = 1.989$, $p = .123$) and the teacher value of STEM competencies ($F(3,71) = 0.309$, $p = .818$). Yet, findings revealed that there were significant differences between the education background groups for the level of difficulties the teachers faced to implement STEM. The one-way ANOVA test showed that $F(3,71) = 3.048$, $p = .034 < .05$. In this case, the education background was not considered a significant contributor to the teacher understanding of STEM education nor an influencer of the teacher value of STEM competencies. Yet, it was a significant contributor to the level of difficulties the teachers faced when implementing STEM. To point out the subgroups among which there were significant differences in the teachers' perceptions towards STEM difficulties, the researcher conducted the Post Hoc analysis, Tukey HSD (Honestly Significant Difference) test. The results of Tukey test for teachers' perceptions of STEM difficulties and teachers' education background revealed that there were statistically significant differences between teachers who had science background and "other subjects" background. The mean scores of teachers with "other subjects" background ($M = 1.622$, $SD = 0.699$) were statistically significantly higher than the means scores of the teachers with science background ($M = 1.533$, $SD = 0.555$) indicating that the science teachers had the least level of difficulties in implementing STEM education among the total subgroups, and that the teachers' background is considered a significant contributor to the teachers' perceptions of STEM difficulties.

		Descriptive							
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minim um	Maximu m
STEM Understanding Total Mean	Science	35	1.5333	.55542	.09388	1.3425	1.7241	1.00	2.67
	Math	21	1.9365	.64652	.14108	1.6422	2.2308	1.00	2.67
	Technology	4	1.6667	.27217	.13608	1.2336	2.0997	1.33	2.00
	Others	15	1.6222	.69996	.18073	1.2346	2.0098	1.00	2.67
	Total	75	1.6711	.61633	.07117	1.5293	1.8129	1.00	2.67
STEM Value of Competencies Total Mean	Science	35	1.3510	.43184	.07299	1.2027	1.4994	1.00	2.71
	Math	21	1.3197	.22087	.04820	1.2192	1.4203	1.00	1.71
	Technology	4	1.5000	.37796	.18898	.8986	2.1014	1.14	2.00
	Others	15	1.4000	.45561	.11764	1.1477	1.6523	1.00	2.00
	Total	75	1.3600	.38186	.04409	1.2721	1.4479	1.00	2.71
STEM Difficulty Total Mean	Science	35	2.1870	.68562	.11589	1.9515	2.4225	1.18	3.45
	Math	21	2.3939	.47004	.10257	2.1800	2.6079	1.73	3.45
	Technology	4	2.1364	1.09720	.54860	.3905	3.8823	1.27	3.64
	Others	15	2.8000	.77460	.20000	2.3710	3.2290	1.82	4.09
	Total	75	2.3648	.70315	.08119	2.2031	2.5266	1.18	4.09

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
STEM	Between Groups	2.179	3	.726	1.989	.123
Understanding Total	Within Groups	25.930	71	.365		
Mean	Total	28.110	74			
STEM Value of	Between Groups	.139	3	.046	.309	.818
Competencies Total	Within Groups	10.651	71	.150		
Mean	Total	10.790	74			
STEM Difficulty	Between Groups	4.174	3	1.391	3.048	.034
Total Mean	Within Groups	32.413	71	.457		

Multiple Comparisons							
Tukey HSD							
Dependent Variable	(I) Education Background	(J) Education Background	Mean		Sig.	95% Confidence Interval	
			Difference (I-J)	Std. Error		Lower Bound	Upper Bound
STEM Difficulty Total Mean	Science	Math	-.20693	.18650	.685	-.6976	.2837
		Technology	.05065	.35661	.999	-.8876	.9889
		Others	-.61299	.20851	.022	-1.1616	-.0644
	Math	Science	.20693	.18650	.685	-.2837	.6976
		Technology	.25758	.36860	.897	-.7122	1.2273
		Others	-.40606	.22842	.293	-1.0070	.1949
	Technology	Science	-.05065	.35661	.999	-.9889	.8876
		Math	-.25758	.36860	.897	-1.2273	.7122
		Others	-.66364	.38022	.308	-1.6640	.3367
	Others	Science	.61299	.20851	.022	.0644	1.1616
		Math	.40606	.22842	.293	-.1949	1.0070
		Technology	.66364	.38022	.308	-.3367	1.6640

Table 12: One-Way ANOVA test between variables education background and teachers' perceptions of STEM subsamples

Table 13 shows the differences in teachers' perceptions of STEM education based on education level. The researcher conducted a T- test in order to examine educational background differences (Bachelor's and Master's groups) on the teachers' perceptions of STEM subsamples (no elementary teachers with doctoral degree completed the questionnaire). However, teachers with Bachelor's degree had the highest mean scores ($M= 1.181$, $SD= 0.664$) in the first and the second ($M= 1.414$, $SD= 0.286$) domains and the least score in the third domain ($M=2.175$, $SD= 2.490$) indicating that they had a more general understanding of STEM education, they valued STEM competencies the most, and compared to the teachers with Master's degree, they faced the least difficulties in implementing STEM. Moreover, results revealed that there were statistically significant differences between teachers with different educational levels towards their

perceptions of STEM difficulties with $t(72.86) = -2.080$ and p-value was less than the standard alpha level of 0.05 ($p = .041 < .05$) indicating that teachers with bachelor's degree faced less difficulties in implementing STEM compared to the teachers with master's degree. Yet, the educational level wasn't found to have significant effect on teachers' value of STEM competencies, nor on their general understanding of STEM. In this case, the educational background is considered a significant contributor to the teachers' perceptions of STEM difficulties. However, it was not a contributor to their value of STEM competencies nor to their general understanding of STEM.

T-Test- Group Statistics										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
STEM Understanding Total Mean	Equal variances assumed	1.590	.211	1.624	73	.109	.23333	.14369	-.05304	.51971
	Equal variances not assumed			1.575	55.611	.121	.23333	.14820	-.06358	.53025
STEM Value of Competencies Total Mean	Equal variances assumed	5.234	.025	1.005	73	.318	.09048	.09000	-.08889	.26984
	Equal variances not assumed			1.088	73.000	.280	.09048	.08313	-.07519	.25615
STEM Difficulty Total Mean	Equal variances assumed	13.955	.000	-1.937	73	.057	-.31515	.16274	-.63948	.00918
	Equal variances not assumed			-2.080	72.862	.041	-.31515	.15154	-.61718	-.01313

Table 13: Independent-samples t-test between variables educational level and teachers' perceptions of STEM subsamples

Table 14 shows the differences in teachers' perceptions of STEM education based on teaching experience. The researcher conducted One-way ANOVA test in order to examine teaching years of experience differences on the teachers' perceptions of STEM subsamples. Results revealed that teachers who had more than 10 years of experience scored the highest (M=

1.791, SD= 0.686) in the first domain indicating that they have a more general understanding of STEM education, whereas the teachers who had 6 to 10 years of experience scored the highest in the second (M= 1.535, SD= 0.586) and the third (M= 2.568, SD= 0.782) domains. This indicated that they value STEM competencies the most, but they faced the most difficulties in implementing STEM. Moreover, Table 14 revealed that there were no statistical significant differences among groups for the STEM general understanding ($F(2,72) = 1.773, p = .177$) and the level of STEM difficulty ($F(2,72) = 2.219, p = .116$) domains indicating that the years of experience variable is not considered a significant contributor to the elementary teachers STEM general understanding nor to the level of difficulty in implementing STEM in STEM schools in Abu Dhabi. Yet, it was a significant contributor to the value of STEM competencies ($F(2,72) = 3.910, p = .024 < 0.05$). To point out the subgroups among which there were significant differences in the teachers' perceptions towards the value of STEM competencies, the researcher conducted the Post Hoc analysis, Tukey HSD (Honestly Significant Difference) test. The results of Tukey test for teachers' value of STEM competencies and teachers' years of teaching revealed that there were statistically significant differences between teachers who had 6 to 10 years of experience and teachers who had more than 10 years of experience ($p = 0.024 < 0.05$). The mean scores of teachers with 6 to 10 years of experience (M= 1.535, SD= 0.586) were statistically significantly higher than the means scores of the teachers with more than 10 years of experience (M= 1.253, SD= 0.263) indicating that teachers with 6 to 10 years of experience value the most the STEM competencies among the total subgroups; therefore, the teachers' years of experience are considered a significant contributor to the teachers' value of STEM competencies.

Descriptive									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
STEM Understanding	1 to 5 years	19	1.4912	.40625	.09320	1.2954	1.6870	1.00	2.33
	6 to 10 years	16	1.5833	.60246	.15062	1.2623	1.9044	1.00	2.67
Total Mean	More than 10 years	40	1.7917	.68641	.10853	1.5721	2.0112	1.00	2.67
	Total	75	1.6711	.61633	.07117	1.5293	1.8129	1.00	2.67
STEM Value of Competencies	1 to 5 years	19	1.4361	.32112	.07367	1.2813	1.5909	1.00	2.00
	6 to 10 years	16	1.5357	.58670	.14668	1.2231	1.8483	1.00	2.71
Total Mean	More than 10 years	40	1.2536	.26379	.04171	1.1692	1.3379	1.00	2.00
	Total	75	1.3600	.38186	.04409	1.2721	1.4479	1.00	2.71
STEM Difficulty	1 to 5 years	19	2.0957	.39681	.09103	1.9044	2.2870	1.36	3.09
	6 to 10 years	16	2.5682	.78238	.19560	2.1513	2.9851	1.18	3.45
Total Mean	More than 10 years	40	2.4114	.75864	.11995	2.1687	2.6540	1.27	4.09
	Total	75	2.3648	.70315	.08119	2.2031	2.5266	1.18	4.09

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
STEM Understanding Total Mean	Between Groups	1.319	2	.660	1.773	.177
	Within Groups	26.790	72	.372		
	Total	28.110	74			
STEM Value of Competencies Total Mean	Between Groups	1.057	2	.529	3.910	.024
	Within Groups	9.733	72	.135		
	Total	10.790	74			
STEM Difficulty Total Mean	Between Groups	2.124	2	1.062	2.219	.116
	Within Groups	34.462	72	.479		
	Total	36.587	74			

Multiple Comparisons							
Tukey HSD							
Dependent Variable	(I) Teaching Experience	(J) Teaching Experience	Mean Difference (I-J)		Sig.	95% Confidence Interval	
				Std. Error		Lower Bound	Upper Bound
STEM Value of Competencies Total Mean	1 to 5 years	6 to 10 years	-.09962	.12475	.705	-.3982	.1989
		More than 10 years	.18252	.10244	.183	-.0626	.4277
	6 to 10 years	1 to 5 years	.09962	.12475	.705	-.1989	.3982
		More than 10 years	.28214	.10876	.030	.0219	.5424
	More than 10 years	1 to 5 years	-.18252	.10244	.183	-.4277	.0626
		6 to 10 years	-.28214	.10876	.030	-.5424	-.0219

Table 14: One-Way ANOVA test between variables teachers' years of experience and teachers' perceptions of STEM subsamples

Table 15 shows the differences in teachers' perceptions of STEM education based on teaching experience in STEM. The researcher conducted One-way ANOVA test in order to examine teaching years of experience in STEM differences on the teachers' perceptions of STEM subsamples. Results revealed that teachers who had 1 year of experience in STEM scored the highest ($M = 1.939$, $SD = 0.814$) in the first domain indicating that they have a more general understanding of STEM education. Teachers who had 2 years of experience in STEM scored the highest ($M = 1.571$, $SD = 0.590$) in the second domain indicating that they value STEM competencies the most. Teachers who had more than 3 years of experience in STEM scored the highest ($M = 2.909$, $SD = 0.630$) in the third domain indicating that they faced the most difficulties in implementing STEM. Moreover, Table 15 revealed that there were no significant differences among groups for the teacher understanding of STEM education ($F(3, 71) = 2.372$, $p = .078$) and the teacher value of STEM competencies ($F(3, 71) = 2.000$, $p = .122$). Yet, findings revealed that there were significant differences between the years of experience in STEM subgroups for the level of difficulties the teachers face to implement STEM. The one-way ANOVA test showed that $F(3, 71) = 17.736$, $p < .001 < .05$. In this case, the years of experience in STEM education was not considered a significant contributor to the teacher understanding of STEM education nor an influencer of the teacher's value of STEM competencies. Yet, it was a significant contributor to the level of difficulties the teachers face when implementing STEM. However, F statistics do not point out the years of experience in STEM subgroups within which there were significant differences in the teachers' perceptions of level of difficulty in implementing STEM. To point out the subgroups among which there were significant differences in the teachers' perceptions towards the STEM implementation level of difficulty, the researcher conducted the Post Hoc analysis, Tukey HSD (Honestly Significant Difference) test. The results of Tukey test for teachers' perceptions of STEM difficulty level of implementation and years of experience in STEM education revealed that there were statistically significant differences between teachers who had more than 3 years of experience and the teachers who had 1 ($p < .001$), 2 ($p = .002$), and 3 ($p < .001$) years of experience regarding their perceptions towards the level of difficulty in implementing STEM (Table 15). Accordingly, the researcher concluded that teachers with more than 3 years of experience in STEM faced the most difficulties in implementing STEM compared

to the other subgroups; therefore, years of experience in STEM is considered a significant contributor to the teachers' perceptions of difficulty level of STEM implementation.

Descriptive									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
STEM Understanding Total Mean	1 year	22	1.9394	.81414	.17357	1.5784	2.3004	1.00	2.67
	2 years	12	1.6944	.45965	.13269	1.4024	1.9865	1.00	2.33
	3 years	10	1.4667	.32203	.10184	1.2363	1.6970	1.00	2.00
	More than 3 years	31	1.5376	.52829	.09488	1.3439	1.7314	1.00	2.67
	Total	75	1.6711	.61633	.07117	1.5293	1.8129	1.00	2.67
STEM Value of Competencies Total Mean	1 year	22	1.2468	.27242	.05808	1.1260	1.3675	1.00	2.00
	2 years	12	1.5714	.59059	.17049	1.1962	1.9467	1.00	2.71
	3 years	10	1.4000	.29966	.09476	1.1856	1.6144	1.00	2.00
	More than 3 years	31	1.3456	.35336	.06347	1.2160	1.4752	1.00	2.00
	Total	75	1.3600	.38186	.04409	1.2721	1.4479	1.00	2.71
STEM Difficulty Total Mean	1 year	22	1.9835	.33152	.07068	1.8365	2.1305	1.36	2.27
	2 years	12	2.0076	.46912	.13542	1.7095	2.3056	1.18	2.73
	3 years	10	1.9455	.68862	.21776	1.4528	2.4381	1.27	3.27
	More than 3 years	31	2.9091	.63027	.11320	2.6779	3.1403	1.73	4.09
	Total	75	2.3648	.70315	.08119	2.2031	2.5266	1.18	4.09

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
STEM Understanding Total Mean	Between Groups	2.560	3	.853	2.372	.078
	Within Groups	25.549	71	.360		
	Total	28.110	74			
STEM Value of Competencies Total Mean	Between Groups	.841	3	.280	2.000	.122
	Within Groups	9.949	71	.140		
	Total	10.790	74			
STEM Difficulty Total Mean	Between Groups	15.673	3	5.224	17.736	.000
	Within Groups	20.914	71	.295		
	Total	36.587	74			

Post Hoc Tests							
Multiple Comparisons							
Tukey HSD							
Dependent Variable	(I) Teaching Experience in STEM	(J) Teaching Experience in STEM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
STEM Difficulty Total Mean	1 year	2 years	-.02410	.19477	.999	-.5365	.4883
		3 years	.03802	.20699	.998	-.5066	.5826
		More than 3 years	-.92562	.15130	.000	-1.3237	-.5276
	2 years	1 year	.02410	.19477	.999	-.4883	.5365
		3 years	.06212	.23239	.993	-.5493	.6735
		More than 3 years	-.90152	.18452	.000	-1.3870	-.4160
	3 years	1 year	-.03802	.20699	.998	-.5826	.5066
		2 years	-.06212	.23239	.993	-.6735	.5493
		More than 3 years	-.96364	.19738	.000	-1.4829	-.4443
	More than 3 years	1 year	.92562	.15130	.000	.5276	1.3237
		2 years	.90152	.18452	.000	.4160	1.3870
		3 years	.96364	.19738	.000	.4443	1.4829

Table 15: One-Way ANOVA test between variables teachers' years of experience in STEM and teachers' perceptions of STEM subsamples

Table 16 shows the differences in teachers' perceptions of STEM education based on teaching instructional level. In order to examine the differences among the elementary teachers teaching at different instructional level (Grade 1, 2, 3, 4, 5, or all) towards their perceptions of STEM domains, the researcher conducted a one-way ANOVA test. Findings revealed that teachers who teach grade 2 had the highest means score in the first domain ($M= 2.410$, $SD= 0.454$) indicating that they have a more general understanding of STEM education, whereas teachers who teach grade 1 scored the highest in the second domain ($M= 1.628$, $SD= 0.547$) indicating that they value STEM competencies the most. Also, teachers who teach grade 2 scored the highest ($M= 2.800$, $SD= 0.922$) in the third domain indicating that grade 2 teachers face the most difficulties in implementing STEM. Moreover, Table 16 revealed that there were no statistical significant differences between groups for the teacher difficulties in implementing STEM ($F(5,69)= 1.356$, $p=.252 >0.05$). Yet, findings revealed that there were statistical significant differences among the instructional levels' subgroups for the teacher understanding of STEM education ($F(5,69)= 7.092$, $p<.001 <0.05$) and the teacher value of STEM competencies ($F(5,69)= 2.356$, $p=.049 <0.05$). To point out the subgroups among which there were significant differences in the teachers' perceptions towards the value of STEM competencies and the general understanding of STEM education, the researcher conducted the Post Hoc analysis, Tukey HSD (Honestly Significant Difference) test. The results of Tukey test revealed that there were statistically significant differences between teachers who teach grade 1 and grade 3 regarding their value of STEM competencies ($p= 0.031 <0.05$) and teachers who teach second graders with teachers who teach grade 1 ($p= 0.001 <0.05$), grade 3 ($p <0.001 <0.05$), grade 4 ($p < 0.001 <0.05$), grade 5 ($p= 0.001 <0.05$), and all grade levels ($p= 0.007 <0.05$) regarding their general understanding of STEM education. Accordingly, the researcher concluded that elementary teachers who teach grade 1 value STEM competencies more than the teachers who teach grade 3, and grade 2 teachers have a better understanding of STEM education compared to other teachers. Therefore, the instructional level is considered a significant contributor to the teachers' value of STEM competencies and to the general understanding of STEM education.

Descriptive									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
STEM Understanding	grade 1	10	1.4667	.47661	.15072	1.1257	1.8076	1.00	2.33
	grade 2	13	2.4103	.45448	.12605	2.1356	2.6849	1.33	2.67
Total Mean	grade 3	8	1.2500	.58418	.20654	.7616	1.7384	1.00	2.67
	grade 4	17	1.5098	.51529	.12498	1.2449	1.7747	1.00	2.33
	grade 5	20	1.6500	.57710	.12904	1.3799	1.9201	1.00	2.67
	grade 1 to grade 5	7	1.5238	.42414	.16031	1.1315	1.9161	1.00	2.00
	Total	75	1.6711	.61633	.07117	1.5293	1.8129	1.00	2.67
STEM Value of Competencies	grade 1	10	1.6286	.54793	.17327	1.2366	2.0205	1.00	2.71
	grade 2	13	1.4725	.24317	.06744	1.3256	1.6195	1.00	2.00
Total Mean	grade 3	8	1.0893	.16968	.05999	.9474	1.2311	1.00	1.43
	grade 4	17	1.2941	.28334	.06872	1.1484	1.4398	1.00	1.71
	grade 5	20	1.3286	.43504	.09728	1.1250	1.5322	1.00	2.71
	grade 1 to grade 5	7	1.3265	.34714	.13121	1.0055	1.6476	1.00	2.00
	Total	75	1.3600	.38186	.04409	1.2721	1.4479	1.00	2.71
STEM Difficulty	grade 1	10	2.8000	.92293	.29185	2.1398	3.4602	1.18	4.09
	grade 2	13	2.2937	.28545	.07917	2.1212	2.4662	1.73	3.09
Total Mean	grade 3	8	2.6023	.76976	.27215	1.9587	3.2458	1.82	3.45
	grade 4	17	2.1658	.68577	.16632	1.8132	2.5184	1.36	3.36
	grade 5	20	2.3182	.63636	.14230	2.0204	2.6160	1.18	3.45
	grade 1 to grade 5	7	2.2208	.94016	.35535	1.3513	3.0903	1.27	3.64
	Total	75	2.3648	.70315	.08119	2.2031	2.5266	1.18	4.09
ANOVA									
		Sum of Squares		df	Mean Square		F	Sig.	
STEM Understanding	Between Groups	9.542		5	1.908		7.092	.000	
Total Mean	Within Groups	18.567		69	.269				
	Total	28.110		74					
STEM Value of Competencies	Between Groups	1.574		5	.315		2.356	.049	
Total Mean	Within Groups	9.217		69	.134				
	Total	10.790		74					
STEM Difficulty	Between Groups	3.273		5	.655		1.356	.252	
Total Mean	Within Groups	33.314		69	.483				
	Total	36.587		74					

Post Hoc Tests							
Multiple Comparisons							
Tukey HSD							
Dependent Variable	(I) Instructional Grade Level	(J) Instructional Grade Level	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
STEM Understanding Total Mean	grade 1	grade 2	-.94359	.21819	.001	-1.5832	-.3040
		grade 3	.21667	.24606	.950	-.5046	.9380
		grade 4	-.04314	.20673	1.000	-.6491	.5629
		grade 5	-.18333	.20091	.942	-.7723	.4056
		grade 1 to grade 5	-.05714	.25564	1.000	-.8065	.6922
	grade 2	grade 1	.94359	.21819	.001	.3040	1.5832
		grade 3	1.16026	.23310	.000	.4770	1.8436
		grade 4	.90045	.19112	.000	.3402	1.4607
		grade 5	.76026	.18481	.001	.2185	1.3020
		grade 1 to grade 5	.88645	.24319	.007	.1736	1.5993
STEM Value of Competencies Total Mean	grade 1	grade 2	.15604	.15373	.911	-.2946	.6067
		grade 3	.53929	.17336	.031	.0311	1.0475
		grade 4	.33445	.14565	.210	-.0925	.7614
		grade 5	.30000	.14155	.290	-.1149	.7149
		grade 1 to grade 5	.30204	.18011	.551	-.2259	.8300

Table 16: One-way ANOVA findings of teachers' instructional level and STEM domains

Table 17 shows the differences in teachers' perceptions of STEM education based on teaching subject. The researcher conducted One-way ANOVA test in order to examine differences on the teachers' perceptions of STEM subsamples based on teaching subject (science, math, ICT, all). Findings of the one-way ANOVA test in Table 17 revealed that teachers who teach all subjects or homeroom teachers scored the highest ($M=1.666$, $SD=0.272$) in the first domain and the third domain ($M=1.678$, $SD=0.375$) indicating that they have a more general understanding of STEM education and that they face the most difficulties in implementing STEM, whereas ICT teachers scored the highest ($M= 1.863$, $SD= 0.946$) in the second domain indicating that they value STEM competencies the most. Moreover, results revealed that there were no statistically significant differences between teachers teaching different subjects towards their perceptions of the STEM general understanding ($F(3,71)= 1.601$, $p= 0.197$) and the value of STEM competencies ($F(3,71)= 1.028$, $p= 0.386$) domains. Yet, there was a statistically significant difference among teachers teaching different subjects towards their perceptions of the STEM difficulty domain ($F(3,71)= 6.899$, $p< 0.001 <0.05$). The results of Tukey test revealed that there were statistically significant differences between teachers who teach science subject and teachers who teach all subjects ($p< 0.001 <0.05$) indicating that homeroom teachers face a higher level of difficulties in implementing STEM than science teachers do. Accordingly, the

teaching subject is considered a significant contributor to the teachers' perceptions of STEM difficulties.

Descriptive									
					95% Confidence Interval for Mean				
			N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum Maximum
STEM Understanding	science	21	1.4286	.55919	.12203	1.1740	1.6831	1.00	2.67
	math	11	1.6970	.60470	.18232	1.2907	2.1032	1.00	2.67
Total Mean	ICT	6	1.7778	.27217	.11111	1.4922	2.0634	1.33	2.00
	All	37	1.7838	.66767	.10976	1.5612	2.0064	1.00	2.67
	Total	75	1.6711	.61633	.07117	1.5293	1.8129	1.00	2.67
STEM Value of	science	21	1.3673	.51621	.11265	1.1324	1.6023	1.00	2.71
	math	11	1.4286	.30639	.09238	1.2227	1.6344	1.00	2.00
Competencies Total Mean	ICT	6	1.5714	.36140	.14754	1.1922	1.9507	1.14	2.00
	All	37	1.3012	.30821	.05067	1.1984	1.4039	1.00	2.00
	Total	75	1.3600	.38186	.04409	1.2721	1.4479	1.00	2.71
STEM Difficulty	science	21	1.9351	.59484	.12981	1.6643	2.2058	1.18	3.27
	math	11	2.1736	.17465	.05266	2.0562	2.2909	1.82	2.36
Total Mean	ICT	6	2.2273	1.02005	.41643	1.1568	3.2977	1.27	3.64
	All	37	2.6880	.66132	.10872	2.4675	2.9085	1.73	4.09
	Total	75	2.3648	.70315	.08119	2.2031	2.5266	1.18	4.09

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
STEM Understanding Total Mean	Between Groups	1.781	3	.594	1.601	.197
	Within Groups	26.329	71	.371		
	Total	28.110	74			
STEM Value of Competencies Total Mean	Between Groups	.449	3	.150	1.028	.386
	Within Groups	10.341	71	.146		
	Total	10.790	74			
STEM Difficulty Total Mean	Between Groups	8.258	3	2.753	6.899	.000
	Within Groups	28.329	71	.399		
	Total	36.587	74			

Post Hoc Tests							
Multiple Comparisons							
Tukey HSD							
Dependent Variable	(I) Teaching Subject	(J) Teaching Subject	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
STEM Difficulty Total Mean	science	math	-.23849	.23510	.742	-.8570	.3800
		ICT	-.29221	.29240	.750	-1.0615	.4771
		All	-.75290	.17258	.000	-1.2069	-.2989
	math	science	.23849	.23510	.742	-.3800	.8570
		ICT	-.05372	.32058	.998	-.8971	.7897
		All	-.51441	.21692	.092	-1.0851	.0563
	ICT	science	.29221	.29240	.750	-.4771	1.0615
		math	.05372	.32058	.998	-.7897	.8971
		All	-.46069	.27800	.354	-1.1921	.2707
	All	science	.75290	.17258	.000	.2989	1.2069
		math	.51441	.21692	.092	-.0563	1.0851
		ICT	.46069	.27800	.354	-.2707	1.1921

Table 17: One-way ANOVA findings of teaching subjects and STEM domains

Table 18 shows the differences in teachers' perceptions of STEM education based on school curriculum. Only teachers teaching in American and British schools completed the teacher questionnaire. The researcher conducted a T-Test in order to examine differences on the teachers' perceptions of STEM subsamples based on school curriculum. Findings in Table 18 revealed that teachers who teach in American schools scored the highest in the first domain ($M = 1.763$, $SD = 0.653$), the second domain ($M = 1.407$, $SD = 0.410$), and in the third domain ($M = 2.383$, $SD = 0.685$) indicating that they have a more general understanding of STEM education and they value the most the STEM competencies. Yet, they face more difficulties in implementing STEM compared to teachers who teach in British schools. Moreover, results revealed that there were statistically significant differences among teachers who teach different curricula towards their perceptions of STEM understanding with $t(73) = 2.212$ and p -value was less than the standard alpha level of 0.05 ($p = .03 < .05$) indicating that teachers in American schools have a better general understanding of STEM education than teachers teaching in British schools. Yet, the school curriculum wasn't found to have significant effect on teachers' value of STEM competencies nor on the level of difficulties in implementing STEM (Levene's Test for equality of variance confirms that means scores between the two groups were not statistically significant with $p_2 = .151$ and $p_3 = 0.415$). In this case, the school curriculum is considered a significant contributor to the teachers' general understanding of STEM Education. However, it was not a

contributor to their value of STEM competencies nor to their level of difficulties in implementing STEM.

T-Test - Group Statistics										
		School Curriculum		N	Mean	Std. Deviation	Std. Error			
							Mean			
STEM Understanding Total Mean		American		55	1.7636	.65317	.08807			
		British		20	1.4167	.41711	.09327			
STEM Value of Competencies Total Mean		American		55	1.4078	.41094	.05541			
		British		20	1.2286	.25131	.05620			
STEM Difficulty Total Mean		American		55	2.3835	.68583	.09248			
		British		20	2.3136	.76486	.17103			

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
STEM Understanding Total Mean	Equal variances assumed	9.156	.003	2.212	73	.030	.34697	.15686	.03435	.65959
	Equal variances not assumed			2.705	53.129	.009	.34697	.12828	.08969	.60425
STEM Value of Competencies Total Mean	Equal variances assumed	2.102	.151	1.826	73	.072	.17922	.09817	-.01644	.37488
	Equal variances not assumed			2.271	55.461	.027	.17922	.07892	.02109	.33735
STEM Difficulty Total Mean	Equal variances assumed	.672	.415	.378	73	.706	.06983	.18468	-.29822	.43789
	Equal variances not assumed			.359	30.808	.722	.06983	.19443	-.32681	.46648

Table 18: Independent-samples t-test between variables school curriculum and teachers' perceptions of STEM subsamples

Table 19 shows the differences in teachers' perceptions of STEM education based on frequency of implementing STEM. The researcher conducted One-way ANOVA test in order to examine differences on the teachers' perceptions of STEM subsamples based on frequency of implementing STEM. Findings of the one-way ANOVA test in Table 19 revealed that teachers

who implement STEM once per term scored the highest in the first domain ($M= 2.222$, $SD= 0.192$) and in the second domain ($M= 2.238$, $SD= 0.824$) indicating that they have a more general understanding of STEM education and that they value STEM competencies the most. Teachers who implement STEM in every lesson scored the highest in the third domain ($M= 2.760$, $SD= 0.726$) indicating that they face most difficulties in implementing STEM. Moreover, results revealed that there was no statistically significant difference among teachers teaching STEM with different frequencies towards their general understanding of STEM education ($F(5,69)= 0.874$, $p=0.503 >0.05$). Yet, there were statistically significant differences among teachers teaching STEM with different frequencies towards their value of STEM competencies ($F(5,69)= 4.885$, $p=0.001 <0.05$) domains and their perceptions of the STEM difficulty level domain ($F(5,69)= 5.787$, $p<0.001 <0.05$). The results of Tukey test revealed that there were statistically significant differences among teachers who teach STEM once per term and teachers who teach STEM in different frequencies regarding their value of STEM competencies. Similarly, there were statistically significant differences between teachers who teach STEM in every lesson and teachers who teach STEM in different frequencies regarding their perceptions of the level of STEM difficulties. Accordingly, the frequency of implementing STEM is considered a significant contributor to the teachers' perceptions of STEM difficulties and to the teachers' value of STEM competencies.

Descriptive									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
STEM Understanding	1 lesson per month	8	1.5000	.39841	.14086	1.1669	1.8331	1.00	2.00
Total Mean	2 lessons per month	16	1.5625	.62915	.15729	1.2272	1.8978	1.00	2.67
	3 lessons per month	19	1.7895	.76344	.17515	1.4215	2.1574	1.00	2.67
	every lesson	25	1.6267	.57187	.11437	1.3906	1.8627	1.00	2.67
	once per term	3	2.2222	.19245	.11111	1.7441	2.7003	2.00	2.33
	Total	75	1.6711	.61633	.07117	1.5293	1.8129	1.00	2.67
STEM Value of Competencies	1 lesson per month	8	1.3393	.28508	.10079	1.1010	1.5776	1.00	1.71
Total Mean	2 lessons per month	16	1.1964	.30806	.07701	1.0323	1.3606	1.00	2.00
	3 lessons per month	19	1.3985	.30706	.07044	1.2505	1.5465	1.00	2.00
	every lesson	25	1.3257	.33125	.06625	1.1890	1.4624	1.00	2.00
	once per term	3	2.2381	.82479	.47619	.1892	4.2870	1.29	2.71
	Total	75	1.3600	.38186	.04409	1.2721	1.4479	1.00	2.71
STEM Difficulty	1 lesson per month	8	2.1591	.19888	.07031	1.9928	2.3254	1.82	2.36
Total Mean	2 lessons per month	16	1.9830	.58373	.14593	1.6719	2.2940	1.36	3.27
	3 lessons per month	19	2.3254	.60021	.13770	2.0361	2.6147	1.27	4.00
	every lesson	25	2.7600	.72627	.14525	2.4602	3.0598	1.36	4.09
	once per term	3	1.3030	.20995	.12121	.7815	1.8246	1.18	1.55
	Total	75	2.3648	.70315	.08119	2.2031	2.5266	1.18	4.09

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
STEM Understanding Total Mean	Between Groups	1.675	5	.335	.874	.503
	Within Groups	26.435	69	.383		
	Total	28.110	74			
STEM Value of Competencies Total Mean	Between Groups	2.821	5	.564	4.885	.001
	Within Groups	7.969	69	.115		
	Total	10.790	74			
STEM Difficulty Total Mean	Between Groups	10.810	5	2.162	5.787	.000
	Within Groups	25.777	69	.374		
	Total	36.587	74			

Post Hoc Tests							
Multiple Comparisons							
Tukey HSD							
Dependent Variable	(I) Frequency of Use of STEM	(J) Frequency of Use of STEM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
STEM Value of Competencies Total Mean	once per term	1 lesson per month	.89881	.23008	.003	.2244	1.5732
		2 lessons per month	1.04167	.21382	.000	.4149	1.6684
		3 lessons per month	.83960	.21113	.002	.2207	1.4585
		every lesson	.91238	.20765	.001	.3037	1.5211
	every lesson	1 lesson per month	.60091	.24827	.164	-.1269	1.3287
STEM Difficulty Total Mean	once per term	2 lessons per month	.77705	.19568	.002	.2034	1.3507
		3 lessons per month	.43464	.18602	.194	-.1107	.9799
		once per term	1.45697	.37346	.003	.3623	2.5517
		1 lesson per month	-.85606	.41379	.316	-2.0690	.3569
	every lesson	2 lessons per month	-.67992	.38454	.493	-1.8071	.4473
		3 lessons per month	-1.02233	.37972	.090	-2.1354	.0908
		every lesson	-1.45697	.37346	.003	-2.5517	-.3623
		1 lesson per month	-.85606	.41379	.316	-2.0690	.3569
		2 lessons per month	-.67992	.38454	.493	-1.8071	.4473

Table 19: One-way ANOVA findings of frequency of implementing STEM and STEM domains

To explore more about the overall teachers' perceptions of STEM education, the researcher looked at how the different domains of the questionnaire correlate with each other and with the overall perceptions of participants by conducting a Pearson Correlation Coefficient test (Table 20). Findings revealed there were significant, strong, and positive correlations among the teachers' overall perceptions of STEM education and all the three STEM domains. Corresponding correlations .668, .579, and .593 were all highly significant at the .01 level. Consequently, the findings proved that the three STEM domains mentioned and explored in this study are actual components of STEM perceptions. The strongest positive correlation was found between the overall perceptions of STEM and STEM Understanding domain ($r=.668, p<0.001$). A positive and moderate correlation was found between STEM value of competencies and STEM understanding ($r=.414, p<0.001$) indicating that combination of these two factors is significant for the teachers' overall perceptions of STEM education. The correlations between STEM difficulty and STEM value of competencies/STEM understanding were found negative indicating an inverse relationship between items, yet they were weak and non-significant.

Correlations					
		STEM Understanding	STEM Value of Competencies	STEM Difficulty	Overall Perception of STEM
STEM Understanding	Pearson Correlation	1			
STEM Value of Competencies	Pearson Correlation	.414**	1		
STEM Difficulty	Pearson Correlation	-.104	-.042	1	
Overall Perception of STEM	Pearson Correlation	.668**	.579**	.593**	1

** Correlation is significant at the 0.01 level (2-tailed)

*p<0.05; **p<0.01; ***p<0.001

Table 20: Results of Pearson correlation coefficient test

The Beta weights in Table 21 indicate that the STEM understanding domain explains 58.7% the variance in teachers' overall perceptions of STEM education, whereas the value of STEM competencies and STEM difficulty account for 36.4% and 67% respectively. All these values are highly significant at $p < 0.001$. Consequently, the STEM difficulty domain appeared to be of the greatest contributor to STEM perception, and any change at its level will largely impact the overall teachers' perceptions of STEM education, followed by STEM understanding. Furthermore, the data were tested for potential violations of multicollinearity assumption by examining tolerance and variance inflation factor (VIF) values. In this study, the tolerance values ranged from .829 and .989, whereas the VIFs ranged from 1.011 and 1.218 indicating that the multicollinearity assumption was not violated (Collinearity tolerance values $> .10$ and VIF < 10.00).

Model		Standardized Coefficients	Sig.	Collinearity Statistics	
		Beta		Tolerance	VIF
1	(Constant)		1.000		
	STEM Understanding	.587	.000	.821	1.218
	STEM Value of Competencies	.364	.000	.828	1.207
	STEM Difficulty	.670	.000	.989	1.011

Table 21: Test of multicollinearity: Tolerance and variance inflation factors

Summary of Quantitative Findings

The descriptive statistics and the inferential statistics conducted via the t-test and one-way ANOVA tests on the quantitative data related to teachers' demographics and their perceptions of the three STEM domains revealed several findings and drew conclusions regarding the elementary teachers who teach in STEM private schools in Abu Dhabi; therefore, they answered the second and the third questions of the study related to their perceptions of STEM education. In a nutshell, results identified that 75% of the elementary teachers in STEM private schools in Abu Dhabi strongly understand what STEM education is and they strongly agree that STEM competencies are extremely important. Yet, 50% of the teachers agree that they find difficulties in implementing STEM education. On the other side, findings revealed that (1) there were statistically significant relationships among the independent demographical variables gender, instructional level, with the school curriculum and the first domain of STEM perception which was the teachers' general understanding of STEM education; (2) there were statistically significant relationships among the independent demographical variables age group, instructional level, teaching experience, and frequency of implementing STEM and the second domain of STEM perception which was the teachers' value of STEM competencies; (3) there were statistically significant relationships between the independent demographical variables educational background, educational level, instructional subject, teaching experience in STEM, and the frequency of implementing STEM on the third domain of STEM perception which was STEM difficulty level. Additionally, Table 22 summarized results disclosed by mean scores in descriptive analyses and which revealed several conclusions related to the differences in teachers' perceptions regarding the three STEM education domains based on their different demographical variables.

Teachers' Demographical Variables	Teachers' Perceptions of STEM Domains		
	Better Understanding of STEM Education	More Value for STEM Competencies	More Difficulties in Implementing STEM Education
Gender	Female	Female	Male
Age Group	Between 35 and 44 years old	Between 25 and 34 years old	Between 45 and 55 years old
Educational Background	Math	Technology	Others
Educational Level	Bachelor's Degree	Bachelor's Degree	Master's Degree
Teaching Experience	More than 10 years of teaching experience	6 to 10 years of teaching experience	6 to 10 years of teaching experience
Teaching Experience in STEM	Teachers with 1 year of experience in STEM	2 years of experience in STEM	More than 3 years of experience in STEM
Teaching Instructional Level	Grade 2 level	Grade 1 level	Grade 2 level
Teaching Subject	All Subjects	ICT	All Subjects
School Curriculum	American Curriculum	American Curriculum	American Curriculum
Frequency of Implementing STEM	Once per term	Once per term	Every Lesson

Table 22: Differences in teachers' perceptions regarding the STEM education domains based on their demographical variables

4.2.1.4 Teachers' Perceptions of STEM Education: Qualitative Findings

This section presents the elementary teachers' responses gathered from a set of five structured, open-ended qualitative questions included at the end of the distributed questionnaire. The five open-ended questions allowed the researcher to investigate the perceptions of STEM elementary teachers by qualitatively analyzing their understanding of STEM education, the difficulties they face when implementing STEM education, and the extent of support they receive to implement STEM in an effective way. Hence, the researcher aimed to investigate the frequency of STEM teachers' meetings to collaborate and discuss STEM activities. Furthermore, the last question highlighted the students' preparation and participation in STEM competition in the UAE to highlight STEM ways of celebration and to evaluate the extent of the importance delegated to STEM on a national level in STEM schools in Abu Dhabi. The teachers were

required to respond and to reflect on their perceptions of STEM education by typing their answers using their own words in a comment box. The section of the five open-ended questions included the following:

- 1) How do you define STEM education?
- 2) What challenges do you face when you implement STEM education in your classroom?
- 3) Do you collaborate with other teachers to discuss STEM lessons? And, how often?
- 4) Did you receive professional development to support you in STEM education in your school? And, how often?
- 5) How often did your students participate in STEM competitions? And, what types of competitions do your students participate in?

In this section, the qualitative analysis of the open-ended questions was achieved by utilizing Krathwohl (2009) three main stages to help the researcher attaining a wider comprehensive understanding of the STEM teachers' perceptions and to reveal any possible overlooked aspects related to STEM education in private elementary schools in Abu Dhabi. Moreover, the analysis of the qualitative data was utilized to corroborate the findings of the quantitative data. The Krathwohl (2009)'s three main stages consisted of (1) familiarization and organization of the participants' answers, (2) coding and recoding of the findings, and (3) summarization and interpretation of the findings. Table 23 outlines the teachers' answers on each open-ended question.

The Question	The Findings
How do you define STEM education?	In addition to their knowledge and experience in STEM, to the introductory paragraph which defined STEM education at the beginning of the teacher questionnaire, and to the quantitative questions related to the general understanding and value of STEM, most of the participants were able to give clear definitions of STEM as the following, while the other teachers gave shallow definitions or skipped the question. 1. An innovative teaching method that integrates knowledge from different disciplines to enhance students' problem-solving skills. 2. When teaching students via hands-on activities by integrating knowledge from different disciplines: science, math, engineering, and technology

-
3. A multidisciplinary approach to applying science, technology, engineering, and mathematics to tackle current challenges and solve real-life problems
 4. STEM is the key to innovation. It is a set of inter-related disciplines that develop students' critical thinking and motivate them to learn and solve real-life problems.
 5. STEM is an integrative way to teach Science, Technology, Engineering, and Mathematics to help students gain the skills required to succeed in today's challenging world.
 6. STEM is a creative, collaborative, and integrative teaching method that integrates science, math, technology, and engineering. STEM is driven by problem-solving, discovery, and exploratory learning that requires students to actively engage in a situation in order to find its solution.
 7. Unlike traditional education experiences in which subject areas are concentrated on separately, STEM education emphasizes technology and integrates subjects in ways that connect disciplines and relate them to each other.
 8. STEM Education, at its core, simply means educating students in four specific disciplines, namely, Science, Technology, Engineering, and Mathematics
 9. It is the future curriculum that every school has to apply.
 10. Education that involves scientific inquiry and engineering practices. Driven with Science or Math standards.
 11. Teaching science, tech, engineering and mathematics through hands on and real-world practices in such a way that will prepare students for careers in these fields.
 12. 21st century skills need
 13. To me STEM is an integrated approach of using all 4 components in curricular and non-curricular areas. It involves not just skills, knowledge but also an inquiry mindset, and developing collaboration and perseverance, because these soft skills also go a long way in ensuring success in any project.
 14. STEAM Education is a 21st century skills that is based on important components such as collaboration, creativity, critical Thinking and Communication vital for student success in a changing society.
 15. It's a unique approach to teaching and learning. Very useful and engaging
 16. It's an integrated approach to teach students science, math, and technology. It requires problem- solving skills. It prepares students to STEM careers and it is generally implemented via PBL
 17. STEM education is the intentional integration of science, technology, engineering, and mathematics, and their associated

	practices to create a student-centered learning environment in which students investigate and engineer solutions to problems, and construct evidence-based explanations of real-world phenomena with a focus on a student's social, emotional, physical, and academic needs through shared contributions of schools, families, and community partners.
What challenges do you face when you implement STEM education in your classroom?	Most of the elementary teachers in STEM schools in Abu Dhabi agreed on the following challenges when implementing STEM activities in their classes. 1. Shortage in resources 2. Shortage in innovative ideas for STEM activities 3. Constraint of time 4. Lack of administrative support 5. Need of training 6. Need of more PD on how to implement STEM efficiently. 7. Busy schedule 8. Lack of pedagogical knowledge 9. As it is a teaching method that is driven by problem-solving, discovery, and exploratory learning, and because it requires students to actively engage in a situation in order to find its solution, STEM is challenging to be implemented at elementary levels. 10. Need for more collaboration between colleagues 11. The lack of quality and flexible curriculum, quality assessment tools, and planning time are the challenges I face in STEM implementation. 12. Integrating STEM curriculum into the existing curriculum is challenging as grade-level standards are not flexible and this prevents a smooth integration of STEM. 13. To be integrated correctly, STEM requires long instructional periods. Therefore, it comes at the expense of other subject matter 14. There are no clear-cut guidelines for educators to follow in the curriculum to integrate STEM in a correct way 15. In elementary levels, the teachers struggle with a huge workload, which does not give them much time or energy to plan interactive STEM lessons plus resources are very limited and there is no enough support from administration 16. Not enough time, lots of curriculum preparation, lots of material preparation, no coherence with national curriculum 17. Lack of experience and external support. 18. Adapting the STEM activities to the curriculum within a limited time frame.

19. That you need another teacher in class to be able to implement the activities so you are able to give effective feedback for students while working on their projects.
20. Material management and organization
21. Communicating material with teachers
22. Planning/finding the activity that is aligned with our curriculum
23. Implementation of STEM activities within the restricted time.
I certainly think all teachers would benefit from more professional development around STEM integration in the classroom.
24. Engaging students who are not interested in this domain
25. Mainly the constraint of time, especially when the scope and sequence of the curriculum defines the start and end dates of units. We are trying to move away from this into more organically integrated units.
26. Collaborative planning and adjusting the schedule in order to accommodate this new way of teaching
27. Resources and activities that connect with curricular objectives
28. Innovative teaching, going digital, Student boredom is a huge challenge faced by most teachers
29. Insufficient time for students to conduct STEM lessons
30. Not many. I have some experience.
31. NA
32. Changing curriculum to suit STEM
33. To choose and to prepare the suitable activities of each stem lesson.

Do you collaborate with other teachers to discuss STEM lessons? And how often?

The teachers' answers were different for this question. The majority of teachers claimed that they often meet and collaborate with other teachers to plan and reflect on STEM activities while the others asserted that they rarely or do not meet at all.

1. Rarely. Teachers from different backgrounds need to meet and collaborate more to plan meaningful STEM activities.
2. Always
3. yes, frequently
4. not at all
5. Yes, whenever needed
6. We collaborate once per term.
7. Yes, once every month.
8. Yes of course and this happens on our weekly meetings.
9. Not as often
10. Yes, daily
11. Less than I would like. I have done one or two collaborations in my 6-year teaching career
12. Yes, on weekly basis

	13. Yes, when we are doing a science or engineering focused unit, we meet twice a week as a team to plan, document and reflect on our units/lessons. 14. Often 15. Yes, grade-level teams will collaborate weekly to discuss STEM-related activities. 16. No, no time 17. Yes, regularly 18. Yes- termly
Did you receive professional development to support you in STEM education in your school? and how often?	The teachers' answers came different for this question. Most of the teachers claimed that they often receive support (training, workshop) from their schools. Yet, they asked for PD to enhance their knowledge in STEM education. Very few teachers asserted that they receive little support or no support from their school. 1. No training related to STEM 2. Rarely. Professional development for teachers of STEM affects their knowledge and motivation to teach STEM and consequently affects the interest of students in STEM fields. 3. Always 4. Yes, weekly 5. Rarely. Yet, a PD in STEM would definitely help. 6. Not at all. 7. Very few times 8. Yes, yearly 9. Yes, through Numinds 10. Too little regarding STEM 11. Yes, but rarely. Need more on STEM 12. Yes, we had NGSS consultants come and walk us through the units and helped us to plan a unit or two initially. They also helped us focus on standards and benchmarks, and assessment boundaries. 13. Once per term 14. Very little in the way of STEM design. 15. Not this year 16. Yes. Workshops 17. Yes, every term. I receive training to implement STEM education
How often did your students participate in STEM competitions? and what are types of competitions do your students participate in?	Most of the teachers agreed that their schools rarely or do not participate in STEM competition at a school level or national level, whereas few teachers asserted that their students participate in coding and robotics competitions between schools or on a national level. 1. Rarely: coding and robotics. 2. Robotics and coding, once a year 3. Rarely. Coding competition between schools

4.	Never
5.	Frequently. Robotics and coding
6.	None
7.	They didn't participate in any competition.
8.	Every year. Robotics and coding
9.	Once a year, coding
10.	Students participate once every two to three years. Usually in robotics, with help from outside the school
11.	Department competition but higher grades participate in local competitions
12.	In our grade 1 class, students do the hour of code, but they don't really participate in competitions.
13.	Often particularly during extracurricular activities
14.	In the elementary school, very seldom.
15.	Maybe once a year or once every 2 years.
16.	Quite often
17.	Twice per year
18.	Once per year robotics competition in school.

Table 23: A summary of the teachers' answers on each open-ended question

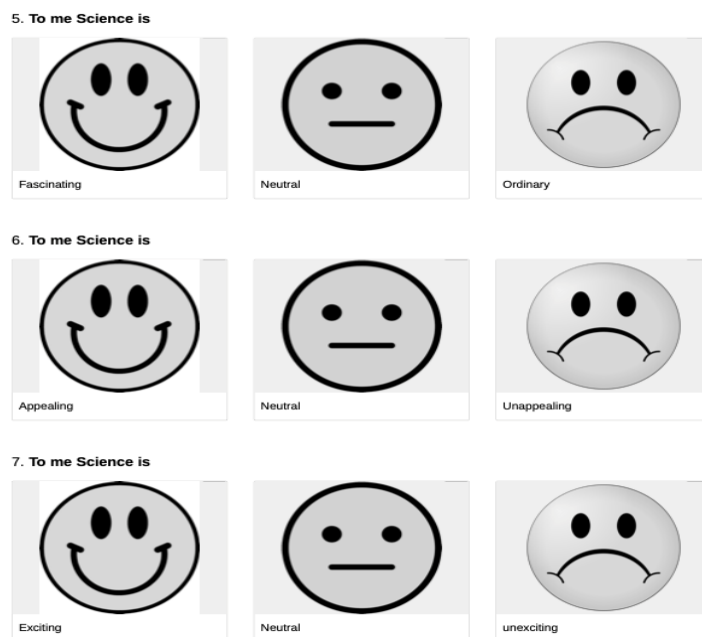
Qualitative findings related to teachers' perceptions of STEM education revealed that ninety percent of the teachers in STEM schools in Abu Dhabi were able to give clear definitions of STEM education. Eighty percent agreed that they were facing challenges when implementing STEM activities in their classes, specifically regarding the lack of resources, the constraint of time, and the need of professional development. Concerning the teachers' collaboration, around eighty- five percent of teachers claimed that they often meet and collaborate with other teachers to plan and reflect on STEM activities. Vis-à-vis school support, seventy percent of the teachers claimed that they often receive support from their schools (training, workshop) but they asked for specific professional development in STEM to enhance their knowledge in STEM education, implementation, and design. Concerning the students' participation in STEM competition, ninety percent of teachers agreed that their schools rarely participated or did not participate in STEM competition at a school level or national level.

4.2.2 Results and Analyses of the Student Questionnaire

This section presents analyses and results of the student questionnaire that examine the students' perceptions of STEM education in STEM private elementary schools in Abu Dhabi. In

this study, a total of 105 student questionnaires were completed by elementary students in STEM schools in Abu Dhabi. Out of the 105 completed questionnaires, five cases were overlooked due to incomplete responses. As a result, 100 questionnaires were analyzed. The elementary students as participants answered a set of twenty-nine questions. The first question was related to the students' agreement to participate in the student questionnaire related to their perceptions of STEM education. The second, third, and fourth questions were related to the students' demographics, such as their gender, their age, and their grade level. The other twenty-five questions were divided into five clusters. Five questions per cluster. The questions were related to factors associated with the elementary students' perceptions of (1) Science, (2) Technology, (3) Engineering, and (4) Maths scientific disciplines along with their (5) interest in STEM careers. Each cluster included five questions or five semantic perception adjective triad as the following: (boring/ neutral/ interesting), (appealing/ neutral/ unappealing), (fascinating/ neutral/ ordinary), (exciting/ neutral/ unexciting), and (means nothing/ neutral/ means a lot).

Figure 19 depicts an example of the five semantic perception adjective triad related to the students' perception of the science discipline.



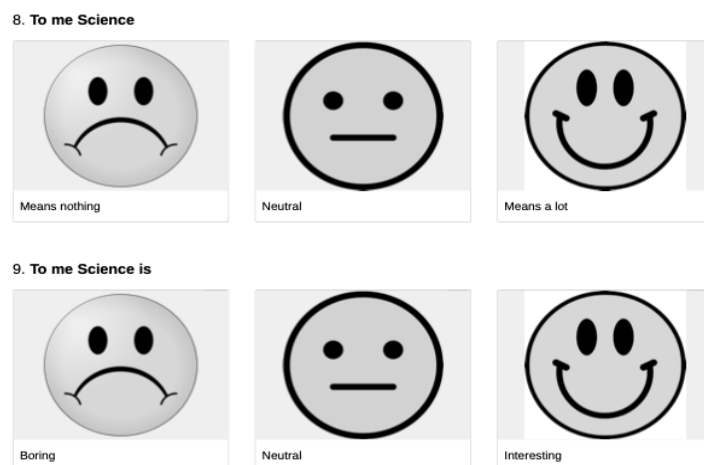


Figure 19: An example of the five semantic perception adjective triad related to the students' perception of the science discipline

The semantic perception adjective triad are considered as descriptors for target statements reflecting the student's perception of the mentioned scientific discipline. For each question, the student was encouraged to choose one emoji graphic among three multi-emoji rating options (Figure 19), between the semantic perception adjective triad related to each indicated scientific discipline in order to rate or indicate how s/he feels about it. All the participants were elementary students who attend STEM schools in Abu Dhabi. The mean age for the students was 9 years old, ranging between 4 and 11. The typical time spent to complete the questionnaire was two minutes and fifty-eight seconds. The completion ratio was 100%.

4.2.2.1 Descriptive Analysis among Demographic Groups

The researcher conducted first descriptive statistics to present the data. The descriptive statistics allow the researcher to gather mixed information and to describe the characteristics of the population by focusing not on the "why", but on the "what" of the research subject. Demographic data delineated the first section in the student questionnaire. Statistics related to students' demographic characteristics such as gender, age, and grade level were analyzed first by utilizing the basic statistics of the SurveyMonkey. The succeeding pie charts present the individual results of the participating elementary students' demographics in this study.

Figure 20 presents the frequency distribution of the students by their gender. The ratio of both males and females was almost the same with participating female students (53 %, n=53) being slightly higher compared to male students (47%, n=47).



Figure 20: Frequency distribution of students by gender

Figure 21 presents the frequency distribution of the students by their age group. The findings revealed that the majority of students who participated in this study were aged between 10 and 11 years old (45 %, n=45), followed by students who were aged between 8 and 9 years old (35%, n=35).

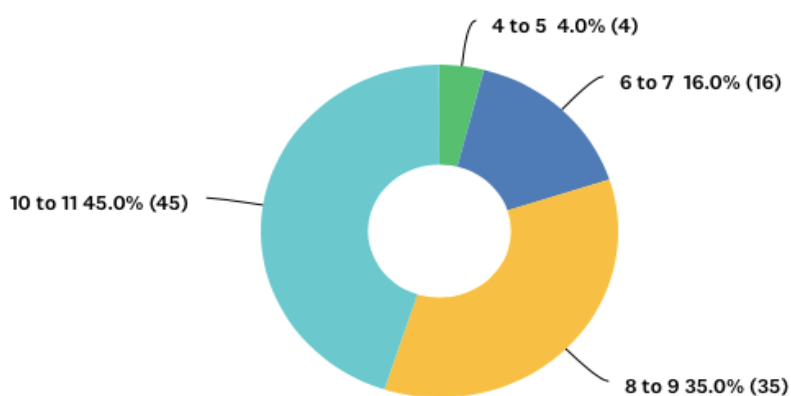


Figure 21: Frequency distribution of students by age group

Figure 22 presents the frequency distribution of the students by their grade level. The majority of students who completed the questionnaire in this study were in grade 5 (43%, n= 43), followed by students from grade 3 (19%, n=19), and grade 4 (16%, n=16).

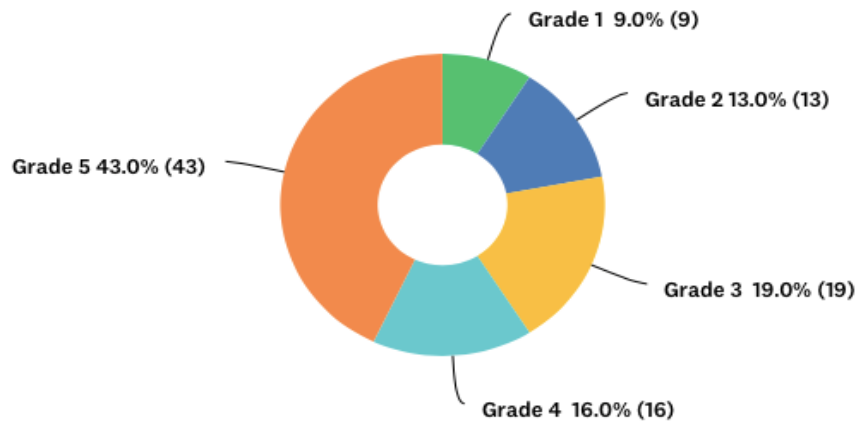


Figure 22: Frequency distribution of students by grade level

Table 24 presents the frequency distribution of students by gender, age, and grade level. The descriptive statistics of the elementary students indicated that the sample representation of participants was from diverse gender, group age, and grade level.

Variable	Percentage
Gender	
Male	47%
Female	53%
Age	
4 to 5	4%
6 to 7	16%
8 to 9	35%
10 to 11	45%
Grade level	
Grade 1	9%
Grade 2	13%
Grade 3	19%
Grade 4	16%
Grade 5	43%

Table 24: Frequency distribution of students by gender, age, and grade level

4.2.2.2 Students' Perceptions of STEM Education

Univariate analysis is the simplest form of analyzing data where data has only one variable. It doesn't deal with causes or relationships and its major purpose is to describe. It takes data, summarizes it, and finds patterns in it. The statistical package for social sciences (SPSS) version 22.0 was utilized to describe and analyze the students' perceptions of STEM education and their interests in STEM careers after creating a codebook to code the collected data. Table 25 presents the students' answers to the questions of the four STEM clusters related to students' perceptions of science, engineering, technology, and math by using frequencies procedure in descriptive statistics for categorical variables in SPSS software. Moreover, measures of central tendency were calculated through mean scores and standard deviations to examine the differences among the STEM disciplines' items scores for elementary students. The majority of the students agreed that science discipline is fascinating (85%), appealing (81%), exciting (83%), means a lot (82%), and interesting (86%). However, fewer students emphasized that science is ordinary (2%), unappealing (1%), unexciting (2%), means nothing (3%), and boring (1%). Yet, the students considered that science was more appealing ($M=1.20$, $SD=0.426$), means lot to them ($M=1.21$, $SD=0.477$), and exciting ($M=1.19$, $SD=0.442$) than being fascinating ($M=1.17$, $SD=0.437$), or interesting ($M=1.15$, $SD=0.385$).

In terms of the students' perceptions of technology, results revealed that the majority of elementary students agreed that technology is fascinating (86%), appealing (84%), exciting (85%), means a lot (85%), and interesting (87%). Whereas fewer students claimed that it is ordinary (1%), unappealing (0%), unexciting (1%), means nothing (3%), and boring (1%). Yet, students considered technology more appealing ($M=1.160$, $SD=0.368$) and exciting ($M=1.160$, $SD=0.394$) than fascinating ($M=1.160$, $SD=0.385$). In terms of their perceptions of engineering, the students' answers fluctuated between fascinating (69%), appealing (62%), exciting (65%), means a lot (57%), and interesting (65%) from one side and neutral on another side (26%, 34%, 29%, 36%, and 27% respectively). However, students considered engineering more exciting ($M=1.50$, $SD=0.627$) and interesting ($M=1.45$, $SD=0.657$) than fascinating ($M=1.36$, $SD=0.577$). In terms of the students' perceptions of maths, results fluctuated between fascinating (66%), appealing (62%), exciting (69%), means a lot (70%), and interesting (67%) from one side and neutral on another side (28%, 33%, 24%, 22%, and 27% respectively). Nevertheless, students

considered math more interesting ($M= 1.43$, $SD=0.639$) and appealing ($M=1.43$, $SD=0.590$) than exciting ($M= 1.38$, $SD=0.615$). In terms of students' interests in STEM careers, findings revealed that 87% of the elementary students agreed that working in science, technology, engineering, or maths domain is fascinating; 87% claimed that it means a lot to them; 89% stated that it is interesting; 82% asserted that it is exciting, and 85% affirmed that it is appealing. Whereas, fewer students argued that it is ordinary (0%), means nothing (2%), boring (1%), unexciting (1%), and unappealing (0%). Furthermore, the overall mean of each domain was calculated to interpret the overall perceptions of elementary students of each STEM disciplines and their interest in STEM careers. The overall means came out as the following: Science ($M=1.1840$, $SD=0.341$), Technology ($M= 1.1620$, $SD= 0.344$), Engineering ($M= 1.4280$, $SD= 0.545$), Math ($M= 1.4020$, $SD= 0.550$), Interest in STEM careers ($M= 1.1560$, $SD= 0.290$).

	To me Science is (Percent %)	To me Technology is (Percent %)	To me Engineering is (Percent %)	To me Maths is (Percent %)
Fascinating	85	86	69	66
Neutral	13	13	26	28
Ordinary	2	1	5	6
SD	0.437	0.385	0.577	0.603
Mean	1.17	1.150	1.36	1.40
Appealing	81	84	62	62
Neutral	18	16	34	33
Unappealing	2	0	4	5
SD	0.426	0.368	0.571	0.590
Mean	1.20	1.160	1.42	1.43
Exciting	83	85	65	69
Neutral	15	14	29	24
Unexciting	2	1	6	7
SD	0.442	0.394	0.627	0.615
Mean	1.19	1.160	1.50	1.38
Means a lot	82	85	57	70
Neutral	15	12	36	22
Means nothing	3	3	7	8
SD	0.477	0.457	0.604	0.630
Mean	1.21	1.180	1.41	1.37
Interesting	86	87	65	67
Neutral	13	12	27	27
Boring	1	1	8	8
SD	0.385	0.419	0.657	0.639
Mean	1.15	1.160	1.45	1.43
Overall Mean	1.1840	1.1620	1.4280	1.4020

Table 25: Frequency table for students' answers to the questions related to their perceptions of science, technology, engineering, and math disciplines

Descriptive analyses revealed that elementary students from different age, grade level, and gender who attend the STEM schools in Abu Dhabi have in general positive perceptions about STEM education and they are interested in STEM careers. Moreover, findings showed that elementary students have more positive perceptions towards engineering ($M=1.4280$) and math ($M=1.4020$) disciplines compared to science ($M=1.1840$) and technology ($M=1.1620$) disciplines. The means scores towards interest in STEM careers scored the least with ($M=1.1560$). Nevertheless, it is critical to determine if there are significant differences in the students' perceptions of each of STEM disciplines based on their demographics' differences to determine which group has more positive perceptions towards each of the disciplines identified from the questionnaire to answer question 3 of the study.

4.2.2.3 Results from Significant Testing Among Demographic Groups

The student questionnaire is divided into five clusters. Five items per cluster. The researcher aimed to analyze to see whether there were differences in students' overall perceptions of STEM disciplines and careers among their demographic characteristics. The succeeding findings and tables present the independent t-test results (when comparing 2 groups) and the one-way variance analysis (independent-between groups ANOVA) test results (when comparing more than 2 groups) for the 5 clusters of the student questionnaire. 05 level of significance was adopted to interpret the results. The outcomes obtained from the collected data in accord with the purpose of the study were displayed in tables. Interpretations based on collected data were revealed.

The independent t-test was conducted to compare the male and female students' perceptions of each of STEM disciplines and interest in STEM careers (Table 26). The null hypothesis is that there is not a significant difference in the students' perceptions of each of STEM disciplines and interest in STEM careers by gender. The alternative hypothesis is that there is a significant difference in the students' perceptions of each of STEM disciplines and interest in STEM careers by gender. By comparing the overall means scores, results revealed that female students generally perceive STEM disciplines in a better way when compared to the male students. Moreover, the outcomes revealed that there were no statistically significant differences

among the mean scores of male ($M=1.132$, $SD=0.257$) and female ($M=1.242$, $SD=0.412$) students towards their perceptions of science discipline ($t(75.216) = -1.583$ and $p = .118 > .05$). Similarly, there were no differences between the means scores of male and female students in their perceptions of math, engineering, and technology disciplines, and in their interest in STEM careers. This indicates that gender did not have any significant effect on students' perceptions of each of STEM disciplines nor on their interest in STEM careers; and, in this case the null hypothesis was accepted. Yet, findings of t-test (Table 27) revealed that there was a statistically significant difference among the mean scores of male ($M= 1.239$, $SD= .253$) and female ($M= 1.355$, $SD= .319$) in their overall perceptions of STEM education indicating that gender is a significant contributor in the overall STEM perceptions of elementary students in schools in Abu Dhabi ($t(87.604) = -1.987$ and $p = 0.05$). The t-test revealed that female students perceive STEM education better than male student.

Group Statistics					
	gender	N	Mean	Std. Deviation	Std. Error Mean
Overall Science	male	53	1.1321	.25703	.03531
	female	47	1.2426	.41270	.06020
Overall Math	male	53	1.3660	.54312	.07460
	female	47	1.4426	.56096	.08182
Overall Technology	male	53	1.1170	.26146	.03591
	female	47	1.2128	.41578	.06065
Overall Engineering	male	53	1.3434	.46472	.06383
	female	47	1.5234	.61510	.08972
Overall Career	male	53	1.1283	.23236	.03192
	female	47	1.1872	.34491	.05031

Independent Samples Tests

		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Overall Science	Equal variances assumed	-1.626	98	.107	-.11048	.06795
	Equal variances not assumed	-1.583	75.216	.118	-.11048	.06979
Overall Math	Equal variances assumed	-.692	98	.490	-.07652	.11051
	Equal variances not assumed	-.691	95.740	.491	-.07652	.11073
Overall Technology	Equal variances assumed	-1.395	98	.166	-.09578	.06866
	Equal variances not assumed	-1.359	75.684	.178	-.09578	.07048
Overall Engineering	Equal variances assumed	-1.662	98	.100	-.18001	.10830
	Equal variances not assumed	-1.635	85.073	.106	-.18001	.11011
Overall Career	Equal variances assumed	-1.012	98	.314	-.05893	.05824
	Equal variances not assumed	-.989	79.138	.326	-.05893	.05958

Table 26: Independent-samples t-test between variables gender and students' perceptions of STEM disciplines and interest in STEM careers

Group Statistics						
	gender	N	Mean	Std. Deviation	Std. Error Mean	
Overall Perception of STEM	male	53	1.2396	.25388	.03487	
	female	47	1.3553	.31969	.04663	

Independent Samples Test							
Levene's Test for Equality of Variances				t-test for Equality of Means			
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference Std. Error Difference
Overall Perception of STEM	Equal variances assumed	3.028	.085	-2.014	98	.047	-.11570 .05744
	Equal variances not assumed			-1.987	87.604	.050	-.11570 .05823

Table 27: Independent-samples t-test between variables gender and overall students' perceptions of STEM education

Table 28 shows the differences in students' perceptions of each of STEM discipline based on age group. The null hypothesis is that there is not a significant difference in the students' perceptions of each of STEM disciplines and interest in STEM careers by age groups. The alternative hypothesis is that there is a significant difference in the students' perceptions of each of STEM disciplines and interest in STEM careers by age group. The one-way ANOVA test was applied to test the influence of the student age group on their perceptions of each of STEM disciplines and interest in STEM careers. By comparing the means scores, results revealed that younger students generally perceive STEM disciplines in a better way compared to the older students. Yet, the older students had the highest mean score regarding the interest in STEM career indicating that they have a higher interest in pursuing STEM careers ($M=1.173$, $SD=0.281$) compared to students in earlier years. Moreover, the between-groups ANOVA test results revealed that there were no significant differences between groups for the students' perceptions of science, technology, and engineering disciplines nor for their interest in STEM careers. Yet, findings revealed that there were significant differences among the students' perceptions of math discipline. The one-way ANOVA test showed that $F(3,96) = 3.669$, $p = .015 < .05$. In this case, the students' age group was not considered a significant contributor to the students' perceptions of science, technology, and engineering disciplines nor to their interest in STEM careers. Yet, an influencer of the student perception of math in STEM schools in Abu Dhabi and in this case only the alternative hypothesis was accepted. Nevertheless, findings of the ANOVA test (Table 29) revealed that there was no statistically significant difference among the between groups mean scores towards their overall perceptions of STEM education indicating that age group is not a significant contributor in the overall STEM perceptions of elementary students in schools in Abu Dhabi ($F(3,96) = 1.779$, $p = .156 > .05$).

Descriptive				
		N	Mean	Std. Deviation
Overall Science	4 TO 5 YO	4	1.3000	.60000
	6 TO 7 YO	16	1.2875	.48973
	8 TO 9 YO	35	1.1486	.28837
	10 TO 11 YO	45	1.1644	.29322
	Total	100	1.1840	.34193
Overall Math	4 TO 5 YO	4	1.8000	.93808
	6 TO 7 YO	16	1.1750	.34157
	8 TO 9 YO	35	1.2686	.47513
	10 TO 11 YO	45	1.5511	.58021
	Total	100	1.4020	.55011
Overall Technology	4 TO 5 YO	4	1.0000	.00000
	6 TO 7 YO	16	1.3250	.42505
	8 TO 9 YO	35	1.1143	.29220
	10 TO 11 YO	45	1.1556	.35391
	Total	100	1.1620	.34430
Overall Engineering	4 TO 5 YO	4	1.5000	1.00000
	6 TO 7 YO	16	1.6375	.65000
	8 TO 9 YO	35	1.2914	.44811
	10 TO 11 YO	45	1.4533	.51944
	Total	100	1.4280	.54533
Overall Career	4 TO 5 YO	4	1.0000	.00000
	6 TO 7 YO	16	1.1875	.37572
	8 TO 9 YO	35	1.1371	.27769
	10 TO 11 YO	45	1.1733	.28155
	Total	100	1.1560	.29070

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Overall Science	Between Groups	.286	3	.095	.812	.490
	Within Groups	11.288	96	.118		
	Total	11.574	99			
Overall Math	Between Groups	3.082	3	1.027	3.669	.015
	Within Groups	26.878	96	.280		
	Total	29.960	99			
Overall Technology	Between Groups	.612	3	.204	1.759	.160
	Within Groups	11.124	96	.116		
	Total	11.736	99			
Overall Engineering	Between Groups	1.405	3	.468	1.603	.194
	Within Groups	28.037	96	.292		
	Total	29.442	99			
Overall Career	Between Groups	.139	3	.046	.541	.655
	Within Groups	8.227	96	.086		
	Total	8.366	99			

Table 28: One-way ANOVA between variables age group and STEM disciplines and interest in STEM careers

Descriptives				
Overall Perception of STEM	N	Mean	Std. Deviation	Std. Error
4 TO 5 YO	4	1.4000	.39791	.19896
6 TO 7 YO	16	1.3563	.34587	.08647
8 TO 9 YO	35	1.2057	.27380	.04628
10 TO 11 YO	45	1.3311	.26656	.03974
Total	100	1.2940	.29105	.02911

ANOVA					
Overall Perception of STEM					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.442	3	.147	1.779	.156
Within Groups	7.945	96	.083		
Total	8.386	99			

Table 29: One-way ANOVA between variables age group and overall perception of STEM education

Table 30 shows the differences in students' perceptions of STEM education based on grade level. The null hypothesis is that there is not a significant difference in the students' perceptions of STEM disciplines and interest in STEM careers by grade level. The alternative

hypothesis is that there is a significant difference in the students' perceptions of STEM disciplines and interest in STEM careers by grade level. The one-way ANOVA test was applied to test the influence of the student grade level on their perceptions of STEM disciplines and interest in STEM careers. By comparing the means scores, results revealed that students in earlier elementary years generally perceive STEM disciplines in a better way compared to students in higher elementary grades except for math discipline where the grade 5 students mean score scored the highest among all grade levels ($M= 1.572$, $SD= 0.584$). Similarly, the grade 5 students had the highest mean score regarding the interest in STEM career indicating that they have a higher interest in pursuing STEM careers ($M=1.172$, $SD=0.284$) compared to students in earlier years. Moreover, the between-groups ANOVA test results revealed that there were no statistically significant differences among groups for the students' perceptions of science, math, technology, and engineering disciplines nor for their interest in STEM careers. Consequently, the students' grade level was not considered a significant contributor to the student perception of science, math, technology, and engineering disciplines nor for their interest in STEM careers and in this case the null hypothesis was accepted. Similarly, findings of the ANOVA test in Table 31 revealed that there was no statistically significant difference among the different grade levels mean scores towards the students' overall perceptions of STEM education indicating that grade level is not a significant contributor to the students' overall perception of STEM education in schools in Abu Dhabi ($F(4,95) = 1.705$, $p=.155 > .05$).

Descriptives				
		N	Mean	Std. Deviation
Overall Science	grade1	9	1.2000	.40000
	grade2	13	1.3385	.53157
	grade3	19	1.1789	.33263
	grade4	16	1.1000	.21909
	grade5	43	1.1674	.29898
	Total	100	1.1840	.34193
Overall Math	grade1	9	1.3778	.70317
	grade2	13	1.2308	.37279
	grade3	19	1.2842	.50471
	grade4	16	1.2375	.45148
	grade5	43	1.5721	.58486
	Total	100	1.4020	.55011
Overall Technology	grade1	9	1.1556	.32830
	grade2	13	1.2923	.42907
	grade3	19	1.2105	.37401
	grade4	16	1.0000	.00000
	grade5	43	1.1628	.36057
	Total	100	1.1620	.34430
Overall Engineering	grade1	9	1.6000	.78740
	grade2	13	1.6000	.64291
	grade3	19	1.3579	.48341
	grade4	16	1.2250	.37148
	grade5	43	1.4465	.53065
	Total	100	1.4280	.54533
Overall Career	grade1	9	1.0889	.26667
	grade2	13	1.1692	.37279
	grade3	19	1.1579	.32372
	grade4	16	1.1375	.22767
	grade5	43	1.1721	.28479
	Total	100	1.1560	.29070

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Overall Science	Between Groups	.438	4	.109	.933	.448
	Within Groups	11.137	95	.117		
	Total	11.574	99			
Overall Math	Between Groups	2.327	4	.582	2.000	.101
	Within Groups	27.633	95	.291		
	Total	29.960	99			
Overall Technology	Between Groups	.686	4	.171	1.474	.216
	Within Groups	11.050	95	.116		
	Total	11.736	99			
Overall Engineering	Between Groups	1.418	4	.355	1.202	.315
	Within Groups	28.023	95	.295		
	Total	29.442	99			
Overall Career	Between Groups	.059	4	.015	.170	.953
	Within Groups	8.307	95	.087		
	Total	8.366	99			

Table 30: One-way ANOVA between variables grade level and STEM disciplines and interest in STEM careers

Descriptives

Overall Perception of STEM	N	Mean	Std. Deviation
grade1	9	1.3333	.31820
grade2	13	1.3654	.35671
grade3	19	1.2579	.31940
grade4	16	1.1406	.19341
grade5	43	1.3372	.27126
Total	100	1.2940	.29105

ANOVA					
Overall Perception of STEM					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.562	4	.140	1.705	.155
Within Groups	7.825	95	.082		
Total	8.386	99			

Table 31: One-way ANOVA between variables grade level and overall perception of STEM education

Pearson Correlation and Test of Multicollinearity

To explore more about the overall students' perceptions of STEM education, the researcher looked at how the different STEM domains of the student questionnaire correlate with each other and with the overall perceptions of participants of STEM education by conducting a Pearson Correlation Coefficient test (Table 32). Findings revealed there were significant, strong, and positive correlations between the students' overall perceptions of STEM education and all the three STEM domains: math, technology, and engineering. Corresponding correlations .707, .527, and .798 were all highly significant at the .01 level. The strongest positive correlation was found between the overall perception of STEM education and the engineering discipline ($r=.798, p<0.001$). Yet, the least positive and moderate correlation was found between the overall perception of STEM education and the science discipline ($r=.464, p<0.001$). A positive and moderate correlation was found between the engineering discipline and the math discipline ($r=.339, p<0.001$) as well as between the engineering discipline and the technology discipline ($r=.423, p<0.001$) indicating that the combination of these disciplines is significant for the students' overall perceptions of STEM education. The correlations between science discipline and

math/technology/engineering disciplines were found weak and non-significant. The same was also applicable to the correlation between the math and technology disciplines.

		Correlations				
		Overall Perception of STEM	Overall Science	Overall Math	Overall Technology	Overall Engineering
Overall Perception of STEM	Pearson Correlation Sig. (2-tailed)	1				
Overall Science	Pearson Correlation Sig. (2-tailed)	.464 .000**	1			
Overall Math	Pearson Correlation Sig. (2-tailed)	.707 .000**	.198 .049	1		
Overall Technology	Pearson Correlation Sig. (2-tailed)	.527 .000**	.019 .853	.058 .566	1	
Overall Engineering	Pearson Correlation Sig. (2-tailed)	.798 .000**	.152 .131	.339 .001**	.423 .000**	1

** . Correlation is significant at the 0.01 level (2-tailed)

Table 32: Pearson correlation coefficient test between students' overall perceptions and the four STEM domains

Similarly, the researcher looked at how the overall students' interest in STEM careers correlate with their overall perceptions of STEM education by conducting a Pearson Correlation Coefficient test (Table 33). Findings revealed there was a significant, strong, and positive correlation between the students' overall perceptions of STEM education and their interest in STEM careers ($r=.520$, $p< 0.001$). The corresponding correlation was highly significant at the .01 level.

		Correlations	
		Overall Perception of STEM	Overall Career
Overall Perception of STEM	Pearson Correlation Sig. (2-tailed)	1	
Overall Career	Pearson Correlation Sig. (2-tailed)	.520** .000	1

** . correlation is significant at 0.01 level (2-tailed)

Table 33: Pearson correlation coefficient test between students' overall perceptions and interest in STEM career

The Beta weights in Table 34 indicate that the overall perception of science discipline explains 29.4% the variance in students' overall perceptions of STEM education, whereas, the overall perception of math, technology, and engineering disciplines account for 47.3%, 29.6%, and 46.8% respectively. All these values are highly significant at $p < 0.001$ level. Consequently, the perception of math discipline appeared to be of the greatest contributor to the overall STEM perception and any change at its level will largely impact the overall students' perceptions of STEM education, followed by the overall perception towards engineering discipline. Furthermore, the data were tested for potential violations of the lack of multicollinearity assumption by examining tolerance and variance inflation factor (VIF) values. In this study the tolerance values ranged from .715 and .952, whereas the VIFs ranged from 1.051 and 1.399 indicating that multicollinearity assumption was not violated (Collinearity tolerance values $> .10$ and $VIF < 10.00$).

Coefficient a					
		Standardized Coefficients		Collinearity Statistics	
Model		Beta	Sig.	Tolerance	VIF
1	(Constant)		1.000		
	Overall Science	.294	.000	.952	1.051
	Overall Math	.473	.000	.855	1.169
	Overall Technology	.296	.000	.812	1.232
	Overall Engineering	.468	.000	.715	1.399

a. Dependent Variable: Overall Perception of STEM

Table 34: Test of multicollinearity: tolerance and variance inflation factors

Summary of the Empirical Study

Chapter 4 presented the data analysis and findings of the Research Questions 1, 2, and 3 by utilizing both, quantitative and qualitative methods. The qualitative findings of the first research question revealed that there are eight themes related to the STEM provisions and the level of its integration in private elementary schools in Abu Dhabi. The related and reported themes from the document analysis were the following: (1) Integrated STEM-based curriculum, (2) Project-based learning, (3) Technology and engineering integration, (4) Teacher willingness to implement STEM, (5) 21st century skills and STEM, (6) Authentic STEM classroom

environment, (7) Authentic STEM assessment, and (8) School administration support of STEM integration. The quantitative findings of the second and the third questions related to the teachers' and students' perceptions of STEM education and to the demographic factors associated with their overall perceptions of STEM education in private STEM schools in Abu Dhabi revealed that both, teachers and students reported positive perceptions of STEM education. Moreover, findings related to the student questionnaire revealed that elementary students were interested in STEM careers. Likewise, the students considered the four STEM disciplines exciting. Nevertheless, they considered math and science less interesting compared to engineering and technology disciplines. Analyses also showed that the math discipline was the greatest contributor to the student overall STEM perception and a strong positive correlation was found between the students' overall perception of STEM education and the engineering discipline. Furthermore, the analysis of Pearson Correlation Coefficient test revealed there was significant, strong, and positive correlation between the students' overall perceptions of STEM education and their interest in STEM careers. Regarding the demographic factors, quantitative analyses showed that the gender was considered a significant contributor in the overall STEM perceptions of elementary students and female students did perceive better the STEM education compared to male students in private STEM schools in Abu Dhabi. Yet, students' gender did not convey a statistically significant effect on the students' level of interest in STEM careers. Similarly, the students' grade level and age group were not considered as significant contributors to the students' perceptions of science, technology, engineering, and maths disciplines, nor to their interest in STEM careers.

Quantitative analyses and findings related to the teacher questionnaire revealed that the majority of the elementary teachers in STEM private schools in Abu Dhabi strongly understand what STEM education is and they strongly agree that STEM competencies are extremely important. Yet, half of the teachers agree that they find difficulties in implementing STEM education. On the other side, statistical analyses revealed that there were statistically significant relationships between the independent demographical variables gender, instructional level, and school curriculum and the teachers' general understanding of STEM education. Moreover, there were statistically significant relationships between the independent demographical variables age group, instructional level, teaching experience, and frequency of implementing STEM and the teachers' value of STEM competencies. Lastly, there were statistically significant relationships

between the independent demographical variables educational background, educational level, instructional subject, teaching experience in STEM, and the frequency of implementing STEM on the third domain of STEM perception which was STEM difficulty level.

Qualitative findings related to teachers' perceptions of STEM education revealed that most of the teachers in STEM schools in Abu Dhabi were able to give clear definitions of STEM education. Additionally, the majority of them agreed that they are facing challenges when implementing STEM activities in their classes, specifically the lack of resources, the constraint of time, and the need of professional development. Considering the teachers' collaboration, the majority of teachers claimed that they often meet and collaborate with other teachers to plan and reflect on STEM activities. Regarding school support, the majority of teachers claimed that they often receive support from their schools, (training, workshop) but they asked for specific professional development in STEM to enhance their knowledge in STEM education, implementation, and design. Concerning the students' participation in STEM competitions, the majority of teachers agreed that their schools rarely participate or do not participate at all in any STEM competition at a school level or at a national level.

The next chapter of the study, chapter 5, presents the discussion of the study results and interprets their significance with relevance to the conceptual framework of this study, in the light of the international and local (UAE) literature conducted within the area of STEM perception, and in relevance to conclusions previously reached via the research in STEM education in primary level. Moreover, it highlights the researcher's recommendations and outlines the limitations of this study.

CHAPTER 5: DISCUSSION, CONCLUSION, RECOMMENDATIONS, AND LIMITATIONS

Overview of the Chapter

Chapter 4 presented the results and the analyses of the collected data related to each question of this study in a descriptive manner. The data collection took place via an exploratory sequential mixed method where qualitative data collection took place first via a document analysis method, and then it was followed by the collection of quantitative and qualitative data via a teacher questionnaire and quantitative data via a student questionnaire.

This chapter is considered one of the most valuable sections when conducting a study, as it presents the discussion of the study results and interprets their significance with relevance to the proposed frameworks of this study, in light of international and local (UAE) literature conducted within the area of elementary STEM perceptions, and in relevance to conclusions previously reached via the research in STEM education in primary level (Madani, 2017; Tuckman & Harper, 2012). Additionally, this chapter presents the conclusion of this study and highlights the researcher's recommendations related to STEM education at the primary level. Lastly, the limitations of this study are outlined at the end of this chapter.

5.1 Discussion of Results of Research Question 1

This section discusses the findings of the first question of this study which is, "What are the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools". The researcher conducted a thematic analysis by applying the six steps of Braun and Clarke (2006)'s strategy to analyze and report themes within the collected data in order to explore the the current provisions that are on offer in relation to STEM education in Abu Dhabi private elementary schools.

Eight themes related to STEM implementation in the mentioned schools were identified from the explored curricula, ADEK inspection reports, and the collected media items. The themes

were interrelated and consistent with the theoretical framework and literature review of the study. Likewise, the themes were highly consistent with the conceptual framework of the study which stated that STEM education is affected by a series of systematic associations linking different concepts.

The revealed themes in this study could be categorized under two categories, interpersonal and structural as per Al Quraan and Forawi (2019). The interpersonal implementation themes in this study were the “Teacher willingness to implement STEM”, “21st-century skills and STEM”, and “School Administration support of STEM integration”. The structural implementation themes were the “Integrated STEM-based curriculum”, “Project-based learning”, “Technology and engineering integration”, “Authentic STEM classroom environment”, “Authentic STEM assessment”, and “School administration support of STEM integration”. The interpersonal implementation themes are mostly related to activities accomplished by educational stakeholders such as teachers, students, or STEM experts. Whereas, the structural implementation themes denote factors that must be presented by the schools for an effective STEM implementation (Al Quraan & Forawi, 2019).

The revealed interpersonal and structural themes are considered key factors and critical components for an effective STEM implementation as they not only denote an integration of the four STEM disciplines, but they also integrate several aspects in order to fulfill the complex process of STEM integration (Al Quraan & Forawi, 2019; Drake & Burns, 2004). Moreover, the revealed interconnected themes in this study align with the findings of the local study conducted by Al Al Quraan and Forawi (2019) which posited that an effective STEM education cannot be implemented without the inclusion of all the revealed themes.

In the light of the literature and in relevance to conclusions previously reached via the research in STEM education in primary level, the revealed themes support the implementation of STEM education in STEM schools in Abu Dhabi.

In fact, the “Integrated STEM-based curriculum”, the “Project-based learning”, the “21st-century skills and STEM”, and the “Authentic STEM learning environment” were highly interconnected in the gathered data which highlighted the existence of experiential STEM-based curricula in STEM schools in Abu Dhabi. Hence, this interconnection is an indicator of a quality

STEM implementation and practices within authentic learning environments which reflected a substantial quality of STEM provisions in the mentioned schools.

Lehman, Kim and Harris (2014) posited that the presence of quality and experiential integrated STEM curriculum would improve the quality and the efficiency of STEM practices. Al Quraan and Forawi (2019) claimed that project-based learning is a significant implementation factor associated to STEM education integration in the UAE. Gullapyan (2020) reported that applying student-centered educational approaches such as PBL with authentic learning environments is considered the most successful practice for effective STEM education. Jacobs and Shahbazi (2019) emphasized the significance of hands-on activities and PBL in influencing positively STEM practices and promoting the students' 21st-century skills, engagement, positive attitude, and academic students' performances in STEM education. Capraro and Slough (2013) posited that PBL helps the students to develop their conceptual knowledge, apply their knowledge, and construct collaborative learning skills, especially if it is applied in elementary levels. Chalmers et al. (2017) emphasized that STEM has to be approached by utilizing strategies of project-based learning and have to be swathed with collaboration, authentic problem-solving skills, and higher-order thinking skills to decipher present issues and real-life problems.

At this point, it is evident that meaningful experiences within authentic environments were part of STEM implementation in the STEM schools in Abu Dhabi. This reflects the stakeholders' efforts in implementing STEM education and the teachers' willingness to implement STEM in the mentioned schools.

Roehrig et al. (2012) argued that the connections of the STEM disciplines between each other and with the real-world problems via the project-based learning in authentic learning environments are the factors that reflect the degree of STEM integration in a STEM curriculum and not the number of disciplines integrated into a STEM lesson. Biagiotti (2021) also stated that the implementation of an integrated STEM curriculum via project-based learning, experiential learning, playing, or hands-on activities in authentic and language-rich elementary classes engages the students actively, fosters their curiosity, enhances their questioning/inquiry skills, and ensures their full immersion in the lesson to achieve the highest level of STEM learning. Thus, it is considered as a critical factor or a key component to successful STEM implementation in early childhood education.

Furthermore, the integration of STEM-based curriculum via hands-on activities within STEM authentic learning environment reflects Dewey's theory of integration which inquired an integrative and experimentalist curriculum especially for young students to build a logical sense of the world they live in (Gutek, 2004). It also stated that learning occurs in social contexts such as in classrooms where students can communicate, collaborate, be active, interactive, and lively involved in their learning via hands-on activities, real-life experiences, and age-appropriate activities (Bentley, 2021; Dewey, 1938; Doddington, Heilbronn & Higham, 2018).

From the coding phase of the thematic analysis and the documents collected from social media, it was evident that the schools in Abu Dhabi implement STEM via PBL or interdisciplinary approach which is a constructivist method that permits the learners to approach their learning via a holistic means by integrating the knowledge from different disciplines and by collaborating with each other and with knowledgeable individuals. The qualitative data collected from the teacher questionnaire validates this notion as most of the teachers defined the STEM implementation and integration in classrooms as "an approach which integrates science, math, and technology in one lesson. It requires problem- solving skills. It prepares students to STEM careers and it is generally implemented via PBL".

The thematic analysis of the collected documents highlighted the "School administration support of STEM integration" theme. This theme is considered a key element for successful STEM education integration and implementation (Al Quraan & Forawi, 2019). Additionally, it is a multifaceted theme that holds an interpersonal facet illustrated by providing continuous professional development in STEM education such as trainings for STEM teachers and workshops for students. It also comprises a structural facet illustrated by cooperating with outside organizations and science centers, or even partnering with global STEM partners to provide the STEM stakeholders the technology tools and resources, which are crucial elements for successful STEM implementation in STEM schools. The multifaceted theme was evident throughout the collected documents and it was intertwined with all the other revealed themes especially with the "Teacher willingness to implement STEM" and the "Technology and engineering integration" themes.

The teacher professional development (PD) which is considered the cornerstone of all kinds of education reform (Chai, 2019) and which elucidates the interpersonal facet of the school support to its teachers was obvious and repetitive throughout the thematic analysis.

However, despite the recurrent occurrence of the professional development in collected documents which reflects high support for teachers in elementary schools, half of the participating teachers in the quantitative section of the teacher questionnaire reported that they faced challenges in implementing STEM in STEM private elementary schools in Abu Dhabi, especially when implementing an inquiry-based curriculum. Furthermore, in their comments in the qualitative part, most of them asked for more training related to STEM education. These findings are backed by Abdallah (2017), Al Basha (2018), Forawi (2020), Eltanahy (2019) and Jarrar (2020) studies in the UAE which disclosed that STEM implementation in the UAE necessitates further support for teachers' knowledge and practices via professional training.

At this point, the schools are required to offer more trainings for STEM elementary teachers as they play a significant role in STEM implementation. PDs support teachers in embracing STEM programs, clarifying their misunderstanding of STEM core concepts, and enhancing their STEM skills, practices, and content knowledge which is considered a major challenge when implementing STEM in early childhood classrooms. Additionally, PDs help teachers embrace digital tools and engineering design in the STEM classroom. They also present them educational models that exhibit how they could enhance problem-solving and real-world applications via project-based learning and hands-on activities to increase their students' curiosity and inquiry skills which are both considered fundamental skills in the authentic elementary STEM learning environments. Thus PDs educate teachers to develop efficient STEM lesson plans and assess group work (Al Quraan, 2017; Biagiotti, 2021; Gao et al., 2020; Gunner, 2019). Fisher, Frey and Pumpian (2012) advised that the delivery of professional development should be over a lengthy period of time to provide the maximum impact on teachers' learning.

The STEM students' workshops via the coordination with and the support of STEM experts and scientists were evident throughout the coding phase of the collected documents. Related literature reveals that inviting scientists, engineers, or experts to work closely with students positively affects the students' STEM implementation. Students enjoy and benefit from engaging, challenging, and interactive presentations presented by passionate and enthusiastic

mentors or experts (Diana & Sukma, 2021). Moreover, the interaction of students and STEM experts aligns with Vygotsky (1978)'s Sociocultural Development Theory which claimed that learning is a social practice, and social interaction along with communication with a More Knowledgeable Other (MKO) are fundamental for the student's cognitive development and for the student's capability of constructing reality.

The structural facet of the "School administration support of STEM integration" theme was evident via the collected data. This facet was illustrated in the thematic analysis via codes related to the cooperation of the STEM schools with outside organizations or global STEM partners to provide their teachers and students the technology tools and resources necessary to successful STEM implementation. This structural facet was highly interconnected with the "Technology and engineering integration" theme. The collected data related to students' practices of STEM education via pictures from social media pages reflecting students' collaboration and enjoyment in STEM labs or via hands-on STEM activities revealing that technology and engineering are infused in STEM education and not treated as stand-alone disciplines. In fact, documents revealed the presence of advanced digital software via computers, iPads, laser cutters, 3D printers, robotics and coding, Lego Mindstorms EV3, and the names of revolutionary technology and science providers such as "Raytheon Emirates", "Exxon Mobil" and "CITI".

These technological/engineering tools or products are needed to transform learning in this changing world, to drive scientific research, to support investigations, and to meet human needs. Malaka (2018) stated that funding for the resources of STEM education from energy and government authorities is a must for supporting and executing an effective STEM practice. Marshall and Harron (2018) posited that classroom resources affect the implementation of STEM education in schools. Diana and Sukma (2021) also argued that the absence of adequate STEM learning tools and materials reduces the STEM teacher's desire to conduct learning activities by utilizing STEM approaches.

Additionally, the literature reveals that the support of and the partnership with STEM community-based- centers are beneficial for teachers as they help them feel more comfortable in taking risks and in delving deeper into STEM concepts outside their comfort area (Al Quraan & Forawi, 2019; El-Deghaidy, 2017; Margot & Kettler, 2019; McLoughlin et al., 2020; Pugalenth, 2019; Walker et al., 2018). Moreover, Syukri, Yulisman and Nurina (2020) stated that for

effective STEM implementation and practices, STEM teachers need to carry out STEM teaching and learning activities that ally with the present educational and technological development by using suitable technology to the delivered STEM content and pedagogy.

Accordingly, it was evident that the STEM schools in Abu Dhabi are supporting their teachers and students on both, structural and interpersonal levels. This is a piece of evidence that STEM is implemented appropriately in the mentioned schools (Al Quraan, 2017) and an indicator that STEM schools in Abu Dhabi are keen to implement STEM in a student-centered and professional way to develop the students' decision-making abilities, creativity, design skills, and questioning/communication skills. Additional objectives are enhancing their interest in STEM careers, sustaining their interests in STEM coursework and preparing them to be scientists, engineers, or technologists in order to leverage the level of the UAE amid the other middle east countries as a prominent supplier for technology and science development (Stivachtis, 2019).

The "Authentic STEM assessment" theme was stated in almost all the reviewed written data items with a focus on teachers' constructive feedback on students' learning processes and formative assessment tasks. Nevertheless, summative assessment procedures which are consistently applied in STEM schools in Abu Dhabi via international benchmarks and standards were also obvious throughout the reviewed curricula and inspection reports. All the collected STEM curricula and inspection reports highlighted the importance of authentic assessment, especially the formative assessment, in enhancing the quality of students' learning and in improving the teachers' teaching approaches and curricula. This finding aligns with Harks et al. (2014) which stated that teachers' authentic assessments and continuous feedback which focus on students' learning processes motivate the students and support their growth mindset development. It also helps in enhancing the elementary students' logical thinking that fall in the concrete operational stage, as per Piaget, to learn how things work and to succeed in solving problems (Cherry, 2018; Piaget, 1957).

The authentic STEM assessment theme reflects a main and effective practice of teachers in STEM schools in Abu Dhabi. Additionally, the "STEM authentic assessment" theme was interconnected with the "School administration support of STEM integration" theme, specifically via its interpersonal facet "professional development". This finding is backed by Gao et al.

(2020) that claimed that PDs educate teachers on how to develop efficient STEM lesson plans and how to assess group work.

In fact, the students' STEM comprehension has to be assessed in an authentic way to understand how they connect knowledge and skills from multiple disciplines. PDs support teachers in assessing their students via suitable interdisciplinary practices that stress on assessing the students' STEM knowledge and skills, concurrently.

However, the STEM elementary teachers claimed via the teacher questionnaire that they find challenges in finding methods to assess the integrated STEM projects which are of non-traditional nature and they asked for more PDs to enhance their skills in assessing STEM projects. This finding aligns with Forawi (2020)'s claims which stated that the absence of a unified framework of STEM application and the lack of quality assessment for STEM implementation are considered obstacles for STEM integration in the UAE. This might be due to the severe deficiency in valid and reliable instruments to measure the STEM teachers' knowledge and skills, the students' comprehension of STEM content, and the outcomes of STEM intervention and classroom practices.

Therefore, investigating and highlighting the obstacles that face the STEM assessment in the STEM schools in Abu Dhabi is an area to be considered in future research especially that evaluation is a must in effective STEM integration (Katzenmeyer & Lawrenz, 2006).

To overcome the mentioned challenges in assessing STEM projects, Huang and Jong (2020) claimed that employing rubrics in STEM education is considered a promising method to promoting learning and augmenting instructional impact by helping teachers communicating their expectations of performance to their students. The researchers added that well-designed rubrics allow the teachers to give feedback on students' achievement. Hence, they suggested that STEM work can be assessed via several aspects such as: the ability to define the problem, the practicality, the group-work, and the total presentation and explanation.

Summary of Research Question 1 Discussion

The thematic analysis helped the researcher answer the first question of the study. The themes reflected the existence of STEM-based curricula and the implementation of interdisciplinary STEM practices such as project-based learning in STEM schools in Abu Dhabi.

Moreover, they reflected the availability of funding, outside support, and high-quality resources and technology tools in the mentioned schools. Furthermore, learner-centered approaches and learning experiences within authentic learning environment that promote the students' twenty-first-century skills were evident in the mentioned schools. The teacher's willingness to implement STEM in authentic ways via real-world projects and the institution support for teachers and students, on both the structural and the interpersonal levels, was also evident.

All the mentioned themes are considered main factors for an effective STEM implementation and an indicator that reflected a quality of STEM in the STEM private schools in Abu Dhabi as per Al Quraan and Forawi (2019). This is key to prepare the national workforce demands in the UAE as they are directly connected to rigorous STEM education, to meet the demands of the rapid technological developments which had driven world labor markets from traditional industry to an innovation-based economy, especially in the UAE, and to better equip the existing generation of students with the academic tenacity to swiftly adapt to fast changes in the workplace and around the world (Office of Innovation and Improvement, 2016; Office of Workforce & STEM Alliances, 2018).

Furthermore, the thematic analysis in this study reflected several STEM implementation attributes of STEM certification evaluation rubric published by Indiana department of education (Ritz, 2013). The STEM attributes such as integrated STEM curricula, instructional approaches to learning STEM such as projects-based learning, technology in instruction, inquiry-based instructions, authentic assessments, authentic learning environments, and community partners domains were evident via the data items of the STEM schools in Abu Dhabi and they reflected critical components that have been identified as being critical attributes for a successful STEM school by the Indiana's STEM Education Implementation Rubric (Appendix 16).

Therefore, in light of Al Quraan and Forawi (2019) study and the STEM Indiana Evaluation Rubric, the analyst revealed an approximate reality related to STEM status in private schools in Abu Dhabi which reflects a quality of STEM education implementation.

By conducting a document analysis, the researcher contributed to the literature related to STEM education and closed a gap related to the existence of integrated STEM in private elementary schools in Abu Dhabi in the context of the global themes for an optimal STEM implementation identified by Al Quraan and Forawi (2019). However, an area to be considered

by future researchers is to analyze and determine the overall level of STEM implementation in each private school in Abu Dhabi in the context of the domains of the Indiana evaluation STEM implementation rubric.

Based on specific standards and criteria, the Indiana's evaluation STEM implementation rubric (Ritz, 2013) categorizes STEM schools in four STEM implementation categories or levels. Level (1): Full Implementation which is considered the highest level of implementation of a STEM school, level (2): Approaching Implementation which is allocated when school meets many of the expectations, level (3): Developing Implementation which is assigned when school has met some components but still needs further development, and level (4): Initial Implementation which is allotted when STEM program discussions have occurred and the program implementation is still in infancy.

5.2 Discussions of Results of Research Question 2

In this section, the researcher discusses and interprets the answers of primary teachers and students from the teacher and the student questionnaires to examine their perceptions of STEM education in order to answer the second question of the study which is, "What are the elementary teachers' and students' perceptions of STEM education in private schools in Abu Dhabi"?

5.2.1 Teachers' Perceptions of STEM Education

The subsequent section provides the discussion related to the teachers' perceptions of STEM education in private elementary schools in Abu Dhabi based on the quantitative and qualitative findings from the teacher questionnaire instrument.

5.2.1.1 Discussion of the Quantitative Results Related to Teachers' Perceptions of STEM Education

One of the objectives of this study was to identify the teachers' perceptions of STEM education in private elementary schools in Abu Dhabi. The researcher collected data from seventy-five STEM elementary teachers via a survey method from different private schools in Abu Dhabi. The teachers were asked to answer twenty-one questions scored on a five-point Likert scale. The questions addressed queries related to three clusters: (i) teachers' overall

perceptions of STEM education, (ii) teachers' value of STEM competencies, and (iii) teachers' difficulties in STEM implementation.

The quantitative analysis of the collected data revealed that the majority of elementary teachers have positive views of STEM education; they have a good understanding of STEM education and they strongly agree on the values of STEM competencies. Nevertheless, half of the teachers claimed that they find difficulties in implementing STEM education.

The teachers revealed a general understanding of STEM education and they perceived STEM education as a teaching method where they can combine optionally knowledge from science, technology, engineering, and math disciplines to compose a STEM lesson. Moreover, they agreed that scientific inquiry and engineering design are two main factors in a STEM lesson. These findings support further the results obtained by Al Basha (2018) in the UAE. The teachers who participated in Al Basha's study showed an informed understanding of the STEM definition. Additionally, they revealed that engineering is the best practice of STEM education, and similarly, these findings are in agreement with that of Thi To Khuyen et al. (2020) and Margot and Kettler (2019). Participant teachers had reasonable general understanding of STEM definition and believed that the cross-curricular connections made in STEM education and learning provide the students with the necessary skills to solve real-world problems, especially via engineering inclusion. A study conducted by Smith, Rayfield and McKim (2015) revealed that teachers believe that engineering adds real-world and practical aspects to teaching and learning and prepares students for their future by helping them solve real-world problems.

These findings are in line with the NGSS framework (2013) which articulated and discussed the role of engineering in science education and included engineering concepts as part of the science academic standards, as well as in accordance with the UAE Ministry of Education's 2017-2021 strategic plan which aims at preparing students for the knowledge-economy and the needs of the job- market by equipping them with creativity and critical thinking skills via strategies and values that endorse knowledge integration in engineering, science, and innovation.

"STEM can help students acquire skills related directly to STEM careers" was perceived as the most important STEM competency by the elementary teachers in STEM schools in Abu Dhabi. These findings differ somewhat from those of Thi To Khuyen et al. (2020) where

Vietnamese teachers perceived skills related to STEM careers as the least important competency in STEM education consequences. Takeuchi et al. (2020) posited that around forty percent of the studies related to STEM education focus on students' interests to pursue STEM-related careers. Hacioglu and Gulhan (2021) confirmed that STEM education affects indirectly the students' career awareness. Hayden et al. (2011) asserted that STEM education increases elementary students' motivation, attitude, and interest towards science and encourages them to pursue STEM careers in the future.

To help teachers implement STEM in an effective way and to positively impact the students' careers ambitions, the STEM stakeholders have to enhance the teachers' pedagogical teachings as they directly affect the students' careers objectives. Therefore, PDs need to be delivered to engage teachers not only to understand STEM education, but also to enhance their awareness of STEM careers (Thi To Khuyen et al., 2020).

Based on the data analysis of the student questionnaire, the elementary students in this study perceived the STEM careers the least compared to STEM four disciplines. By perceiving STEM education positively, practicing it effectively, and considering it a teaching method that helps students acquire skills related to STEM careers, elementary teachers in private schools in Abu Dhabi can help in enhancing the students' perceptions of STEM careers. In addition, they can help the future generations master the STEM skills making them adaptable to economic changes in the UAE, fulfill the vocational careers, and meet the objectives of the UAE National Agenda.

Teachers in elementary schools in Abu Dhabi reported that they face challenges in implementing STEM education, especially in implementing an inquiry-based curriculum in comparison with all the other difficulties when implementing STEM education. This reflects challenges in teachers' STEM pedagogical knowledge and content knowledge. These findings mirror those of Tairab (2010) who indicated that teachers in the UAE face many challenges regarding STEM pedagogical content knowledge, especially the lack of content knowledge in science in elementary education (Forawi, 2020). They also match those of Thi To Khuyen et al. (2020) where teachers struggled with the content knowledge and pedagogy knowledge when implementing STEM. Moreover, they broadly support the results obtained by Shidiq and Nasrudin (2021), where elementary teachers struggled in integrating the STEM subjects and in

offering contextual aspects relevant to the elementary students' real-life. Yet, the revealed results differ somewhat from the results of Swaid (2015), Al Basha (2018) and Park et al. (2016) where teachers claimed that the difficulties they mostly faced in implementing STEM were shortage of time and resources and lack of administration support.

These findings are likely to be the results of the teachers' tendency to implement conventional teaching by teaching separate subjects in separate lessons oriented to their own disciplines (El-Deghaidy & Mansour, 2015), or they are likely related to the teachers' struggles to teach disciplines they do not master (lack in content knowledge) and to difficulties in teaching and implementing integration (lack in pedagogy knowledge) (Thi To Khuyen et al., 2020). To overcome these challenges, it is recommended to enhance the teachers' content knowledge of STEM disciplines beyond their majors. Moreover, teachers are asked to shift their pedagogical habits to implementing the cross-cutting concepts and meeting the core idea of STEM learning (Chesnutt et al., 2019).

The teacher's ability to use proper technology, effective interdisciplinary content knowledge of STEM disciplines, and pedagogical knowledge needed to deliver the STEM challenging standards to transfer the correct knowledge for learners and to face the STEM students' learning difficulties and misconceptions in a technology-based learning environment can be seen via the TPACK framework (Mishra & Koehler, 2006; Yulisman et al., 2019).

Parker et al. (2015) stated that STEM association with TPACK is fundamental in developing the students' twenty-first-century skills as STEM education requires teachers to integrate technology, pedagogy, and associated content knowledge through design. TPACK also facilitates the teachers' job and the authentic students' learning via design thinking.

Therefore, professional trainings on STEM based contextual learning are mandatory to be delivered to elementary STEM teachers to enhance their technological, pedagogical and content knowledge in STEM. The aim of professional trainings is to overcome the challenges in implementing STEM education, to become STEM thinkers, to sustain STEM education, and to prepare scholars for the technological revolution that the world is experiencing (Shidiq & Nasrudin, 2021; Thi To Khuyen et al., 2020).

5.2.1.2 Discussion of the Qualitative Results Related to Teachers' Perceptions of STEM Education

This section discusses the teachers' answers on a set of five structured open-ended qualitative questions. The questions at the end of the teacher questionnaire required the teachers to explain further and reflect on their perceptions of elementary STEM education. The five questions that helped the researcher interpret qualitatively and analyze the perceptions of STEM elementary teachers, the difficulties they face when implementing STEM education, and the extent of support they receive to implement STEM in an effective way, were the following: 1) How do you define STEM education? 2) What challenges do you face when you implement STEM education in your classroom? 3) Do you collaborate with other teachers to discuss STEM lessons? And how often? 4) Did you receive professional development to support you in STEM education in your school? and how often? 5) How often did your students participate in STEM competitions? and what are types of competitions your students participate in?

The open-ended questions helped the researcher reveal any possible overlooked aspects related to STEM education in private elementary schools in Abu Dhabi. The qualitative questions were developed by the researcher based on the insights of the documents' analysis, in the first qualitative phase of the study, in addition to the insights gathered from the conceptual framework and the literature review of the present study. The open-ended questions were utilized to validate the quantitative data and to attain a wider comprehensive understanding of the STEM teachers' perceptions in private elementary STEM schools in Abu Dhabi.

1- How do you define STEM education?

In the first question, few teachers defined STEM as per its acronym where they denoted “*STEM Education, at its core, simply means educating students in four specific disciplines, namely, Science, Technology, Engineering, and Mathematics*”. Navy et al. (2021) emphasized the significance of developing teachers' understanding of STEM beyond its acronym for science, technology, engineering, and math, especially at the elementary level. In addition, the researchers highlighted the necessity of enhancing the teacher's STEM knowledge and skills at the elementary level to better prepare the students for the future.

Nonetheless, the majority of the participants were able to give clear and detailed definitions of STEM education. This finding corroborates the quantitative findings in the teacher questionnaire which revealed that the majority of the elementary teachers in STEM schools in Abu Dhabi have a general understanding of STEM education. For instance, teachers posited that STEM education is *“An innovative teaching method that integrates knowledge from different disciplines to enhance students' problem-solving skills; A multidisciplinary approach to tackle current challenges and solve real-life problems via hands-on activities; A key to innovation; A set of inter-related disciplines that develop students' critical thinking and help students gain the skills required to succeed in today's challenging world; Education that involves scientific inquiry and engineering practices; 21st century skills need; It is generally implemented via PBL.”*

These findings differ from those of Alumbaugh (2015) who stated that elementary STEM teachers do not have clear understanding of STEM education. Yet, they highly match those of Madani (2017) and Thi To Khuyen et al. (2020). The STEM various definitions in this study support those of Koonce et al. (2011) who stated that STEM education definition is ramified but called for a unified STEM definition that best encounters the educational needs of students and suits their country needs. Additionally, the attained results including definitions that call for integrative teaching approaches via hands-on activities, PBL, and engineering practices to solve real-world problems reflect the STEM teaching practices' requirements revealed in the related literature (Dare, Ellis & Roehrig, 2014; Van Haneghan et al., 2015; Williams et al., 2015) and advocated by early childhood teachers (Park et al., 2016). Hence, they mirror the Drake (1991)'s theory of integration which advocates for a transdisciplinary approach that associates STEM with real-world applications to empower students with twenty-first-century skills so as to encounter future careers problems (Smith, Rayfield & McKim, 2015).

Nevertheless, teachers did not focus on the students' collaboration when they defined STEM education, despite the fact that this twenty-first-century skill is considered a significant factor in STEM education implementation, especially at elementary level as it helps students to interact socially and find innovative solutions related to their real-life problems (Le, Janssen & Wubbels, 2018; Rosita & Leonard, 2015). Indeed, the collaborative hands-on STEM activities support the learning by doing and enable the students to exhibit higher levels of knowledge (Dewey, 1938; Vygotsky, 1978). Neither did the teachers focus on STEM ability in preparing the

students for future careers despite the fact that they valued this competence the most in the quantitative part of the questionnaire.

2- *What challenges do you face when you implement STEM education in your classroom?*

In the second question, the elementary teachers shared similar perceptions related to the challenges and difficulties in implementing STEM such as *“the shortage in resources, the shortage in innovative ideas for STEM activities, the constraint of time, the lack of administrative support, the need of training, the lack of pedagogical knowledge, the need for more collaboration between colleagues, the lack of quality and flexible curriculum, and the lack quality assessment tools”*.

These findings support those of Henriksen (2017) and Margot and Kettler (2019) who described the teachers' challenges in practicing STEM education. Moreover, they highly reflect those of Shidiq and Nasrudin (2021) who depicted the teachers' obstructions in implementing STEM at the elementary level. Additionally, the teachers' answers revealed additional reasons behind the quantitative results of the teacher questionnaire which highlighted that half of the teachers face challenges in implementing STEM education, especially in implementing an inquiry-based curriculum in private elementary schools in Abu Dhabi. For instance, the need for more PD and the constraint of time to implement STEM activities were the most repetitive obstructions revealed by the elementary teachers.

“The need for more PD to enhance the pedagogical knowledge, to acquire innovative ideas for STEM activities, to authentically assess STEM projects, and to implement integrated STEM curricula” was revealed by elementary teachers in this study and was consistent with Kelley and Knowles (2016), Nadelson et al. (2012), Madani (2017), Fisher, Frey and Pumpian (2012), and Forawi (2020) descriptions of STEM challenges and need for PDs implementation to provide the maximum impact on elementary teachers' practices of STEM education.

Whereas the *“constraint of time”* to implement effective STEM highly reflects the findings of Park et al. (2016) and Bagiati and Evangelou (2015) who posited that the workload associated with STEM practices within the school's busy schedules requires extensive time and hinders effective STEM implementation. It also mirrors the findings of Abdallah (2017) who

claimed that one the main barriers that challenged her teachers to design and implement STEM projects in the UAE schools was the time constraint.

Teachers also declared that they need to “*collaborate more*” to better implement integrated STEM. This finding mirrors McFadden and Roehrig (2017) argument on the necessity of teachers’ collaboration in planning and designing STEM activities and teachers’ collaboration with external companies to better understand STEM education, STEM practices, and real-life problems to prepare their students for future careers (Vennix, den Brok & Taconis, 2017).

Additionally, “*the lack of quality and flexible curriculum*” mirrors the findings of Van Haneghan et al. (2015), McMullin and Reeve (2014), and Forawi (2020) who posited that STEM teachers call for a quality and flexible STEM curriculum with ready-made STEM problems as they believe that it is imperative for successful STEM initiatives and it helps them acquire higher self-efficacy to teach STEM and to implement it immediately in their classes (Asghar et al., 2012).

Furthermore, the revealed teachers’ challenges mirror the findings of Malaka (2018) and Al Basha (2018) in the UAE. Malaka (2018) disclosed that STEM implementation in the UAE necessitates further support for teachers via professional training and workshops; whereas, Al Basha (2018) claimed that teachers in her study complained about a dearth of professional training. They also reported a deficiency of significant collaboration among the diverse parties in school and the inadequate time to implement STEM activities which all result in implementing STEM as an activity per term or as an extra-curricular activity.

Furthermore, few elementary teachers in private elementary schools in Abu Dhabi argued that there is a “*shortage in STEM resources*” to implement STEM education. These findings mirror those of Malaka (2018) and Al Basha (2018). Yet, this raises the question of the validity of the “School administration support of STEM integration” theme in the document analysis which revealed that elementary schools in Abu Dhabi cooperate with outside organizations or global STEM partners to provide their teachers and students with the technology tools and resources necessary for successful STEM implementation. These resources are needed to transform learning in this changing world, to drive scientific research, to support investigations, and to meet human needs.

Hence, the teachers' request for "*valid and authentic STEM assessment tools*" is in agreement with that of Nadelson and Seifert (2013) and Herro and Quigley (2017) who claimed that teachers argue that there is a lack of assessments for STEM programs, a difficulty in assessing STEM lessons, a concern of group grading, and an unease in assessing each member of the group. Sabri (2015) asserted that the utilization of formative assessment strategies to assess students' comprehension in science classrooms in the UAE enables teachers to collect evidences regarding students' understanding. This helps them amend their teaching strategies in order to tackle the students' scientific misconceptions and build their critical thinking skills.

Lastly, the revealed challenges in implementing STEM education were consistent with the literature review of this study which revealed that, although the teachers value STEM education and recognize its benefits, they believe that it is a challenging and complicated endeavor with many obstacles (Forawi, 2020; Hammack & Ivey, 2019; Katzenmeyer & Lawrenz, 2006; Park et al., 2016). Abdallah (2017) highly recommended the establishment of a consistent Next Generation Science Standards (NGSS) learning environment culture and the implementation of the holistic contextual teaching and learning approach to engage the students, develop their skills, and ease STEM implementation in the UAE.

3- Do you collaborate with other teachers to discuss STEM lessons? And how often?

In this question, the majority of teachers claimed that they often meet and collaborate with other teachers to plan and reflect on STEM activities. These findings highly support those of Malaka (2018) in the UAE, where teachers affirmed that they collaborate to plan STEM activities. They also mirror the findings of Goodnough, Pelech and Mary (2014) where elementary teachers collaborate to plan, share, and reflect in order to conceptualize and implement their STEM action research projects. Asghar et al. (2012) posited that teachers' collaboration is significant in STEM planning and implementation. Margot and Kettler (2019) argued that teachers' collaborative planning is critical to STEM successful implementation. Also, Alumbaugh (2015) stated that collaboration among STEM elementary teachers is very beneficial.

However, few teachers claimed that they do not collaborate to design STEM activities and they asked for more collaborative opportunities to design STEM activities and implement STEM

efficiently. These findings mirror those of Al Basha (2018) where teachers reported a deficiency of significant collaboration among the diverse parties in school and the inadequate time to implement STEM activities which all result in implementing STEM as an activity per term or as an extra-curricular activity. Hence, this reflects the teachers' request for more collaborative STEM sessions in question two to overcome STEM challenges and better implement integrated STEM.

4- *Did you receive professional development to support you in STEM education in your school? and how often?*

The elementary teachers' answers came different to this question. Most of the teachers claimed that they often receive support (training, workshop) from their schools. Yet, they asked for specific STEM related PDs to enhance their knowledge and practices in STEM education. The revealed findings validate the teachers' answers in question two when they asked for more PDs to overcome their STEM challenges. Forawi (2020) claimed that elementary teachers in the UAE face many challenges such as the lack of content knowledge in science.

These findings are consistent with those of Goodnough, Pelech and Mary (2014) where elementary teachers asked for PD to increase their competences in STEM education. They also mirror those of Goodnough, Pelech and Mary (2014) where elementary teachers required PDs that provide effective collaborative, relative, and contextual opportunities to meet their needs in STEM education.

Guskey and Yoon (2009) stated that in STEM, the context is as important as the content. Han, Capraro and Capraro (2015) claimed that PDs enhance the teachers' STEM skills and practices and empower them to deliver successful STEM education. PDs also support the teachers, motivate them, and clarify their misunderstanding of STEM content and core concepts (Hammack & Ivey, 2019) especially if they are delivered over a lengthy period of time (Fisher, Frey & Pumpian, 2012).

However, few teachers asserted that they receive little support or no support at all from their school related to STEM education, e.g., *"once in a year or none related to STEM design"*. These findings are in agreement with those of Malaka (2018) where most of participants claimed that they do not receive PDs related to STEM education. Additionally, they highly support those

of Shaer, Zakzak and Shibl (2019) who claimed that teachers in the UAE have a lack of structured training in STEM education which obstructs their deliverables.

Parker (2011) asserted that professional development supports teachers in STEM teaching and learning, especially if it focuses on teachers' content knowledge, pedagogical needs, curriculum needs, and collaboration and if it is linked to students' learning. Forawi (2020) added that delivering professional development for teachers to explore STEM as an integrative approach to learning by focusing on student-centered and problem-solving techniques in order to meet the twenty-first-century skills requirements and to recognize its importance in motivating students in teaching and learning is considered a significant factor for an effective STEM implementation.

5- How often did your students participate in STEM competitions? and what are types of competitions your students participate in?

In this question, few teachers asserted that their students participate in coding and robotics competitions between schools or on a national level. These claims reflect those of Forawi (2020) who stated that students' interests in science and STEM related areas are sparked in their participation in school projects or via rare STEM programs in the UAE such as the Advanced Technology Investment Company (Mubadala Investment Company, 2013).

This finding aligns with the UAE Government's National Agenda that aims to foster students' innovation, creativity, and ambition by encouraging them to put their STEM knowledge to the test and to compete on a national level to find practical solutions to real-world challenges. These practices empower the students' minds and help developing future leaders become capable to contribute to the UAE economy and to embrace the evolving technological world we live in (Abu Dhabi University, 2021; Fouad, 2018).

However, most of the teachers agreed that their schools rarely do or do not participate at all in STEM competitions at a school level or at national level. Barcelona (2014) and Munn et al. (2018) asserted that participating in STEM competitions and celebrating STEM students' wins spark the students' motivation, enjoyment, and interest in STEM areas. Also, it allows them to be highly engaged in scientific discussions and experiments. Moreover, STEM competitions and celebration help the STEM scholars to identify what works and needs to be improved in STEM

education. Furthermore, Forawi (2020) stated that STEM competitions enhance the students' interdisciplinary research skills and outline their career choices.

5.2.2 Students' Perceptions of STEM Education

The subsequent section provides the discussion related to the students' perceptions of elementary STEM education and their interest in STEM careers in private elementary schools in Abu Dhabi based on the findings from the student questionnaire instrument. Students' perceptions of STEM education and their interest in STEM careers were interpreted and discussed in a comprehensive way in this section in the light of previous research findings related to students' STEM perceptions to give explicit meanings to the revealed results. The purpose was also to gain a better insight of how the elementary students perceive the four STEM disciplines (science, technology, engineering, and math) and to decipher their state of interest in STEM careers in private elementary schools in Abu Dhabi.

Results of the quantitative analyses derived from the statistical means of the student questionnaire revealed various significant outcomes. In general, students reported positive perceptions on all STEM subscales (science, technology, engineering, math).

Descriptive analyses revealed that elementary students from different ages, grade levels, and genders who attend the STEM schools in Abu Dhabi have positive perceptions about STEM education and they are interested in STEM careers. This reflects students' positive views of STEM education in private elementary schools in Abu Dhabi. These analyses match those of Rehmat (2015) and Ugras (2018) who claimed that students perceive STEM education positively and they consider it a motivating teaching strategy that improves their creativity in STEM areas and contributes to their future career choices.

The elementary students were more favorable of engineering and math disciplines compared to science and technology disciplines. These findings are likely to be the result of the focus of elementary teachers on mathematics and literacy in most of the instruction time due to the stress on standardized tests (Rosenshine, 2015) or because students receive much more instructional time in mathematics as opposed to science (Bush et al., 2020). These results could also be related to the challenging problems the science education is facing in the UAE, such as sustainable curricula, teacher training, and implementation (Forawi, 2020).

Nevertheless, the teacher has to give more attention to science and technology disciplines in elementary classrooms as evidence shows that STEM skills built starting from the early learning years help students in developing the required knowledge to prompt an interminable STEM understanding and proficiency (Rosenshine, 2015). Moreover, a decrease in educational time for science education is problematic as studies revealed that interest in science careers develop in K-12 schools (Madani, 2017).

The students considered the four STEM disciplines exciting, but they considered math and science more challenging and less interesting compared to engineering and technology disciplines. A similar phenomenon occurred in Marasco and Behjat (2014), Razali et al. (2018), and Mun and Hertzog (2018) studies which revealed that elementary students perceive math and science subjects as too challenging, difficult, and uninteresting. Yet, enjoyment and interest are considered crucial factors that affect the elementary students' perceptions of STEM. Enjoyment and interest can be fulfilled by integrating music and art into STEM activities (Hwang & Taylor, 2016; Srikoorn, Hanuscin & Faikhamta, 2017) or by introducing STEM-focus extracurricular robotics programs (Bentley, 2021; Ching et al., 2019). It can also be achieved by involving elementary students in more active learning approaches that sustain their interests in STEM subjects (Shahali et al., 2019) such as learning mathematical concepts and science via engineering-design methods (Firdaus et al., 2020) or through web-based systems that offer students flexible instructional tools that provide students prompt feedback to enhance their learning process (Forawi, 2020).

Research had shown that students who demonstrate high interest in science, mathematics, and engineering in the early years of their educational journey are more likely to pursue that interest resulting in a STEM-related career (Roberts et al., 2018).

In parallel, Forawi (2020) asserted that the investment in science and math education through a systematic science education reform with cultural and contextual connections and with continuous follow-up and evaluation, helps in elevating the UAE to the upper ranks in global index. While Madani (2017) asserted that the UAE government's commitment and support along with curricular reforms are mandatory to improve the science and math education in the UAE in order to inspire students in STEM and motivate them to pursue STEM careers.

Moreover, results revealed that there were significant, strong, and positive correlations between the students' overall perceptions of STEM education and all the three STEM domains: math, technology, and engineering. However, the strongest positive correlation was found between the overall perception of STEM education and the engineering discipline; whereas, the least positive and moderate correlation was found between the overall perception of STEM education and the science discipline. These results were consistent with those of Lewis (2005) and Ayaz and Sarikaya (2019) who claimed that design-based engineering activities promote the students' perceptions of STEM education.

To promote the positive students' perceptions of engineering, teachers have to integrate it effectively in STEM education by understanding the nature of engineering practice which is a decision-making process or a way of thinking to identify, evaluate, and solve problems to meet a desired performance or objective by taking into consideration the identified set of constraints (Dym, 1999). Then, teachers need to involve in their practices and classrooms cooperative and problem-based learning, hands-on and engaging learning experiences that foster the students' comprehension in STEM education, and a curriculum that recognizes the interaction between scientific concepts and engineering as these connections are evident and needed for students to perceive how the real- world works (Purzer, Strobel & Cardella, 2014).

In order to promote the students' perceptions of science discipline in specific and the overall perception of STEM, Midrack (2019) and Park, Wu and Erduran (2020) encouraged teachers to approach the science subject in science classrooms by integrating mathematics, engineering design, and technology. On the other hand, Jarrar (2020) demonstrated the efficiency of implementing STEM PBL on the elementary students' perceptions and achievement in science. Nonetheless, Dou et al. (2019) emphasized the necessity of participating in science experiments in elementary levels to raise the students' overall perception of science subject and their likelihood of pursuing STEM majors and careers. However, Komalawardhana, Panjaburee and Srisawasdi (2021) suggested the implementation of mobile-game-based learning systems as they proved their effectiveness in improving elementary students' perceptions towards science education.

Thomas (2016) highly suggested that the teachers should utilize the efficient concept mapping approach to learning science concepts. This constructivist teaching and learning strategy

has the potential to promote meaningful learning and longer retention of knowledge and to enhance the students' cognitive skills. Whereas Forawi and Abdallah (2019) called for learning opportunities that grant elementary students to apprehend the science process and content in the UAE.

On the other hand, The NGSS (2013) articulated and discussed the significant role of engineering in promoting science education and included engineering concepts as part of the science academic standards.

Furthermore, a positive and moderate correlation was found between the engineering discipline and the math discipline as well as between the engineering discipline and the technology discipline indicating that combination of these disciplines is significant for the students' overall perceptions of STEM education. These results emphasize the efficiency of integrating the engineering discipline while approaching and teaching other scientific disciplines in elementary levels and they pinpoint its significance in enhancing the overall students' perceptions of STEM education.

These findings were consistent with Wang and Chiang (2020) findings which posited that integrating engineering in STEM education is an effective way that provides the students with authentic experiences and it improves their twenty-first-century skills besides promoting their overall attitude towards STEM and especially towards mathematics. Additionally, integrating engineering is essential in STEM education at elementary level as it promotes teamwork and enhances the students' twenty-first-century skills by exposing and engaging them in authentic and interdisciplinary problems. It similarly enhances the students' attitude towards STEM careers by offering them opportunities to address and understand problems via rich and engaging authentic experiences. Additionally, engineering facilitates STEM integration and the students' learning of mathematics and science by providing them a fun framework that integrates the different STEM disciplines and hands-on settings that imitate the real-world context (Hirsch et al., 2007; Koszalka, Wu & Davidson, 2007; Purzer, Strobel & Cardella, 2014).

Furthermore, results from the student questionnaire analyses revealed that the students' perception of math discipline was the greatest contributor to the students' overall STEM perception. This means that any perception change at math level, largely impacts the overall students' perception of STEM education. This result was consistent with Maass et al. (2019)'s

findings which posited that there is a strong connection between math education and STEM education. Du Sautoy (2009) portrayed Mathematics as the Queen of Science and the main driving force behind scientific discovery. Yet, Delaney and Devereux (2020) considered mathematics as a skill that has to be included in the STEM focus to enhance the students' twenty-first-century skills, to improve their academic achievement, and to promote their abilities to deal with real-life situations. Consequently, exposing students to math concepts starting from the early years and fostering them via student-centered and STEM strategies do not only enhance the students' overall perception of STEM education, but it also helps the students achieve better academically and acquire the mathematical skills and the twenty-first-century skills needed to deal with the changing world (Delaney & Devereux, 2020; Fouad, 2018; Jarrar, 2020; Maass et al., 2019).

Hence, the analysis of Pearson Correlation Coefficient test revealed there was significant, strong, and positive correlation between the students' overall perceptions of STEM education and their interest in STEM careers. This finding was consistent with Cho (2013), Chesky and Wolfmeyer (2015) and Razali et al. (2018) results which emphasized that STEM education prepares the STEM workforce and with Thi To Khuyen et al. (2020) findings which posited that the sustained STEM education implementation inspires students for future STEM careers and contributes to the targets of sustainable development goals (SDG 4).

However, for quality STEM implementation, higher STEM perception, and better preparation for STEM workforce, studies revealed that students have to be exposed to math concepts starting from the early years, be engaged in authentic and interdisciplinary problems via engineering experiences, as well as acquire a decent mastery in science discipline that can offer them a clear view to fulfill future STEM careers (Christensen & Knezek, 2017; Delaney & Devereux, 2020; Lin et al., 2018; Maass et al., 2019).

Additionally, the students need to be provided with enough time to think and process in STEM classes (Al Quraan, 2017). They also need to discuss STEM careers with STEM professionals (Wyss, Heulskamp & Siebert, 2012). By doing so, the elementary students' perceptions of STEM education increase and their interest in pursuing STEM careers increases accordingly.

The development of the students' STEM career interest is highly needed in the UAE, especially in private schools in Abu Dhabi where findings of this study revealed that the students' perceptions towards interest in STEM careers scored the least.

Summary of Research Question 2 Discussion

This section discussed the explored teachers' and the students' perceptions of STEM education in STEM private elementary schools in Abu Dhabi in order to answer question two of this study. In a nutshell, the results of the discussion revealed that the majority of elementary teachers have positive views of STEM education, they have a good understanding of STEM education and, they strongly agree on the values of STEM competencies. Yet, half of the teachers claimed that they find difficulties in implementing STEM education, especially in implementing an inquiry-based curriculum and they asked for specific STEM related PDs to enhance their knowledge and practices in STEM education. Similar comments were made by Al Basha (2018) and Malaka (2018) in the UAE. Hence, these results highly support those of international studies such as Thi To Khuyen et al. (2020) and Nguyen, Nguyen and Tran (2020) where teachers elucidate a general understanding of STEM education and contemplate STEM competencies as valuable. Findings also match those of Goodnough, Pelech and Mary (2014) where elementary teachers asked for PD to increase their competence in STEM education and where elementary teachers required PDs that provide effective collaborative, relative, and contextual opportunities to meet their needs in STEM education.

Vis-à-vis the elementary students' perceptions of STEM education, descriptive analyses revealed that elementary students from different age, grade level, and gender who attend the STEM schools in Abu Dhabi have positive perceptions about STEM education and they are interested in STEM careers. In addition, they were more favorable towards engineering and math disciplines compared to science and technology disciplines. They considered math and science too challenging compared to engineering and technology disciplines.

These findings were in line with those of international studies such as Rehmat (2015) and Ugras (2018) who claimed that students have positive perceptions towards STEM education and Lewis (2005) and Ayaz and Sarikaya (2019) who stated that design-based engineering activities

motivate the students to learn STEM areas, to enhance their perceptions towards STEM education, and to develop their creativity and social and psychomotor skills. Similarly, results were in agreement with those of Razali et al. (2018) and Mun and Hertzog (2018) who argued that elementary students perceive math and science subjects as too challenging. Findings in this study revealed that there was significant, strong, and positive correlation between the students' overall perceptions of STEM education and their interest in STEM careers. These results were in agreement of those of Cho (2013), Chesky and Wolfmeyer (2015), Razali et al. (2018) and Thi To Khuyen et al. (2020) who argued that STEM education increases the students' interest to pursue STEM careers.

5.3 Discussion of Results of Research Question 3

This section discusses and interprets the answers of primary teachers and students related to their demographic variables to answer the third question of the study which is, "Are there any demographic differences in elementary teachers' and students' perceptions of STEM education in private schools in Abu Dhabi?". The purpose of the third question was to examine significant demographic variables associated with the teachers' and the students' perceptions of STEM education in private elementary schools in Abu Dhabi. The revealed results from the student and the teacher questionnaires showed that the STEM perceptions vary across the participants depending on their background.

5.3.1 Discussion of Teachers' Perceptions Based on Their Demographical Variables

Findings of the descriptive and the inferential statistics reached by the researcher via the IBM SPSS software showed that the teachers' perceptions of STEM education in private elementary STEM schools in Abu Dhabi vary depending on their background. The cross-examining of the demographic variables: gender, age, education background, education level, years of teaching experience, years of experience in STEM, subject taught, instructional grade level, and implemented curriculum revealed different conclusions related to the association of the elementary teachers' perceptions of STEM education in private schools in Abu Dhabi and their background.

According to the revealed findings, the male teachers have a better understanding of STEM education than female teachers in private elementary STEM schools in Abu Dhabi. Findings vis-à-vis teachers' gender and STEM education highly support those of Park et al. (2016) who claim that male teachers have better views of STEM education than female teachers do. However, they contradict Srikoorn, Hanuscin and Faikhamta (2017)'s backgrounds do not influence the teachers' perceptions of STEM education. They also differ somewhat from the findings of Maltese and Cooper (2017), Wahono and Chang (2019), and Wong and Maat (2020) who posit that there is no significant difference between male and female elementary teachers in STEM education and who tout that STEM information and acknowledgment could be equally received by male and female teachers. However, a study with mixed-method research design conducted by Vlasopoulou, Kalogiannakis and Sifaki (2021) at elementary level, emphasized that STEM female teachers have more positive perception and intention apropos STEM education integration and practices in primary schools than male teachers do. Yildirim and Türk (2018) asserted that STEM trainings enhance the teachers' knowledge in STEM in general and promote the female teachers' perceptions of STEM, in specific, especially towards engineering and technology.

Results also revealed that teachers' age group is not considered a significant contributor to the teacher's understanding of STEM education nor a significant contributor to the level of difficulties the teachers face when implementing STEM. However, age is considered a significant contributor to the teachers' perceptions of the value of STEM competencies. The youngest teachers in the study considered STEM competencies as more valuable. These findings contradict with those of Nadelson and Seifert (2013) and Margot and Kettler (2019) who claimed that teacher's value of STEM increases when the teacher's age increases. Yet, they support the findings of Srikoorn, Hanuscin and Faikhamta (2017) who claimed that teachers' age has no influence on teachers' understanding of STEM education and difficulty levels in implementing STEM.

Furthermore, the education background was not considered a significant contributor to the teacher understanding of STEM education nor an influencer of the teacher value of STEM competencies. Yet, it was considered a significant contributor to the level of difficulties the

teachers face when implementing STEM. Findings revealed that science teachers had the least level of difficulties in implementing STEM education among the total subgroups.

The results revealed further that there were statistically significant differences between teachers who teach science subjects and teachers who teach all subjects, indicating that homeroom teachers face a higher level of difficulties in implementing STEM than science teachers do. These results are consistent with those of Al Basha (2018)'s findings which revealed that teachers' majors have significant impacts on STEM implementation and problem-solving practices and teachers with science backgrounds exhibit positive and better practices of problem-solving than teachers with different backgrounds do. On the other hand, the results support those of Wang et al. (2011) and Wong and Maat (2020) who touted that STEM elementary teachers with math backgrounds are more worried and less confident than science teachers when it comes to STEM practices, especially in helping students solve authentic problems. However, findings contradict those of Wahono and Chang (2019) and Thi To Khuyen et al. (2020) who stated that science teachers have a better understanding of STEM education and value more STEM competencies as opposed to teachers with other educational backgrounds.

Interestingly, statistical analysis showed that teachers with bachelor's degrees face fewer difficulties in implementing STEM compared to the teachers with master's degrees. These results broadly support the results obtained by Thi To Khuyen et al. (2020) which revealed that teachers with higher educational background have more difficulties in implementing STEM. Sedlak and Bruce (2010) claimed that younger teachers are generally more aggressive and absorb changes in a quicker way compared to older ones. However, Weinstein (1998) stated that teachers' willingness in engaging in and implementing STEM and their ratings on difficulties in implementing STEM are not related, especially if they have high values of STEM education. Nevertheless, education level was not a contributor to the teachers' value of STEM competencies nor to their general understanding of STEM. These findings contradict the results of Wahono and Chang (2019) and Thi To Khuyen et al. (2020) who touted that teachers with higher educational level have better understanding of STEM education as postgraduate academic enriches their professional growth, extend their abilities to practice STEM, and offers them an ample amount of learning, especially concerning educational innovations. Hite and Milbourne (2018) added that teachers with advanced STEM degrees and qualifications have critical perspectives as they can

foretell issues in STEM education programs and implementation and they can address them with appropriate levels of knowledge, support, and pedagogical strategies for higher programmatic efficiency.

Furthermore, the years of teaching experience variable is not considered a significant contributor to the elementary teachers' STEM general understanding nor to the level of difficulty in implementing STEM in STEM private elementary schools in Abu Dhabi. Yet, it was considered a significant contributor to the value of STEM competencies. Veteran teachers in this study with 6 to 10 years of experience perceived STEM competencies as more valuable than novice teachers. These findings contradict those of Ghaith and Yaghi (1997), Wahono and Chang (2019), and Thi To Khuyen et al. (2020) who touted that novice teachers value the STEM competencies more as opposed to veteran teachers. Researchers emphasized in their studies that the more experience the teachers have, the less they are enthusiastic to adopt new instructional innovations. However, the results in the study broadly support those of Thibaut et al. (2018) who argued that novice teachers express a less positive view of STEM education compared to experienced teachers.

Nevertheless, Srikoorn, Hanuscin and Faikhamta (2017) declared that the teachers' years of experience seem to be inconstantly related to teachers' perceptions and values of STEM education, and the teacher's interest in STEM education may intervene in this inconsistent relationship. Margot and Kettler (2019) affirmed that the value the teachers place on STEM education does not only affect the feeling of readiness to teach STEM, but it also influences the teachers' willingness to implement STEM curriculum. Bell (2016) added that the teachers' perceptions of the importance of STEM education affect the teachers' ability to learn and develop STEM and ultimately the way to teach STEM.

In parallel, the statistical analysis revealed that the years of experience in STEM education was a significant contributor to the level of difficulties the teachers face when implementing STEM. Teachers with more STEM experience face more difficulties than teachers with less experience in STEM education. These results differ somewhat from those of Rozenszajn and Yarden (2014) and Madani (2017) who claimed that experienced teachers have a better positive perception on applying new teaching practices related to STEM education and the ability to coordinate the four STEM areas in their practices compared to novice teachers who

generally depend in their practices on one area of learning. In contrast to Thi To Khuyen et al. (2020) who asserted that novice teachers are more energetic and more exposed to informal learning. They search for information and explore new ways to integrate STEM education; such as, self-learning on the internet and attending STEM workshops and exhibitions as opposed to veteran teachers. Weinstein (1998) asserted that novice teachers are more enthusiastic about and approach educational innovations in an easier way compared to expert teachers who are inclined to stick to and not upgrade the knowledge they already have. However, Parker, Kruchten and Moshfeghian (2017) stated that when the teachers' years of experience in STEM increase, the teachers' readiness to STEM implementation increases, but only if they value STEM education, and if not, the increasing number of years of experience does not affect the teachers' feelings of readiness to teach STEM.

Additionally, statistical analysis demonstrated that the teaching level is considered a significant contributor to the teachers' value of STEM competencies and to the general understanding of STEM education. In this study, lower primary (grades one and two) teachers showed a better understanding of STEM education and advocated STEM competencies as more valuable compared to upper primary teachers. However, the teaching level is not considered a main contributor to STEM difficulties. These results differ somewhat from those of Srikoorn, Hanuscin and Faikhamta (2017) and Park et al. (2016) who stated that lower primary teachers feel unprepared to teach STEM and tend to have more difficulties in implementing STEM education compared to upper-primary teachers.

Lastly, results in this study revealed that elementary teachers find difficulties in implementing STEM curricula. Teachers who implement STEM in every lesson in both British and American schools find more difficulties to implement STEM curricula compared to teachers teaching STEM with different frequencies. These findings highly support those of Al Basha (2018) who claimed that although teachers in private American system schools in the UAE were well-informed of inquiry learning and scientific literacy related to STEM implementation, they, nevertheless, showed difficulties in implementing core concepts required for STEM implementation. Al Basha's teachers complained about a dearth of professional training in STEM, a lack of STEM resources and funding, a deficiency of significant collaboration among

the diverse parties in school and inadequate time to implement STEM activities which all result in implementing STEM as an activity per term or as an extra-curricular activity.

In general, studies reveal that the integrated nature of STEM education is not flexible (Margot & Kettler, 2019). In addition, combining an inflexible curriculum along with curricular plans is challenging to teachers (Bagiati & Evangelou, 2015; Lesseig et al., 2016). El-Deghaidy (2017) touted that teachers worry about creating STEM-based curricula with teachers from other subject areas and about STEM curriculum ability to disclose fruitful learning (Asghar et al., 2012).

A clear, supportive, and integrative curriculum with adjusted targets under STEM implementation is mandatory for effective STEM practices. Lehman, Kim and Harris (2014) claimed that the presence of a quality, coherent, rigorous, inquiry-based, well-defined, flexible, and experiential integrated 21st century STEM curriculum design which is founded on STEM concepts, tightly driven by standards, and compelled with clear goals and objectives would help the teachers in implementing STEM and would improve the quality and the efficiency of STEM practices. Alumbaugh (2015) argued that for a STEM curriculum to be selected as a highly effective STEM elementary curriculum, it should meet specific criteria. For instance, the curriculum has to be challenging, experiential, and inquiry-based with clearly-defined objectives and assessment where educational goals are well-defined and attainment is measured against them.

Roche et al. (2021) advised teachers to play the role of facilitators and to apply student-centered approaches besides fostering group work in their classrooms. Furthermore, the engineering design process is highly recommended in STEM lessons as it allows for students to utilize their cognition in defining the problem, planning the research, applying different solutions, testing the results, and evaluating their learning (Roche et al., 2021).

In the UAE, STEM curricula need to undergo reforms to meet the growing needs of today and the future society as well as to meet the vision of Mohammed Bin Rashed Al Maktoum's global initiatives (Shaer, Zakzak & Shibl, 2019). For instance, curricula reforms have to take into consideration the urgent need to educate students to be future innovators who can cope with the changing world by involving them in problem-solving and innovative thinking challenges and by sparking their interest in STEM areas via high quality hands-on and real-life-related experiences.

Moreover, the reforms have to be supported by the school administration based on educational standards and policies, and be embraced by STEM teachers through their collaboration and commitment; in addition to continuous training and workshops that focus on their needs to apply the curricula modifications (Barcelona, 2014; Shaer, Zakzak & Shibl, 2019).

To practice effective STEM activities, teachers need to design and apply effective lesson plans which allow the students to seek solutions for relevant real-world issues by making connections between the STEM acquired content in classrooms and the real-world concepts. Hands-on activities fit well the STEM lesson plans as they require the students to build, design, create, role-play, and find solutions for relevant problems by mimicking real-world scenarios. Moreover, collaboration and communication are key to effective STEM lessons.

A study conducted by Malaka (2018) regarding the educational stakeholders' and students' perceptions of STEM practices in the UAE disclosed that STEM implementation in the UAE necessitates further support for teachers via professional training and workshops, adequate time for teacher collaboration, availability of the necessary STEM resources and environments such as STEM labs and campuses, in addition to strong leadership for better guidance. The researcher added that strong coordination among the UAE government, the energy authorities, and the educational institutions contribute to a sturdy STEM reform and an effective STEM implementation.

Moreover, STEM teachers' satisfaction and well-being have to be fulfilled by increasing their wages and by providing them with a welcoming and positive STEM environment with necessary educational resources, STEM labs, and maker-space to implement clear, updated, and practical STEM curricula (Al Basha, 2018; Malaka, 2018).

5.3.2 Discussion of Students' Perceptions Based on Their Demographical Variables

Findings of the descriptive and the inferential statistics reached by the researcher via the IBM SPSS software were discussed in light of the literature review of the study and in relevance to conclusions previously reached via research in STEM education in primary level with an aim to examine the factors associated with students' STEM perceptions and interest in STEM careers in private elementary schools in Abu Dhabi. The cross-examining of the three demographic variables: gender, grade level, and age group revealed different conclusions related to the

association of the elementary students' perceptions of STEM education/ interest in STEM careers and their background.

According to the revealed findings of t-test, there was a statistically significant difference among the mean scores of male and female students towards their overall perceptions of STEM education indicating that gender is a significant contributor in the overall STEM perceptions of elementary students. The results revealed that female students perceive better the STEM education than male students do in private STEM schools in Abu Dhabi. Yet, students' gender did not convey a statistically significant effect on the students' level of interest in STEM careers.

Findings vis-à-vis students' gender and STEM perceptions differ somewhat from those of Iskander et al. (2013)'s, Abdallah (2017)'s, and Bernasconi (2017)'s which stated that boys do express better attitude towards STEM education than girls do. Findings apropos students' gender and interest in STEM careers were not in line with those of Stoeger et al. (2013)'s who reported that males' interest in STEM areas is three times greater than girls' interest, nor with those of Bernasconi (2017)'s who claimed that male students have better skills in STEM careers even though female students reveal higher school accomplishment, or with those of Elizabeth Kurz, Yoder and Zu (2015) who argued that elementary male and female students have similar perceptions towards STEM education. Similarly, the study findings were not consistent with those of Christensen, Knezek and Tyler-Wood (2014) who posited that female students showed higher significant and positive interest in STEM careers compared to male students, but in agreement with Elizabeth Kurz, Yoder and Zu (2015) who contended that elementary male and female students have similar interest in STEM careers.

To promote the students' positive perceptions towards STEM education, Roberts et al. (2018) recommended teaching and learning in informal learning environments which provide context and purpose to formal learning, offer students opportunity and access, and extend STEM content learning and student engagement. On the other hand, Edarabia (2015) asserted the need of fostering the hands-on and Robotics activities at primary levels to learning STEM in the UAE to motivate the elementary students in STEM education through play and problem-solving.

Furthermore, the revealed findings in this study showed that students' grade level was not considered a significant contributor to the students' perceptions of science, technology, engineering, and maths disciplines, nor was it to their interest in STEM careers. Similarly,

findings of the ANOVA test revealed that there was no statistically significant difference among the different grade levels mean scores towards the students' overall perceptions of STEM education, indicating that grade level is not a significant contributor to the students' overall perception of STEM education in schools in Abu Dhabi. These findings reflect those of Elizabeth Kurz, Yoder and Zu (2015) who argued that elementary students have similar overall perception of STEM education and interest in STEM careers.

Moreover, the age group demographic variable was not considered a significant contributor to the students' overall perception of STEM education in schools in Abu Dhabi, nor was it to their perceptions of science, technology, and engineering disciplines, or to their interest in STEM careers. However, age group demographic variable is a significant influencer of the student perception of math in STEM schools in Abu Dhabi. Results of ANOVA test revealed that there were significant differences in students' perceptions between subsamples categorized by age group of math discipline, and conclusions showed that students from 4 to 7 years old perceive math discipline better than students who age 8 to 11 years old. These findings highly support those of Elizabeth Kurz, Yoder and Zu (2015) who stated that lower elementary students have stronger perceptions towards Math discipline when compared to upper elementary students.

To increase the students' perception towards math discipline in elementary schools, Samuelsson (2021) encouraged teachers to implement math related activities that support the students' basic psychological needs for competence, relatedness, and autonomy, whereas, Ching et al. (2019) solicited them to introduce STEM via robotics programs. Bartholomew (2017) asked teachers to involve their students in mathematical practices by encouraging them to contribute with ideas and to make individual choices related to their learning needs in order to enhance their perceptions towards math.

The majority of the conducted and published studies related to students' perceptions of STEM education were mostly related to upper grade levels (Bush et al., 2020; Farwati et al., 2021). Additionally, studies published in the UAE were mostly related to teachers' perceptions and best practices of STEM education (Al Basha, 2018; Malaka, 2018). This increases the academic value of the current study. However, Roberts et al. (2018) shed the light on the importance of the students' academic and social experiences in developing and gaining students' positive perceptions of STEM education at elementary levels, specifically by providing authentic

opportunities to the student to learn through and participate in STEM experiences. Bush et al. (2020) pinpointed the significance of the student awareness of the relevance of the science and math curricula to the authentic problems that are solved in classes for making the world a better place.

Summary of Research Question 3 Discussion

In this section, the researcher discussed the results of the carried out statistical tests related to quantitative data collected via the teacher and the student questionnaires in order to answer question three of this study.

The central points in the first part of this section discussed how teachers' perceptions of STEM education change according to their demographic variables as the generated results in this study indicated that there were statistically significant relationships between the independent demographical variables gender, instructional level, and school curriculum and the teachers' general understanding of STEM education. Moreover, there were statistically significant relationships between the independent demographical variables age group, instructional level, teaching experience, and frequency of implementing STEM and the teachers' value of STEM competencies. Furthermore, there were statistically significant relationships between the independent demographical variables educational background, educational level, instructional subject, teaching experience in STEM, and the frequency of implementing STEM on the third domain of STEM perception which was STEM difficulty level. The obtained findings were discussed and compared to previous related studies. Discussions revealed that findings of this study reflect those of Park et al. (2016), Srikoorn, Hanuscin and Faikhamta (2017), Al Basha (2018), Wong and Maat (2020), and Thi To Khuyen et al. (2020). Yet, they contradict those of Madani (2017), Maltese and Cooper (2017), Wahono and Chang (2019), and Margot and Kettler (2019).

The second part of this section discussed statistical differences of elementary students' perceptions of STEM education based on their demographical variables in STEM private elementary schools in Abu Dhabi. In a nutshell, the executed tests related to elementary students' perceptions of STEM education indicated that statistical differences were found across students

relatable to their gender. Female elementary students perceived STEM education better than male students though the grade level and the age group were not found significant contributors to the students' perceptions of STEM education of elementary schoolers, nor to their interests in STEM careers. The obtained findings were discussed and compared to previous related studies. Discussions revealed that findings of this study broadly reflect the study of Elizabeth Kurz, Yoder and Zu (2015). However, they contradict those of Christensen, Knezek and Tyler-Wood (2014), Abdallah (2017)'s, and Bernasconi (2017)'s.

5.4 Conclusion

The purpose of this study was to explore the current provisions that are on offer in relation to STEM education and to investigate the teachers' and the students' perceptions of STEM education in Abu Dhabi private elementary schools.

Since this study is among the few research studies that had been pursued to investigate the elementary teachers' and students' perceptions of STEM education in the UAE, it endeavored to fill a gap in the literature related to this domain and context.

To meet the purpose of the study, the researcher conducted an empirical study with an exploratory sequential mixed methods design. The mixed research methods included both qualitative and quantitative methods including document analysis, teacher questionnaire, and student questionnaire.

The document analysis reported eight themes related to the STEM provisions and implementation in private elementary schools in Abu Dhabi. The themes were categorized under two categories, interpersonal and structural. The interpersonal implementation themes in this study were the "Teacher willingness to implement STEM", "21st-century skills and STEM", and "School Administration support of STEM integration". The structural implementation themes were the "Integrated STEM-based curriculum", "Project-based learning", "Technology and engineering integration", "Authentic STEM classroom environment", "Authentic STEM assessment", and "School administration support of STEM integration".

All the mentioned themes are considered main factors for an effective STEM implementation and an indicator that reflected a quality of STEM in the STEM private schools in Abu Dhabi. This is key to prepare the national workforce demands in the UAE as they are

directly connected to rigorous STEM education to meet the demands of the rapid technological developments which had driven world labor markets from traditional industry to an innovation-based economy, especially in the UAE, and to better equip the existing generation of students with the academic tenacity to swiftly adapt to fast changes in the workplace and around the world.

The teacher questionnaire helped the researcher investigate and interpret the elementary teachers' perceptions of STEM education via their perceptions of STEM education, STEM competencies, and STEM difficulties. The majority of the teachers in STEM schools in Abu Dhabi revealed positive views regarding STEM education. The majority of the elementary teachers in STEM private schools in Abu Dhabi strongly understand what STEM education is and they strongly agree that STEM competencies are extremely important.

This is agreeable with the UAE 2021 vision which aims to sustain STEM-related areas by stipulating innovative educational standards and developing scholars' critical thinking via the establishment of a high-quality academic system supported by qualified teachers that promotes successful researching outputs that conduce to driving the helm of the knowledge-based economy in the UAE.

However, half of the teachers agreed that they find difficulties in implementing STEM education, especially in implementing an inquiry-based curriculum. Additionally, qualitative data related to the teacher questionnaire revealed more difficulties related to the lack of resources, the constraint of time, and the need for professional development. To promote teachers' perceptions of STEM education and facilitate its implementation to sustain its development in primary schools, the study implied that providing teachers with PDs to handle STEM classrooms, interdisciplinary approaches and strategies, pedagogical content knowledge, and tools, along with curricular reforms, availability of resources and time, and pedagogical collaboration, are a precondition.

These results might be valuable in terms of stipulating implications for elementary education program developers as teachers' perceptions affect and shape their decisions in STEM. Moreover, confident STEM teachers are more effective teachers at integrating and practicing STEM activities, and the execution of better instructions lead to better gain in students' learning.

In parallel, the student questionnaire helped the researcher investigate and interpret the elementary students' perceptions of STEM education in private STEM elementary schools in Abu Dhabi. The majority of the elementary students perceived STEM education positively and they were interested in STEM careers as well. This is significant in the UAE context as fostering STEM starting from the early years is considered significant in the enhancement of the students' motor and social skills. Creating also a passion for STEM fields in young minds pushes the students to be more adventurous, to pursue STEM careers, and to search for solutions for the current challenges in a nation and consequently, to achieve national goals in the future. Yet, students considered math and science too challenging compared to engineering and technology disciplines. Related literature revealed that hands-on approaches, design-based engineering activities, STEM-focus extracurricular robotics programs, and web-based systems that offer students flexible instructional tools and provide them with prompt feedback motivate the elementary students to learn STEM areas, enhance their learning process, promote their perceptions towards STEM education, and develop their creativity, social, and psychomotor skills. Additionally, the UAE investment in science and math education through a systematic science education reform helps in elevating it to the upper ranks in global index.

Moreover, this study discussed how teachers' perceptions of STEM education change according to their demographic variables. The generated results in this study confirmed that there were statistically significant relationships between the independent demographical variables gender, instructional level, and school curriculum and the teachers' general understanding of STEM education as well as between the variables age group, instructional level, teaching experience, and frequency of implementing STEM, and the teachers' value of STEM competencies. Lastly, there were also significant relationships between the variables educational background, educational level, instructional subject, teaching experience in STEM, the frequency of implementing STEM, and the STEM difficulty level.

Furthermore, the executed tests related to elementary students' perceptions of STEM education indicated that statistical differences were found across students relatable to their gender.

Female elementary students perceived STEM education better than male students did. To motivate the students and improve their perceptions of STEM education at primary level,

teachers need to foster hands-on and Robotics activities which enhance the students' STEM learning via play and problem-solving.

Nevertheless, the grade levels and the age groups were not found significant contributors to the students' perceptions of STEM education of elementary schoolers nor to their interests in STEM careers.

The obtained statistically significant findings related to the teachers' and students' perceptions of STEM education and their demographic variables were discussed and compared to previous related studies.

5.5 Recommendations

The purpose of this study was to explore the current provisions that are on offer in relation to STEM education and to investigate the teachers' and the students' perceptions of STEM education in Abu Dhabi private elementary schools. The findings of this study with exploratory sequential design provided valuable insights into STEM education implementation at the elementary level as well as their contribution in several ways to the understanding of STEM elementary teachers' perceptions of STEM education and the difficulties they face in implementing it in private schools in Abu Dhabi. Hence, the results are one of the first findings to identify the elementary students' perceptions of STEM education and interests in STEM careers in private elementary schools in Abu Dhabi.

First, the qualitative thematic analysis in this study contributed to the revelation of the themes related to STEM education in private elementary schools in Abu Dhabi. The themes reflected the existence of STEM-based curricula and the implementation of interdisciplinary STEM practices such as project-based learning. Moreover, they reflected the availability of funding, outside support, and high-quality resources and technology tools in the mentioned schools. Furthermore, learner-centered approaches and learning experiences within an authentic learning environment that promote the students' twenty-first-century skills were evident in the mentioned schools as well as the teacher's willingness to implement STEM in authentic ways via real-world projects and the institutional support for teachers and students, on both the structural and the interpersonal levels. All the mentioned themes are considered main factors for an

effective STEM implementation and an indicator that reflected the quality of STEM in the STEM private schools in Abu Dhabi. Therefore, this study contributed to the literature related to STEM education and closed a gap related to the existence of integrated STEM in private elementary schools in Abu Dhabi in the context of the global themes for an optimal STEM implementation identified by Al Quraan and Forawi (2019).

Second, the quantitative data collected via the teacher questionnaire along with the related descriptive and inferential analyses contributed to the understanding of the teachers' perceptions of STEM education in private elementary schools in Abu Dhabi, and to the significant differences among teachers' perspectives apropos to the demographic variables. In a nutshell, the results of the study revealed that the majority of elementary teachers have positive views of STEM education; they have a good understanding of STEM education and, they strongly agree on the values of STEM competencies. Yet, half of the teachers claimed that they find difficulties in implementing STEM education.

Based on the study results and the related literature, the following are key recommendations that can be beneficial to promote the teachers' perceptions of STEM education and to facilitate its implementation at the elementary level.

Schools are recommended to offer STEM elementary teachers PDs. PDs have to be ongoing, contextualized, and customized to align with the elementary teachers' instructional needs and the students' learning needs. Moreover, they have to model STEM practices implemented at the elementary level to help teachers translate STEM theories and curricula into practices. They also have to support teachers in their STEM content, pedagogical, technological, and management knowledge to be able to handle STEM classrooms, interdisciplinary approaches and strategies, and technological tools. Moreover, PDs have to involve STEM careers instructions to help the teachers bridge the gap between STEM in manpower and STEM in education.

In parallel, schools have to give special attention to the availability of STEM resources and to the time for teachers to collaborate, plan, and discuss STEM activities as teachers complained from lack of resources, the constraint of time, and the need to collaborate with other subjects' teachers or like-minded peers who understand and value STEM to facilitate STEM integration. Once the teachers' issues are addressed, their perceptions of STEM education positively increase, and therefore, the students' motivation in STEM areas increases.

The STEM elementary teachers find challenges in finding methods to assess the integrated STEM projects which are of non-traditional nature in private schools in Abu Dhabi. This is due to the absence of a unified framework of STEM application, the lack of quality assessment for STEM implementation, and the severe deficiency in valid and reliable instruments to assess the students' comprehension of STEM content and the outcomes of STEM intervention and classroom practices. Related literature suggested that students' learning has to be assessed via formative assessments as they suit the nature of the STEM learning process. Therefore, STEM stakeholders are recommended to deliver workshops related to formative assessments that focus on students' learning process for teachers to apply them effectively and continuously. Hence, these workshops should aim at promoting their abilities in developing formative assessment tasks and rubrics to evaluate the students' deliverables towards the STEM educational goals and to increase their understanding of STEM education.

The majority of the teachers in this study had a general understanding of STEM education. Yet, few were still unable to define it correctly. Related literature asserted that STEM elementary teachers have to be knowledgeable in STEM education and well informed about the advantages of STEM education at primary level to engage, inspire, and nurture the students' interests in STEM areas. Therefore, schools are recommended to hire teachers with qualifications related to STEM disciplines and STEM pedagogy to ensure they are equipped with content and pedagogical knowledge necessary for effective STEM integration and practices. If not, periodic PDs are a precondition for teachers to enhance their STEM content and pedagogical knowledge.

Third, the quantitative data collected via the student questionnaire along with the related descriptive and inferential analyses contributed to the understanding of the students' perceptions of STEM education in private elementary schools in Abu Dhabi as well as to the significant differences among students' perspectives apropos to the demographic variables. In a nutshell, the elementary students of different ages, grade levels, and gender who attend the STEM schools in Abu Dhabi have positive perceptions about STEM education and are interested in STEM careers. However, they were more favorable towards engineering and math disciplines compared to science and technology disciplines, and they considered math and science too challenging as opposed to engineering and technology disciplines. Therefore, elementary teachers are recommended to implement STEM via hands-on approaches, design-based engineering, and

robotics activities to enhance their students' learning process and to promote their perceptions towards STEM education. These strategies were identified by the literature as critical to successful STEM education at the primary level, especially if they are implemented via play and problem-solving. Training and workshops are keys to preparing the math and science teachers to design and practice instructional activities for effective STEM integration.

Furthermore, the related literature and the proposed framework of this study highlighted the significance of creating a passion for STEM fields in young minds in pushing the students to pursue STEM careers and to search for solutions for the nation's challenges to achieve national goals in the future. However, a minimal number of private schools in Abu Dhabi implement STEM education. Therefore, the federal government has to push STEM education from primary schools to higher education via cultural and ideological transformations within UAE schools to prepare the students for the jobs of the future, to foster their critical thinking skills to keep up with the rapid changes of the job sectors, and to guarantee the graduation of scientists and engineers who will help in achieving the UAE national goals. Furthermore, related literature asserted that parents have an influence on their kids' interests in STEM careers by exposing them to STEM at an early age (Fomunyan, 2019). Therefore, parents should be familiarized with STEM via schools' authorities. For instance, STEM parents' seminars that introduce and discuss the significance of STEM in the students' daily life and future careers can help in promoting the parents' STEM education awareness, in changing their cultural dynamics, and consequently, in enhancing their kids' STEM career awareness.

Moreover, studies related to STEM practices emphasized the role of competitions in empowering the students' minds and in helping develop future leaders by allowing them to be highly engaged in scientific discussions and experiments. Therefore, schools' authorities are advised to plan and implement STEM fairs and competitions to engage the students in interdisciplinary research skills and outline their career choices without forgetting the importance of awards for excellence to better motivate the students in STEM (Fomunyan, 2019).

Additionally, numerous areas of research were identified through the recommendations associated with future research to investigate and promote the elementary teachers' and students' perceptions and implementations of STEM education at the elementary level.

Because of the dearth of elementary STEM supporting studies in the UAE, more studies are needed in the STEM education field in the UAE, especially at the elementary level to provide a broader picture about STEM perception and implementation at this stage. An urge for additional local research is essential to identify the gaps related to elementary STEM education. The purposes are to enhance the STEM education implementation in the region, to carry on with the exponential growth of the UAE and the rapid technological development, to better equip the existing generation of students via rigorous STEM education with the academic tenacity to swiftly adapt to fast changes in the workplace and around the world, and to help in meeting the “Excellent Education” pillar of the UAE centennial which aims to place the UAE between the best countries in the world by 2071 by focusing on STEM subjects such as engineering, technology and science (Pillars of UAE Centennial 2071, 2021). Therefore, this study could be replicated by incorporating larger samples of elementary students and teachers from different STEM private schools from different Emirates. First it should be done to confirm its discoveries, and second to acquire a broader idea about STEM elementary perception and implementation in the UAE, especially that STEM education is key for effective implementation of the UAE's Fourth Industrial Revolution Strategy (2022).

This study contributed to the literature related to STEM education and closed a gap related to the existence of integrated STEM in private elementary schools in Abu Dhabi in the context of the global themes for an optimal STEM implementation identified by Al Quraan and Forawi (2019). Yet, an area to be considered by future researchers is to analyze and determine the overall level of STEM implementation in each private school in Abu Dhabi in the context of the domains of the Indiana evaluation STEM implementation rubric.

This study did not include interviews of elementary students and teachers attending STEM private elementary schools in Abu Dhabi. Future research to consider includes interviews to gain better qualitative insights from the participants on their perceptions of STEM education and the difficulties they face in implementing it and to improve the validity of the study.

Moreover, classroom observation of STEM elementary classes is recommended to present an extensive description of the STEM practices in the mentioned schools and to validate the findings of this study.

Additionally, further research to investigate teachers' and students' perceptions of STEM education in STEM schools in Abu Dhabi at the middle and high school levels would complement this study. It would also offer insights into the vertical alignment of integrated curricula in the mentioned schools, help researchers pinpoint challenges that hinder STEM integration efficiently, and offer insights to STEM stakeholders to better integrate STEM education in order to sustain its development in the UAE. Indeed, sustaining STEM education integration needs a collaborative effort.

Furthermore, a comparative study between this study and a replicated study in STEM elementary governmental schools would unveil differences and similarities between the practices, integrated curricula, and STEM stakeholders' perceptions in private and governmental elementary schools.

Lastly, further research on elementary STEM education would add to the literature related to STEM education integration, perceptions, development, assessment, challenges, and sustainability at the elementary level in the UAE.

5.6 Limitations of the Study

Every research has its limitations, especially research in the education field. Creswell and Poth (2013) defined limitations as aspects that affect the degree of trustworthiness of a study and the generalization of its revealed results. In the present study, the researcher was keen to follow proper procedures to abate its limitations. Hence, several limitations appeared while conducting the research. The limitations were out of control of the researcher.

First, although the online student questionnaire was simple, easy to complete, and effective in reaching a larger number of elementary principals, the majority of them refused to participate in this study via their elementary students which impacted the sample size and the response ratio in the students' section. A larger sample size would improve the representation of the student population for all variables, and would yield to more reliable, accurate, and valid results (Collie, Shapka & Perry, 2011). Additionally, convenience sampling was utilized in this study to collect quantitative data from STEM schools in Abu Dhabi. This affected the generalization of the findings to the larger STEM schools' population.

Similarly, the collected data were amassed from the American and the British schools in Abu Dhabi as other schools refused to participate in this study. This led to a context-specific data and limited the generalizations of the findings. Therefore, different findings and conclusions might be revealed if the study is conducted in different contexts.

Second, two cross-sectional surveys were utilized to examine the teachers' and students' perceptions of STEM education in private elementary schools in Abu Dhabi at a certain time. Therefore, this study gave a snapshot of the STEM teachers' and students' perceptions of STEM education, and yet, a follow-up study has to be reproduced over time as the teachers' and students' perceptions of STEM education might change in time (Pynoo et al., 2012), especially in the UAE where STEM is still considered new and flourishing in the education field.

Third, the research data, in all stages, was collected by the researcher via self-reported scales. The researcher made sure to accurately and objectively describe, report, and interpret the study results by being authentic and transparent and by continuously and critically self-reflecting on the findings. Yet, the study results might be affected by the inevitable level of common method bias even though the researcher followed adequate measures throughout the whole research (Podsakoff et al., 2003).

Lastly, this study has a mixed-method design that despite all its advantages, it held few disadvantages such as the requirement of extra resources and a longer time to be completed (Johnson & Christensen, 2012b). For instance, the researcher had an intention to explore the teacher- students' practices of STEM education in their natural context via classroom observation to answer a question related to STEM practices in private elementary schools in Abu Dhabi which is "What are the elementary teachers' and students' practices of STEM education in private schools in Abu Dhabi?". A classroom observation checklist (Appendix 4) was the tool to be utilised to collect data and the Krathwohl (2009)'s three main stages were to be utilised to analyse the recorded personal notes, the field notes, the classroom activities and their relation to real-life scenarios, the students' involvements and input, and the teacher-students' interactions (Merriam, 2009). Whitebread et al. (2009) described the classroom observation checklist as a

practice employed by the researcher to observe definite comportments, skills, and dispositions of the learners in their classrooms' settings. The checklist was developed by the researcher based on the literature review and the conceptual framework of the study. It accentuated key indicators to focus on during the classroom observation, such as evidence for PBL and IBL implementation, student behavior in STEM classes, student STEM skills, student collaboration, teaching practices, STEM classroom setting along with STEM resources, curricula, plans, and materials

The checklist was divided into three sections. The first section emphasized evidence for PBL integration across STEM subjects (observation of students-teachers' interactions in STEM classes to identify if students are communicating and brainstorming via self-learning approach; if students are collaborating in an effective way to solve the learning issues; if students are highly engaged in hands-on activities; if students are solving messy problems via trial-and-error problem solving method; if the hands-on activities are related to real-life problems; if the teachers are playing the role of facilitators; if students and teachers are interacting in an effective way; if teachers' feedback is effective and intends to adjust the students' learning; and if students share their findings based on clear rubrics/ success criteria). Hence, the second section stressed on evidence of IBL integration across STEM subjects (observation of the teachers-students' practices in STEM classes to identify if students construct their scientific knowledge through student-centered approach; if students are curious and work actively; if students are enabled to think critically; if students are enabled to ask investigative questions; if students are enabled to observe, hypothesize, and carry out investigations as scientists; if students are enabled to gather evidence, explain and justify their results as scientists; if teachers verbally affirm the students in a positive way; if students learn in a safe learning environment; and if students are assessed at various levels). Thus, the last section underlined evidence related to STEM curricula, teachers' plans, STEM environment, and STEM resources (to understand if STEM is integrated by combining Science, Technology, Engineering, and Math disciplines; if STEM topics are connected to real-world problems; if STEM is approached via PBL, IBL, or PjBL; if STEM lessons are swathed with collaboration and higher order thinking skills; if STEM physical environment is safe; if STEM environment is rich in resources that excite and inspire the students; if STEM resources enhance the visualization and the fine motor skills of the students; if the teacher's plan endorses continuity, progression, and sustainability; if the teacher's plan is

endorsed with clear guidelines and learning outcomes; if the teacher's plan is endorsed with differentiated instructions; if the teacher's plan identifies the challenges of the topic with their solutions; and if STEM students' success is celebrated).

To ensure the validity of the classroom observation tool, the researcher piloted it by sharing it with colleagues in the STEM education field to pinpoint any missing point and to suggest modifications. However, no comments were received regarding the classroom observation checklist.

However, due to several factors, such as the covid-19 situation and the school management policies, the researcher was not able to access the primary schools in Abu Dhabi to observe the teacher- students' interactions in their natural context despite the fact that the researcher was granted with an official letter from the BUiD to consent access to schools. Accordingly, the researcher was not able to observe the teacher-students' interactions in their natural classroom settings to attain an overall picture of STEM practices, to identify the presence of the revealed themes by document analysis, to corroborate the findings of the students and teachers' questionnaires, and to answer the last research question.

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Appendix 1

Permission to adopt the Teacher Questionnaire related to teacher perceptions of STEM education from Prof. Chun-Yen Chang in February 25th 2021

Dear Lin and Chang

My name is Heba Chaya, I am a doctoral student at the British University in Dubai, completing a dissertation in STEM education. I am writing to ask your permission to utilize the survey you developed for your study titled “Measuring Teachers’ Perceptions to Sustain STEM Education Development”. In fact, my dissertation aims to investigate the teachers’ perceptions of STEM education in the UAE and I will be much grateful if I can adapt your instrument in my study. I would appreciate if I can receive a copy of the instrument and a permission to reproduce it in the appendix of my dissertation.

The survey will be used under the following conditions:

- I will use the survey only for my research study and will not sell or use it for any other purposes
- I will include a statement of attribution and copyright on all copies of the instrument. If you have a specific statement of attribution that you would like for me to include, please provide it in your response.
- At your request, I will send a copy of my completed research study to you upon completion and publication of the study.

If you do not control the copyright for these materials, I would appreciate any information you can provide concerning the proper person or organization I should contact.

If these are acceptable terms and conditions, please indicate so by replying to me through e-mail at <heba.shaya@gmail.com>.

Sincerely,

Heba

From: Chun-Yen Chang <changcy@ntnu.edu.tw>
Subject: Re: A permission to utilize the survey instrument
Date: 22 February 2021 at 4:29:35 PM GST
To: Heba Shaya <heba.shaya@gmail.com>
Cc: nguyên khuyển <ntkhuyen.aliza.231@gmail.com>

Dear Heba,

No problem at all and by copy this to Khuyển, she will email you a copy.

Best,

Jim

Sent from my iPhone

Chun-Yen Chang, Ph.D.

NTNU Chair Professor
Director of Science Education Center

Appendix 2
Teacher Questionnaire

Teachers' Perceptions of STEM education

Investigating Teachers' Perceptions of STEM Education in Elementary Schools.

Greetings,

As part of an academic doctoral research project to understand the teachers' perceptions of STEM* Education in elementary schools, you have been selected to answer a few questions about the topic, which I would greatly appreciate should you agree to.

Kindly take a few minutes to respond to the below list of questions.

*STEM: An integrated approach to teaching Science, Technology, Engineering, and Maths.

The questionnaire is anonymous and the collected data are used for academic research only. Besides, confidentiality is guaranteed.

The estimated time to complete this questionnaire is 8 minutes. Thank you for your valuable contribution and for taking the time to complete it.

* 1.

I agree to participate in the teacher questionnaire related to teacher perceptions of STEM education. I totally understand that participation in this research study is voluntary and I may withdraw at any time from this study without any penalty.

☐ Yes

☐ No

Let's start this questionnaire with a few questions about you.

2. Gender

☐ Female

☐ Male

3. Age

☐ Below 25

☐ 25 to 34

☐ 35 to 44

☐ 45 to 54

☐ Above 55

4. Education background

- ☐ Science
- ☐ Maths
- ☐ Technology
- ☐ Engineering
- ☐ Others

5. Level of education

- ☐ BS
- ☐ MS
- ☐ Ph.D.

6. Teaching Experience

- ☐ 1 to 5 years
- ☐ 6 to 10 years
- ☐ More than 10 years

7. Teaching experience in STEM

- ☐ 1 year
- ☐ 2 years
- ☐ 3 years
- ☐ More than 3 years

8. Grade Level

- ☐ Grade 1
- ☐ Grade 2
- ☐ Grade 3
- ☐ Grade 4
- ☐ Grade 5

9. Teaching subject

- ☐ Science
- ☐ Maths
- ☐ ICT
- ☐ All

10. Frequency of the use of STEM in classroom

- ☐ 1 lesson per month
- ☐ 2 lessons per month
- ☐ 3 lessons per month
- ☐ Every lesson
- ☐ Once per term
- ☐ Once per year
- ☐ Other (please specify)

11. The curriculum in which STEM is taught

- ☐ After school program
- ☐ regular curriculum
- ☐ Other (please specify)

12. STEM education in my school is

- ☐ Connection of math and science
- ☐ Connection of science and technology
- ☐ Connection of math, science, and technology
- ☐ Connection of math, science, technology, and engineering
- ☐ Other (please specify)

13. Which curriculum is your school implementing?

- ☐ American curriculum
- ☐ Canadian curriculum
- ☐ Australian curriculum
- ☐ Indian curriculum
- ☐ British curriculum
- ☐ Other (please specify)

Please respond to the statements related to your thoughts about STEM education. In this questionnaire, there is no true or false answer. Your thoughtfulness and candid responses will be greatly appreciated.

* 14. Overall perceptions of STEM education and Values of STEM competencies

	Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
A-The concept of STEM education is teaching about knowledge, skills, and logical thinking related to STEM careers.	☐	☐	☐	☐	☐
B-Teachers can combine optionally science, technology, engineering, and mathematics knowledge in the current curriculum to compose STEM lessons.	☐	☐	☐	☐	☐
C-Scientific inquiry and Engineering design are two main factors in a STEM lesson.	☐	☐	☐	☐	☐
D-STEM education can help students acquire skills related directly to STEM careers.	☐	☐	☐	☐	☐
E-STEM education can help students develop scientific literacy.	☐	☐	☐	☐	☐
F-STEM education can help students develop technological skills.	☐	☐	☐	☐	☐

	Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
G-STEM education can help students acquire critical thinking that is usually conducted by scientists, technologists, engineers, and mathematicians.	☐	☐	☐	☐	☐
H-STEM education can help students acquire authentic problem solving skills to make a decision in the real world.	☐	☐	☐	☐	☐
I-STEM education can help students to better collaborate with each others to execute STEM learning projects.	☐	☐	☐	☐	☐
J-STEM education can help students acquire engineering abilities to make meaningful products (define the needs, design, and make a certain product).	☐	☐	☐	☐	☐

Difficulties in STEM education

* 15. What are the difficulties you face when conducting STEM education in your school?

	Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
K-Need to enhance knowledge beyond your major; related to STEM subfields (Technological, pedagogical, and content knowledge)	☐	☐	☐	☐	☐
L-Difficulty to implement an inquiry-based curriculum	☐	☐	☐	☐	☐
M-Difficulty to authentically assess students' achievement (formative and summative assessments)	☐	☐	☐	☐	☐
N-Difficulty to plan STEM activities	☐	☐	☐	☐	☐
O-Difficulty to manage STEM activities	☐	☐	☐	☐	☐
P-Difficulty to evaluate the suitable approach for each STEM activity.	☐	☐	☐	☐	☐
Q-Insufficient time for students to conduct STEM lessons	☐	☐	☐	☐	☐
R-Need an extra support from school administration, scientists, and advisors.	☐	☐	☐	☐	☐
S-Need to collaborate more with other STEM teachers	☐	☐	☐	☐	☐
T-Need for Professional Development	☐	☐	☐	☐	☐
U-Difficulty in preparing students for national and international STEM competitions (Robotics, Coding, Innovation competition)	☐	☐	☐	☐	☐

Please answer the following open-ended questions.

16. How do you define STEM education?

17. What challenges do you face when implementing STEM education in your classroom?

18. As a teacher, do you collaborate with other teachers to discuss STEM lessons? How often?

19. In your school, did you receive any type of professional development to support you in STEM education? if yes, how often?

20. How often did your students participate in a STEM competition? and what are types of competitions do your students participate in? (Robotics, Lego, Coding,...)

Classroom Observation

In order to explore the STEM teachers' and students' practices of STEM education in private elementary schools, the researcher is required to observe the teacher-student interactions in their natural classroom settings.

Your agreement to participate in classroom observation will be highly appreciated.

21. I agree to be observed along with my students in a natural STEM classroom setting. I understand that there is a risk of loss of privacy and there may be some discomfort of being watched. I totally understand that participation in this research study is voluntary and I may withdraw at any time from this study without any penalty.

- ☐ Definitely I want to participate
- ☐ No, Thank you!

22. Your participation in classroom observation will be highly appreciated. Kindly, write down your email or your contact number (for further communication) if you do agree to participate.

Appendix 3

Student Questionnaire

Students' Perceptions of STEM education

Investigating elementary students' perceptions of STEM education in elementary schools.

This questionnaire investigates the elementary students' perceptions of Science, Maths, Technology, and Engineering subjects.

Your participation is completely voluntary and your answers will remain confidential.

Your approval to participate in this questionnaire is highly appreciated. It should require about 2 minutes of your time.

Thank you.

1.

I agree to participate in the student questionnaire related to student perceptions of STEM education.

I totally understand that participation in this research study is voluntary and I may withdraw at any time from this study without any penalty.

- ☐ I agree
- ☐ I do not agree

2. What is your gender?

- ☐ Female
- ☐ Male

3. What is your grade level

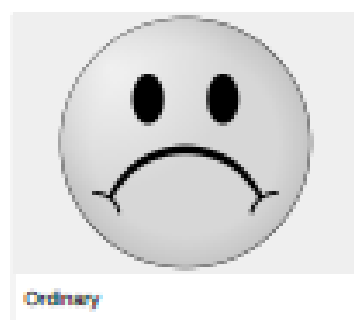
- ☐ Grade 1
- ☐ Grade 2
- ☐ Grade 3
- ☐ Grade 4
- ☐ Grade 5

4. What is your age?

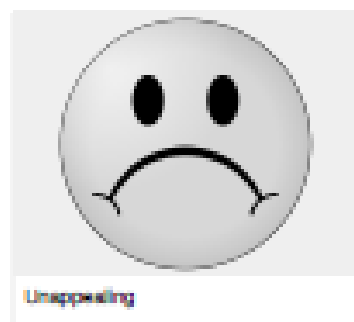
- ☐ 4 to 5
- ☐ 6 to 7
- ☐ 8 to 9
- ☐ 10 to 11

Please answer the following questions. Usually, it is best to respond with your first impression, without giving a question much thought.

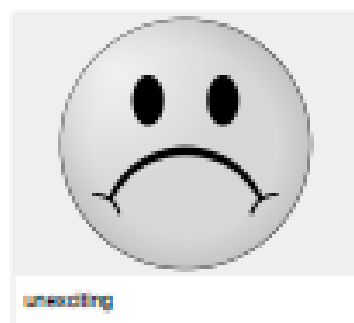
5. To me Science is



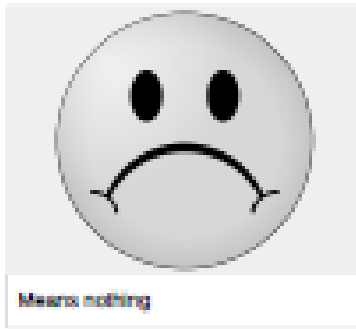
6. To me Science is



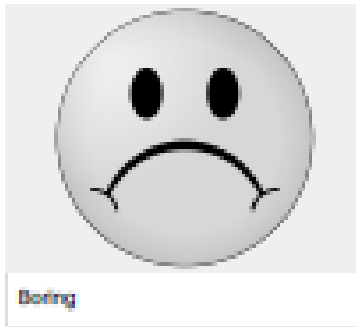
7. To me Science is



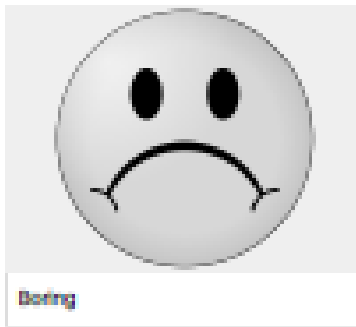
8. To me Science



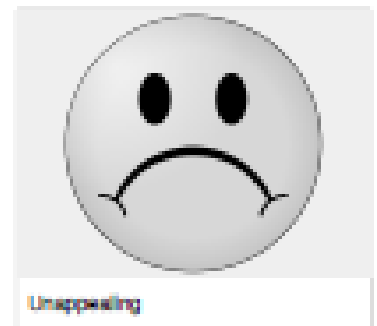
9. To me Science is



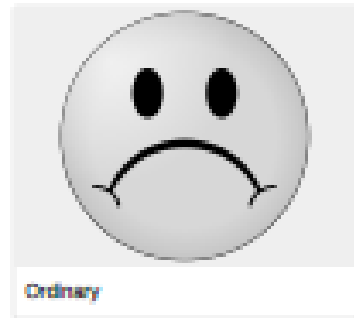
10. To me Maths is



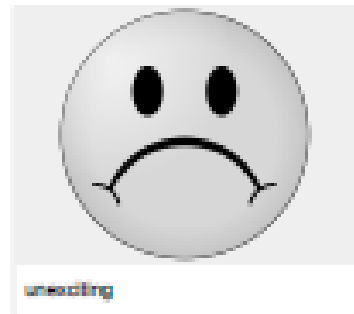
11. To me Maths is



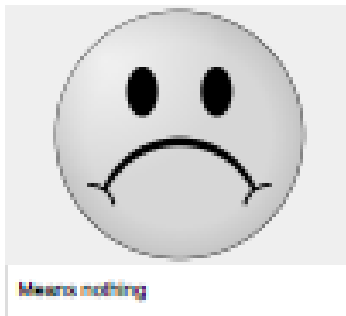
12. To me Maths is



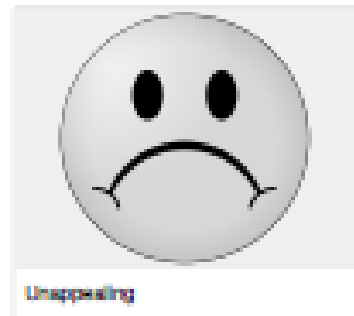
13. To me Maths is



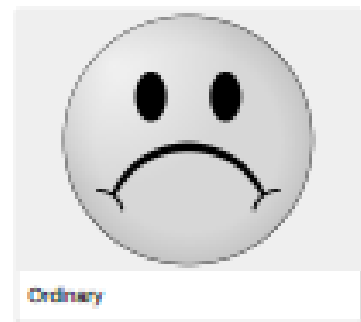
14. To me Maths



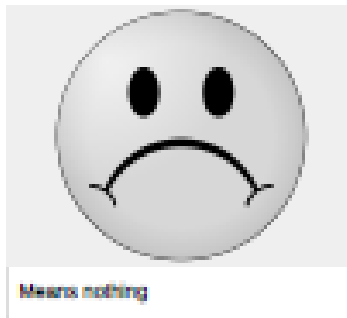
15. To me Engineering is



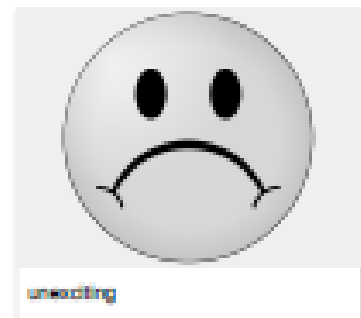
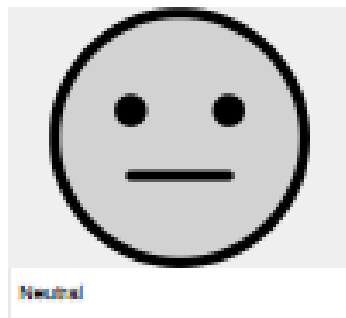
16. To me Engineering is



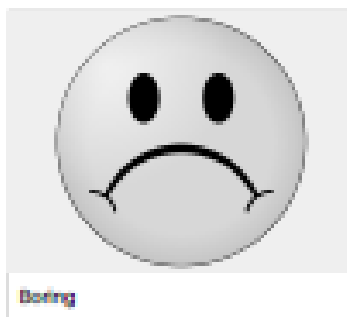
17. To me Engineering



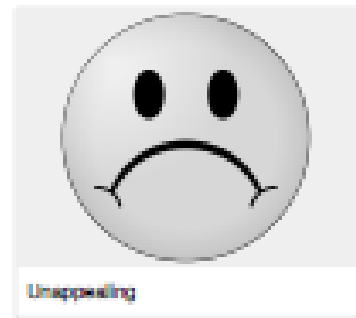
18. To me Engineering is



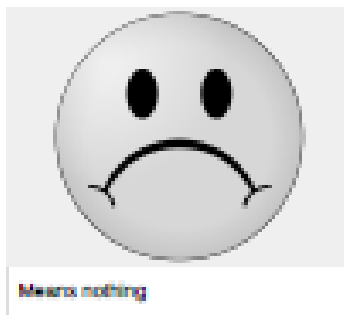
19. To me Engineering is



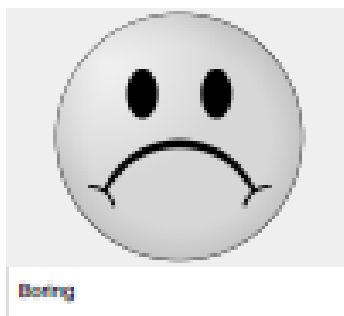
20. To me Technology is



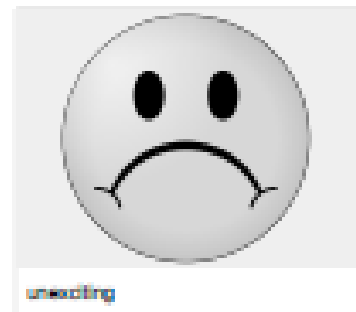
21. To me Technology



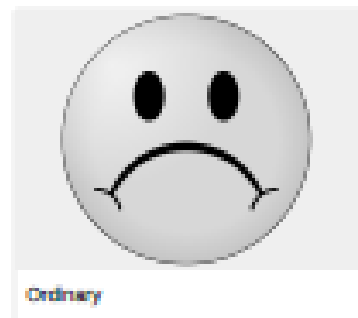
22. To me Technology is



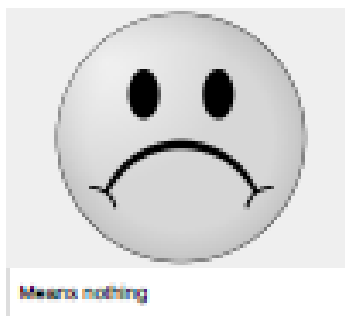
23. To me Technology is



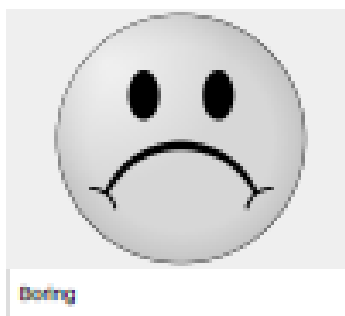
24. To me Technology is



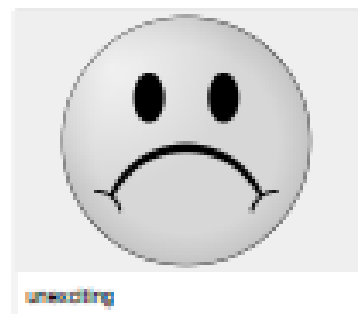
25. TO ME A JOB IN SCIENCE, MATHS, ENGINEERING, OR TECHNOLOGY



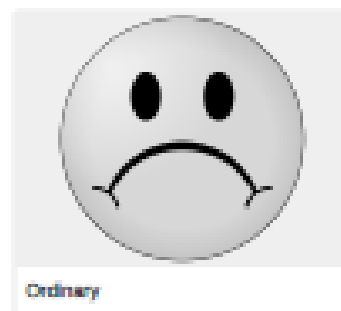
26. TO ME A JOB IN SCIENCE, MATHS, ENGINEERING, OR TECHNOLOGY IS



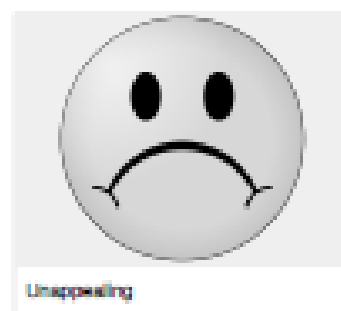
27. TO ME A JOB IN SCIENCE, MATHS, ENGINEERING, OR TECHNOLOGY IS



28. TO ME A JOB IN SCIENCE, MATHS, ENGINEERING, OR TECHNOLOGY IS



29. TO ME A JOB IN SCIENCE, MATHS, ENGINEERING, OR TECHNOLOGY IS



Appendix 4

Classroom Observation Checklist

School Pseudonym	Date/ Time			
Grade Level	Subject			
Session number:	Level of Implementation			
Checkkey indicators list	Yes	Partially	No	Comments
Evident integration of PBL across STEM subjects				
8. Students are communicating and brainstorming via self-learning approach				
9. Students are collaborating in an effective way to solve the learning issues				
10. Students are highly engaged in hands- on activities				
11. Students are solving messy problems via trial-and- error problem solving method.				
12. The hands-on activities are related to real-life problems				
13. Teachers are playing the role of facilitators				
14. Students and teachers are interacting in an effective way				
15. Teachers' feedback are effective and intend to adjust the students' learning				
16. Students share their findings based on clear rubrics/ success criteria				
Evident integration of IBL across STEM subjects				
17. Students construct their scientific knowledge through student- centered approach				
18. Students are curious and work actively				
19. Students are enabled to think critically				
20. Students are enabled to ask investigative questions				
21. Students are enabled to observe, hypothesise, and carry out investigations as scientists				
22. Students are enabled to gather evidences, explain and justify their results as scientists				
23. Teachers verbally affirm the students in a positive way				
24. Students learn in a safe learning environment				
25. Students are assessed at various levels				

STEM curricula, teachers' plans, STEM environment, and STEM resources provide a robust focus on STEM practice.

26. STEM is integrated by combining Science, Technology, Engineering, and Math disciplines
27. STEM topics are connected to real- world problems
28. STEM is approached via PBL, IBL, or PjBL
29. STEM lessons are swathed with collaboration and higher order thinking skills
30. STEM physical environment is safe
31. STEM environment is rich in resources that excite and inspire the students
32. STEM resources enhance the visualisation and the fine motor skills of the students
33. Teacher's plan endorses continuity, progression, and sustainability
34. Teacher's plan is endorsed with clear guidelines and learning outcomes
35. Teacher's plan is endorsed with differentiated instructions
36. Teacher's plan identifies the challenges of the topic with their solutions
37. STEM students' success is celebrated

Descriptive information

Reflective information

 The University of Dubai
 www.buid.ac.ae

To whom it may concern

Dr. Amer Alaya
Head of Student Administration



Appendix 6

Permission to conduct research

Date: XYZ, 2021
For Attention: ABS
Elementary School Principal of () school Abu Dhabi, UAE

Dear Mr./Mrs. ABC

Greetings,

Permission to Conduct Research Study

My name is Heba Chaya. I am developing a doctoral study titled “Investigating Teachers’ and Students’ Perceptions and Practices of STEM Education in Private Elementary Schools in Abu Dhabi” and I am writing to seek your kind permission to conduct the research study at your establishment.

The study will be conducted under the supervision of Professor Sufian Forawi, a professor of Science Education in the faculty of Education in the British University in Dubai, UAE.

Purpose of this study:

One of the furthestmost essential reforms in education is STEM education. It comes as a priority in the well- developed nations’ national agendas as it is acknowledged for preparing scholars for the technological revolution that the world is experiencing.

STEM education has to be implemented from the early years as this period is critical for the children's cognitive development where they come into contact with stimuli that grant to the growth of a conscious perception of how the world works. More, by learning STEM from early years, students can grow communication skills, scientific literacy, and vocabulary use more effectively than commencing to instill STEM in higher schooling years.

STEM teachers are considered as the vanguard of STEM implementation in schools and the leaders who inculcate and train scientists and technologists. Though, few studies were conducted to tackle the elementary STEM teachers’ and students’ perceptions and practices of STEM education in the UAE in general, and in Abu Dhabi, in specific. Therefore, the purpose of this study is to investigate the elementary teachers’ and students’ perceptions of STEM education in elementary schools in Abu Dhabi.

Significance of this study:

This study is significant as its results are estimated to be a strong foundation in elementary STEM curriculum reforms. More, the findings of this study will reveal the extent of STEM implementation and the efficiency of the elementary STEM learning environments in elementary schools as well as the efficacy of the elementary teacher- teaching strategies which are considered valuable factors in terms of attaining student outcomes in STEM education. Besides, the findings of this academic paper will be valuable by adding to the existent literature associated with the effective preparation and professional development of the elementary STEM teachers to sustain the elementary STEM education.

I trust that I will receive your consent to permit your school's elementary STEM- related subjects' teachers (Science, Math, ICT) to complete an online teacher questionnaire related to their perceptions of STEM education. As well as your consent to permit your primary students (G1- G5) to complete an online questionnaire related to their perceptions of STEM education.

I am sharing with you the links of the teacher and the student questionnaires. Upon your approval, please forward the attached link of the online teacher questionnaire to all the elementary STEM-related subjects' teachers (G1- G5) <https://www.surveymonkey.com/r/C3CCZQS> and the following link of the online student questionnaire to the elementary G1-G5 students <https://www.surveymonkey.com/r/TZ63SBS>

The elementary teachers' and students' participations are totally voluntary and there are no identified physical, psychological, or social threats related to this study.

More, your approval along with the STEM-related subjects' teachers' approval to observe the Elementary STEM classrooms in a natural setting will be highly appreciated.

The questionnaires' results, as well as notes of the classrooms' observations will remain completely confidential and anonymous and will be retrieved after being encrypted for the study analysis only. If the study will be published, only emerged results will be documented.

When the study is accomplished, a bound copy of the full research report will be provided to the Department of Education of the BUiD and a copy can be made available to your school, upon your request.

Your agreement to conduct this study will be greatly valued. I will be available to answer any question or concern that you may have at anytime. I can be reached via email (....) or mobile (....).

I will highly appreciate if you can confirm your school participation in this study by November 4, 2021.

Thank you for your time and consideration in this matter. Sincerely,
Heba Chaya.
Doctoral Student

Enclosures: An online teacher questionnaire. An online student questionnaire.

An official letter from BUiD.

Approved by:

Name: Date: Signature:

Appendix 7

Analysis of an ADEK inspection report of a STEM school in Abu Dhabi

Latest Inspection Report

Curriculum adaptation	Outstanding	Outstanding	Outstanding	Outstanding
- The overall quality of the curriculum is outstanding. The school adapts the English National Curriculum very effectively to promote students' rapid language acquisition, ambition and self-reliance. It has been designed imaginatively in all phases to engage students in captivating learning experiences which link curriculum areas very successfully. - The curriculum develops students' learning skills very effectively and promotes continuous and progressive learning between foundation and primary, and between middle and high phases. The curriculum in the foundation stage is occasionally over-structured and this limits opportunities for learning through discovery. The numerous subject options in the high phase helps students align their courses with their career ambitions. - The curriculum has been reviewed and developed to raise achievement. The robust link between teachers' analysis of assessment data and their planning of the curriculum has helped them to successfully meet the needs of all groups of students. The curriculum in foundation and primary phases promotes children's development of English, and this helps them to access the wider curriculum. The curriculum is less well adapted in the Arabic medium subjects to ensure students are progressing at the same rate as in English medium subjects. - The school's rich curriculum is enhanced further by a broad range of extra-curricular opportunities. These are frequently used in a targeted way to build capacities in students which enhance their learning. The 'Academy of Excellence' accelerates and diversifies the learning of high achieving students. Opportunities for innovation, creativity and social contribution are embedded in all curricular areas. - Moral education is delivered expertly through a combination of discrete lessons and planned cross-curricular learning in all subjects and experiences. Students demonstrate their learning in moral education through their outstanding moral character, ambitious attitudes and commitment to the values of the UAE.				

Learning experiences

Rich Curriculum

Assessment

Innovation

Creativity

A

Appendix 8

Open-codes, codes, sub-themes, and themes of document analysis

Open Codes	Codes	Potential Themes	Themes
Students are skilled in peer assessment	Students' abilities to assess their work	Ongoing STEM assessment	Authentic STEM Assessment
Students are skilled in self-assessment	in STEM and their peers' works in STEM		
Students receive regular feedback on their work	Authentic STEM formative assessment		
The assessment procedure is rigorous and consistently applied via international benchmarks and standards.	Authentic STEM summative assessment		
Robust external testing provides information about student achievement			
Robust link between the assessments' results and lesson plans	STEM Study plans based assessments' results	Ongoing STEM curriculum reform	
Teachers use the test information to plan lessons and identify areas of improvement			
Teachers use the assessments' results to adapt the curriculum and meet the learnings' needs of the students	STEM curriculum-reform based assessments' results		
Open Codes	Codes	Potential Themes	Themes
Teachers promote the group activities	Collaboration in STEM activities	21 st century skills in STEM classes	21 st century skills and STEM
Collaboration			
Students work together			
Embracing collaboration in students			
Collaborating in STEM labs			
Global collaborator			
Creativity	Creativity		
Embracing creativity in students	Curiosity		
Critical thinking	Communication		
Embracing curiosity in students	Reasoning		
Natural curiosity	Innovation		
Reasoning			
Communicating information			
Opportunities for creativity and innovation			
Needed skills for the 21st century	21st century skills		

21st century skills

Open Codes	Codes	Potential Themes	Themes
Teachers receive hands- on trainings Workshops for teachers with leading engineers and scientists	Teachers' STEM workshops	STEM Professional development	School Administra- tion support of STEM integration
Student workshop Activities and workshops for students in summer	Students' STEM workshops		
Teachers use a lot of STEM resources to enhance students learning STEM Lab Innovation Lab	Availability of STEM resources	STEM resources	
Raytheon Emirates Exxon Mobil CITI	Innovation STEM partners	STEM Partnership	
Open Codes	Codes	Potential Themes	Themes
Teachers support and empower the students to meet the challenging activities' targets	Teacher support of students in solving STEM- related problems and projects	Teacher support of students in STEM problems and projects	Teacher willingness to implement STEM
Teachers provide the students with the constructive feedback to support their learning needs			
Students receive regular feedback on their work	Teacher support of students to meet their learning needs in STEM		
Teachers provide opportunities for students to critically analyse and use learning for problem solving	Teachers foster STEM problem- solving skills in students	High- quality and knowledgeable STEM teachers	
Teachers use open- ended questions to extend the critical thinking and problem – solving skills	Teachers foster STEM critical- thinking skills in students		
Teachers plan innovative and imaginative lessons that stimulate student interest and engagement	Teachers foster STEM innovative thinking skills in students		
Teachers are skillful in asking questions that promote discussion and debate			

Teachers play the role of a facilitator by asking questions Teachers play a role in enhancing students' creativity	Teachers enhance the STEM inquiry skills of the students	Teachers' readiness to implement STEM	
Teachers plan imaginative and creative lessons	Teachers enhance the creative skills of the students		
Teachers use a lot of STEM resources to enhance students learning	Availability of STEM resources	STEM preparation and implementation	
Teachers provide inspiring learning environment throughout the use of technology and needed resources	Availability of STEM learning environment		
Open Codes	Codes	Potential Themes	Themes
Students learn through discovery Scientific Methods Curriculum includes scientific investigations	Scientific methods	Inquiry based curriculum	Integrated STEM- based curriculum
Curriculum aligned with 2021 vision NGSS Opportunities for creativity and innovation are embedded in all curricular areas Curriculum promotes innovation Extra- curricular activities in STEM Curriculum includes innovation lessons Curriculum includes scientific investigations Curriculum offers learning experiences that develops students' interests Reasoning Think outside the box Innovative designer Transferable skills Curriculum includes innovation lessons Develop skills for better future	Integrated curriculum/ Innovative Curriculum	Innovative STEM curriculum	
Khan Academy, Prodigy, Math workout Science Experiments in science labs Raytheon Emirates Exxon Mobil	STEM Resources	Experiential STEM curriculum	

CITI			
Outdoor science activities	STEM activities/		
Extra- curricular activities in STEM	Outdoor activities		
Experimental scientific investigations			
Knowledge constructor	Learning / Learning		
Less memorisation, more sense making	experiences		
Basic understanding			
Scientific literacy			
Curriculum offers learning experiences that develops students' interest			
Integrated courses	Interdisciplinary	Interdisciplinary	
Cross- curricular links are meaningful	approach	STEM curriculum	
Interdisciplinary approach	Cross- cutting		
NGSS	concepts		
Cross- cutting concepts			
Open Codes	Codes	Potential Themes	Themes
Developing models to explain real-world events	Innovation and creativity via engineering	Inquiry- based curriculum	Project – based learning
Planning investigations	Investigation		
Designing solutions using engineering and technology	Designing / Finding/		
Solving Real- world challenge	communicating		
Analysing data	solutions via		
Engaging in arguments	Engineering and		
Communicating information	technology		
Using evidence for ideas	Learning /		
Making sense of real-world objects	Evidences- based		
Knowledge constructor	learning		
Experiments	Hands- on activities	Project – based	
Experimentation	/	learning	
Hands- on problem solving	Real- world projects		
Hands- on activities			
Cross- functional activities			
Projects related to careers			
Open Codes	Codes	Potential Themes	Themes
Technology	Technology	Technology	Technology
Engineering	/Engineering/	Integration/	and
Robotics	Virtual environment	Engineering	Engineering
Robots		Integration	Integration
Coding			
Building robots			

Bioengineering Students are skilled in ICT Digital citizen Computer science Artificial intelligence		
Teachers provide inspiring learning environment throughout the use of technology and needed resources Career and technology foundation	STEM Engaging environment Technology resources	STEM resources within engaging STEM environments
Raytheon Emirates Exxon Mobil CITI	Innovation partners	
Solve real- world problems Find innovative solutions to complex problems Imagination and ingenuity to create solutions Solve problems Problem solving	Problem solving	Problem – based learning

Appendix 9

A picture of elementary students performing in a STEM lab retrieved from Instagram
(2021)



Appendix 10

A picture of a robotics activity in a STEM lab retrieved from Instagram (2021)



0 likes
[Redacted]

Creating fashion for Robots and tricky Coding.
Will they make it down the runway? 😊👏🤖 ... more

Appendix 11

A picture of elementary students exploring the real world in a natural context retrieved from Instagram (2021)



102 likes

1 in 3 mouthfuls of food we eat is dependent on pollinators. If we lose the pollinators we lose the ability to grow food. The science of pollination is critical to life on Earth. Year 5 showed us just how fun, but also how incredibly important pollination is to life on our precious planet.

Appendix 12

A picture of students collaborating via a hand- on activity in a math session retrieved from Instagram (2021)



87 views · Liked by acsadalumni

mrddickinsonsclassroom Hands on experience with volume!

Appendix 13

A picture illustrating CITI as an innovation partner in a STEM school in Abu Dhabi
retrieved from Instagram (2021)



2021 INNOVATION PARTNER

CITI



Liked by [acs_ms_hs_library](#) and 27 others

[acsbudha](#) "Tomorrow belongs to those who invest in its full potential" - #Citi

We salute our INNOVATION PARTNER [@Citi](#) -- powering technology education in 2020-21 for more than 500 students Grades K-5 in our new Elementary School Innovation Lab.

Appendix 14

A picture illustrating Raytheon Emirates as an innovation partner in a STEM school in Abu Dhabi retrieved from Instagram (2021)



34 likes

[@abudhabi_raytheontechnologies](#) "enabling a brighter future" for more than 30 years in the UAE.

We salute our INNOVATION PARTNER RaytheonEmirates -- powering technology education in 2020-21 for more than 500 students Grades K-5 in our new Elementary School Innovation Lab.

Appendix 15

A picture illustrating EXXONMOBIL as an innovation partner in a STEM school in Abu Dhabi retrieved from Instagram (2021)



Liked by salambaaklinimoujaes and 45 others

acsabudhabi "Performance excellence through partnerships," #ExxonMobilUAE proud ACS partner. For more than 30 years, together shaping the future of education.

We salute our INNOVATION PARTNER ExxonMobil, powering technology education in 2020-21 for more than 500 students Grades K-5 in our new Elementary School Innovation Lab.

Appendix 16

A snapshot of Indiana Department of Education STEM certification Evaluation Rubric (2013)

INDIANA DEPARTMENT OF EDUCATION STEM ATTRIBUTES	Initial IMPLEMENTATION	Developing IMPLEMENTATION	Approaching IMPLEMENTATION	FULL IMPLEMENTATION
1 – Infrastructure: Is a structure and process in place to support the program's mission, vision, and goals? STEM school requires several leadership teams that collaborate and dialogue frequently about the program's design and effectiveness. Teachers are highly collaborative and community members are included in decision-making.				
1.1 Leadership Teams at the district and school levels				
1.2 School schedules				
1.3 Community Engagement				
1.4 School Environment				
1.5 Technology Resources				
1.6 Data (state, district, school, classroom)				
1.7 Evaluation				
1.8 Equity				
2 – Instruction: Does the instruction environment provide time and professional development for educators to develop and improve their craft of pedagogy and content? Students in a STEM school engage in inquiry based learning that may include authentic problems. Classrooms are facilitated by teachers who are highly effective in this type of instruction and require professional development and collaboration time to help develop and improve their craft of pedagogy and content. In addition, teachers consistently use and model technology in classroom instruction and use creative assessment opportunities like science fair, portfolios, labs, debate, etc.				
2.1 Instructional Programming				
2.2 Integrated STEM				
2.3 Professional Development				
2.4 Instructional Technology				
2.5 Instructional Strategies				
2.6 Teacher Content Knowledge				
3 – Curriculum: Is your STEM curriculum aligned to the adopted Indiana Academic Standards? Courses/Classes are integrated across content and infused with community needs and content progresses from grade to grade and are aligned across content areas.				
3.1 Curriculum Integration				
3.2 Curriculum Progression and Alignment				
3.3 Community Engagement				
3.4 21st Century Skills (http://www.p21.org/)				
3.5 Student Performance Assessments				
4 - Extended Learning: Does the STEM program offers opportunities outside the school day? STEM program offers opportunities outside the school day that may or may not be held at the school. There are multiple opportunities for students to extend their STEM learning, but the program has a strong connection to the school curriculum and activities that lie within and processes to maintain connections.				
4.1 Programming				
4.2 Program Alignment				
4.3 Community Engagement				

Modified from the STEM Immersion Matrix for Schools and Districts © 2012, The Immersion Guide © 2013, created by and work product of The Arizona STEM Network, led by Science Foundation of Arizona in collaboration with Maricopa County Education Service Agency.