Teacher Perceptions of the New Mathematics and Science Curriculum: A Step Towards STEM Implementation in Saudi Arabia

تصورات المدرسين للمنهج المضمن حديثاً لمادتي الرياضيات والعلوم : تطبيق لأحد النماذج من برنامج "STEM" بالمملكة العربية السعودية

by

REHAF A. MADANI

A thesis submitted in fulfilment
Of the requirements for the degree of

PhD of EDUCATION
at
The British University in Dubai

Prof. Sufian Forawi

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Approved for award:

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Name Name
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ABSTRACT

Universally, STEM education is one of the most growing areas in educational reform. Sadly, it has been introduced in the Kingdom of Saudi Arabia without a clear description of its meaning, purpose and framework of application. Even though, STEM is commonly recognized as a way of strengthening mathematics and science curricula, its exact implications is still unclear, for any intervention or modification in any of the subjects related to science, mathematics, engineering and technology can be considered as STEM implementation.

In 2009, the Ministry of Education (MOE) introduced a new mathematics and science curriculum in a joint effort with al Obeikan Research Development Company, as an adapted series of science and mathematics textbooks produced by the American publishing company McGraw Hill. The new adapted curricula attempts to make meaningful connections between students' lives and their educational experiences through the implementation of new teaching practices including, student centered, investigation strategies and problem-based learning. The purpose of this research study is to investigate teachers' perceptions and instructional practices of the new mathematics and science curricula as a step towards STEM reform in the kingdom of Saudi Arabia. To help improve the standards of Saudi Arabia's educational system and the quality of its students in the fields of mathematics and science in particular. This can be addressed by filling the existing gap within the Saudi literature that failed to notice the importance of teachers' views and perceptions on educational matters. Moreover, the study provides the MOE with new information related to significant issues that address future educational reforms and policies.

The methodology of the study was completed by using a parallel mixed method design, including teachers interviews and class observational methods in the qualitative part of the research study, and a cross sectional questionnaire in the quantitative part which was distributed to 547 high school mathematics and science teachers in different regions in Saudi Arabia in order to address the following research questions: What are the major aspects of the new mathematics and science curricula as a form of STEM education implementation in Saudi Arabia? What are the perceptions of teachers on the implementation of the newly adapted science and mathematics curricula? How is the newly adapted mathematics and science curricula delivered in the classrooms, as a form of STEM education?

Results revealed that even though there is haziness on the actual meaning of STEM concept and its instructional practices among mathematics and science teachers in Saudi Arabia, the new teaching strategies required from the MOE for a successful implementation of the adjusted curricula, were found to be equivalent to teaching practices that have proven its effectiveness in the implementation of STEM education. Moreover, the strategies were related with the Next Generation Science Standards framework (NGSS). Results achieved from the qualitative instruments applied were consistent and were supported by the numerical data achieved from the distributed questionnaire. The study ends with recommendations to legislate STEM education in Saudi Arabia by additional correlation and reorganization among topics within individual STEM subjects, in order to meet the requirements of the coordination with other associated subjects within the curriculum. Additionally, there is a requirement for coordination between teachers who teach different STEM disciplines, as well as a requirement for re-designing and restructuring teachers' development programs and workshops coupled with STEM training and implementation practices.

مستخلصانطباع المعلمين حول مناهج العلوم والرياضيات الجديدة: خطوة نحو تطبيق منظومة "العلوم والتقنية والهندسة والرياضيات" في المملكة العربية السعودية

الخلاصة

عالميًا، يُعد التعليم الذي يرتكز على منظومة " STEM" (العلوم، والتقنية، و الهندسة، والرياضيات) من أكثر المجالات التي تشهد توسعًا في عملية الإصلاح التعليمي. غير أن هذه المنظومة،وللأسف الشديد، تم تقديمها في المملكة العربية السعودية دون أن يصاحبها وصفًا دقيقًا للمعنى الذي ينطوي عليه، ودون تحديدٍ لغرضهِ، وللإطار العملى لتطبيقه. وبالرغم من أن منظومة "STEM" تحظى بإعتراف واسع الانتشار بأنها تعزز منهج مادتي الرياضيات والعلوم، إلا أن التطبيق الفعلي لهذا التوجه لا زال يشوبه الغموض خاصة وأن أي إضافة أو تعديل في أي درس من دروس الرياضيات و العلوم ينظر اليه على أنه توجه يرتكز على تطبيق منظومة "STEM" .

في عام 2009، قامت وزارة التربية والتعليم بإستحداث منهج جديد لمادتي الرياضيات والعلوم من خلال جهد مشترك مع شركة العبيكان للأبحاث والتطوير، حيث أثمر هذا الجهد عن نشر سلسلة من الكتب الدراسية المعدلة في العلوم والرياضيات صادرة عن شركة ماكجرو هيل McGraw Hill للنشر بالولايات المتحدة الأمريكية. ويعتبر تعديل هذه الكتب محاولة لإحداث ترابط بين الحياة الخاصة للطلاب و تجاربهم الدراسية، وذلك عبر ممارسات جديدة في مجال التدريس، و تشتمل هذه المحاولات على استراتيجيات استقصائية يكون الطالب هو محور تركيزها، بالإضافة إلى التعلم المستند على ما تم رصده من مشاكل. والغرض من هذه الدراسة هو بحث ودراسة مدى استيعاب المعلمين، والممارسات المتبعة في الفصول الدراسية المعنية بالتوجه التدريسي للمنهج الجديد لمادتي الرياضيات و العلوم، ويعتبر هذا بمثابة خطوة الى الأمام في طريق تطبيق منظومة "STEM" في المملكة العربية السعودية. وتساعد هذه الممارسات على الإرتقاء بالمستوى التربوي في المملكة العربية السعودية بصفة عامة، وبالجودة التي يتمتع بها الطلاب في حقلي الرياضيات و العلوم على وجه الخصوص. ويمكن معالجة هذا الجانب من خلال سد الثغرة الحالية في الدارسات السابقة بالمملكة العربية السعودية والتي أخفقت في إبراز أهمية آراء المدرسين ومدى تقبلهم للجوانب التربوية قبل الشروع في وضع أي سياسات تربوية في المستقبل. إضافة لذلك، فإن هذا التوجه ينطوي على توفير معلومات جديدة لوزارة التربية والتعليم تتعلق بقضايا هامة حول السياسات المستقبلية و الإصلاح في مجال التربية والتعليم.

إشتملت منهجية الدراسة على تصميم متوازي ومتنوع تتضمن مقابلات مع المعلمين، ومراقبة الفصول الدراسية، في ما يخص الجانب النوعي من الدراسة، وفي الجانب الكمي اشتملت الدراسة على استبيان يمثل مقتطف نموذجي وتم توزيعه على 547

مدرس بالمرحلة الثانوية من مدرسي الرياضيات والعلوم بمختلف مناطق المملكة العربية السعودية، من أجل تناول أسئلة البحث التالية: ما هي الجوانب الرئيسة في المنهج الجديد الذي تم تطبيقه لمادتي الرياضيات والعلوم في المملكة العربية السعودية باعتباره جزء من تطبيق منظومة "STEM" في المملكة العربية السعودية؟ ما مدى تقبل المعلمين لتنفيذ منهج مادتي العلوم والرياضيات المعدل؟ كيف يتم تدريس المنهج الجديد- الذي تم تعديله- في الفصول الدراسية باعتباره أحد أشكال منظومة "STEM" التعليمية؟

بالرغم من الغموض الذي اكتنف المعنى الحقيقي لمفهوم منظومة "STEM" وأساليب التدريس المتبعة فيها لدى مدرسي مادتي الرياضيات والعلوم بالمملكة العربية السعودية، فقد كشفت النتائج بأن استرتيجيات التدريس الجديدة التي يتعين وضعها من قبل وزارة التربية والتعليم للحصول على تطبيق ناجح للمنهج المعدل، كانت متوافقة مع استراتيجيات التدريس التي أثبتت فعاليتها في التوجه التربوى الذي يرتكز على منظومة "STEM" . علاوة على ذلك، كان لهذه الاستراتيجيات صلة وثيقة بإطار العمل لمعايير العلوم للأجيال القادمة (NGSS). وأيضاً كان هناك اتساق في النتائج التي تم الحصول عليها عبر أدوات الرصد النوعي، وهي معززة بالبيانات الرقمية التي تم رصدها من الاستبيان.

وفي نهاية الدراسة، طُرحت توصيات تهدف الى وضع تشريع للنظام التربوى يرتكز على منظومة "STEM" بالمملكة العربية السعودية من خلال مزيد من الربط بين دروس كل مادة من مواد منظومة "STEM" وإعادة التنظيم لهذه المواد حتى يتسنى استيفاء مقتضيات التنسيق بينها وبين المواد الأخرى ذات الصلة بالمنهاج. وهناك مقتضيات أخرى تتمثل في ضرورة التنسيق بين المدرسين المعنيين بتدريس مختلف المواد ضمن منظومة "STEM" .

DEDICATION

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

ACKNOWLEDGMENTS

First of all, I would like to thank God for giving me the strength and patience throughout my educational journey. In addition, I would like to thank numerous individuals, in a manner of first importance, my Director of Studies, Dr. Sufiyan Forawi, for his constant advice and support.

To my parents, I can't thank you enough for the extraordinary support, I know I am always in your thoughts and prayers as you are in mine. To my family and friends, your encouragement and motivational words have carried me throughout this process, not to forget your help in distributing the questionnaire.

To my husband, for understanding my frustrations and stressful deadlines. To my sisters and brother, especially my youngest sister Rana'a, who has been my personal editor throughout my doctorate journey. Finally, to my seven year old son, Alhassan, may you realize that nothing is impossible as long as you have the support of loving family and friends. Always remember to set your goals high and hard work always pays off at the end.

Table of Contents

List of Illustrations

List of Tables

CHAPTER 1: INTRODUCTION

A series of scientific advancements occurred in the 21st century have impacted every division of people's social foundations. In order to succeed in these changing economies the Science, Technology, Engineering, and Mathematics (STEM) education has been considered a chief priority (Kelley & Knowles, 2016; Weis, et al., 2015; Asunda, 2011; English & King, 2015). According to various studies, interest in STEM's instructional models is increasing across the educational landscape (Stanford, et al., 2016; Slavit, Nelson & Lesseig, 2016; Zeidler, 2016; Avery & Reeve, 2013). STEM's instructional models, are now considered as one of the most emergent areas in the context of education, concerning both developed and developing countries (UNESCO, 2010). Recently, many resources have been allocated towards developing programs that attempt to integrate STEM individual content areas into a unified curriculum. The curriculum may be based on the idea of students' education in an interdisciplinary and applied approach, offering students a cohesive learning paradigm, based on real-world applications and authentic purposes to learn and solve problems (Milner, 2017; Lawrenz, Huffman & Thomas, 2006).

The implementation of STEM has gained great significance in diverse foundations; such as professional organizations, universities, publishers, schools systems and educational materials procedure. It takes place among different groups and individuals in order to meet current and future socio-economic challenges (English, 2016; Johnson, 2013; Kuenzi, 2008; Herschbach, 2011). Despite the global interest and recognition of STEM benefits in the educational sector, the nature of its applications and international instructional practices has remained limited (Tofel-Grehl & Callahan, 2016; Honey et al. 2014; English, 2016; Czajka & McConnell, 2016; Bybee, 2013). Apprehensions have emerged from both research and curricular perspectives about the absence of a unified application and the need for integrating its four discipline. Moore et al. (2014) stated that teachers have encountered the inadequate multi-disciplinary content knowledge due to the absence of a precise curricula. In order to achieve a balanced image of STEM disciplines, equilibrium is required between new instructional practices, applied by educators and students use of this learning approach (English & King, 2015).

A noteworthy objective of the STEM plan is to enhance the proficiency of all students in STEM fields, regardless to whether they seek to persue their professions in STEM feilds or not. Accomplishing more noteworthy STEM capability starts in the K–12 instructive frameworks, to foster the 21st-century skills among students, required for their future success. It incorporates basic consideration, critical thinking, coordinated effort, innovativeness, self-coordinated learning, logical, natural and technological literacy (DeCoito, 2015). Given the worldwide significance to STEM accomplishments, as measured by national and global assessments, many countries are now scrutinizing the quality of their curricula, educational modules and the strategic activities. The aim of these countries is to upgrade STEM disciplines and incorporate them as a part of their educational system (English, 2016). Generally, curricula of STEM subjects are usually recognized as content heavy, which entailed much repetition (Badri et al., 2016).

Science education may sometime neglects to encourage the critical thinking abilities of students. It may also neglects to connect with other students and uncover how the material can be connected to take care of genuine issues. To overcome the limitations of didactic learning, problem-solving activities have seen an increased emphasis in STEM education reform (Trueman, 2013). The new adapted mathematics and science curricula in Saudi Arabia have attempted to make meaningful connections between students' lives and their educational experiences. It was achieved by setting more weight on students' centred learning and understanding the concepts instead of relying on memorizing texts. A constructivist theory was adopted by the new curricula regarding learning, which focuses on critical thinking and problem solving techniques. Previous research revealed that depending on traditional approaches in teaching mathematics and science subjects is associated with student's negative attitudes towards STEM disciplines. Moreover, results showed failure to introduce students to the real world of scientific advancements and work forces (Gao & Schwartz, 2015; Deslauriers et al., 2011). In Abu Dhabi schools, Badri et al. (2016) described mathematics and science as unattractive subjects, distinct from society, where it failed to provide students with a clear picture of the subjects taught. Such subjects are fragmented in strictly isolated disciplines including mathematics, physics, chemistry and biology.

Various theories of progress have been advanced to justify the complex relationship and factors that contributes to instructional change. Some theories stretched the significance of changing the perception of instructors as a major aspect of advancement, which in turn prompts changes in instructional practices and the enhancements of students' educational outcomes (Czajka & McConnell, 2016). Individual educational professionals as policy and curricular developers usually develop new instructional strategies gained from educational research. It is then distributed to the educational landscape for implementation, not taking into consideration the uniqueness of students, teachers and schools in every region. As some strategies lead to educational success and expected results, in other cases it may lead to undesired outcomes such as in the case with STEM education implementation (Henderson & Dancy, 2011).

Almannie (2015) argued that despite Saudi Arabia's continuous investments in education and development of the new mathematics and science curricula, educational outputs do not reflect this investment. Badri et al. (2016) described the educational system as complex, due to the fact that curricular developments or advancements are not the only issue to achieve K-12 educational success. There are many other factors that can contribute to a quality science and mathematics class experience. One of the important factors argued was insufficient teacher's preparation. It could have been avoided if more concentration was focused on teachers' teaching strategies rather than concentrating mainly on curricular content. It was concluded that the teaching practices in Saudi Arabia remained traditional; because of which, it resulted in low students' performance achievement in international examinations (Almannie, 2015).

A study indicated a gap related to teachers' perceptions and beliefs that shape their practices in actualizing curriculum reform (Bin-Salamah, 2001). Instructors reported that the most predominant barriers for adopting reformed teaching strategies were scarce time for learning these new reformed teaching strategies, limited training programs, and inadequate resources (Henderson & Dancy, 2007). Al-Rwathi et al. (2014) argued that the new mathematics and science curricula depends heavily on teachers' classroom capability; while on the same time, it also reflected that teachers are not implementing appropriate required teaching strategies.

According to Han et al., (2015), there is a positive relationship between teachers' perceptions, their understandings, and the implementations of STEM education on students' level of understanding about content and developing skills. Clarke and Hollingsworth (2002) generated the Interconnected Model (IM) of teacher professional development program, in which instructional reform was based on diverse interactions between four domains. The first domain was the external domain, including outside source of information or motivational factors. Second domain was related with the personal domain, including teacher's knowledge, perceptions and attitudes towards change. The third domain was the domain of practice, including classroom instructional practices. Finally, the fourth domain was consequences including students' relevant outcomes. Oyaid (2009) described the importance of teachers' perspectives on current and future educational matters and policies, as no policy can fulfil its objectives without its executers' involvement and awareness. Past studies have recommended that teacher's quality and classroom practices are the key determinant of students' learning and accomplishments (Nye et al., 2004; Goe, 2007). Consequently, teachers have positive convictions towards new teaching approaches that are one of the critical components, influencing their acknowledgement and eagerness to apply new instructional practices into their classrooms.

During the past several years, many developing nations, particularly Arab countries, have come to recognize that a good education system is a foundation to its economic growth (Mansour & Alshamrani, 2015). The need for education reform in the Arab world has been demonstrated in the different exercises that were aimed for enhancing the quality and quantity of its education system. Within the past years, Arab nations have endorsed different endeavors to create and execute comprehensive education reform programs that can bring about an equipped information based workforce in accordance with socioeconomic objectives (Mansour & Alshamrani, 2015). Despite that fact, STEM education is still considered as a new era in the educational field. However, limited amount of research is conducted within this area. It includes teacher's examinations requirement, qualifications, knowledge, experience, and convictions necessary for teaching STEM disciplines. These challenging factors are also applicable to STEM integration, specifically in Saudi Arabia (Frykholm & Glasson, 2005).

1.1 Context of the Research Study

The context of this research study is in light of the Kingdom of Saudi Arabia (KSA) since, curricular reform has been a central issue to cope with the universal educational transformation. In 2009, Ministry of Education introduced a new science and mathematics curricula in a joint effort with Al Obeikan Research Development Company as a step towards STEM implementation in Saudi Arabia (Obikan for Research and Development, 2010). The curricula were an adapted series of science and mathematics textbooks, produced by the American publishing company McGraw Hill (Al ghamdi & Al-salouli, 2013; Almazroa & Al-Shamrani, 2015). McGraw-Hill Education is a learning science association that offer effective learning experience for helping students, guardians, instructors, and specialists to drive appropriate results. McGraw-Hill Education has work environments crosswise over North America, India, China, Europe, Middle East, and South America to make its learning courses of action available in about 60 different language (www.mheducation.com).

The study has focused on the mathematics and science teachers, who were teaching the new mathematics and science curricula as a step towards STEM education implementation in Saudi Arabia's high schools. It has been reported that three categories were involved for a curricular reform to take place. Firstly, curricular developers were associated with the Ministry of Education in Saudi Arabia. The second were the teachers, who acted as a mediator to any educational reform transmitting information to the third party, who are students. Past studies recommended that teacher's quality and classroom practices are the key determinants of students' learning and accomplishment (Nye et al., 2004; Goe, 2007; English, 2016; Badri et al., 2016). In this study, teachers' perceptions of the new mathematics and science curricula and the implementation of its required new instructional practices were studied as a way of implementing STEM education in Saudi Arabia.

1.2 Statement of the Problem

Notwithstanding the kingdom's investment in educational reform and curricular development; STEM education implementation is considered as a challenging task that should be introduced gradually with appropriate care. The educational environment in Saudi Arabia is strongly focused on a separate subjects' orientation, academic achievement, testing, and an emphasis on the basics (MOE, 2010). Regardless of the way that the new curricula endeavors to make instruction more relevant to life, it is difficult to perceive how STEM programming is incorporated with such useful subjects. The strains between current topic divisions and the integrative programming, suggested by STEM make various programming issues that yet are to be settled. One noteworthy issue, is the constrained impression of what STEM represents.

In order to assess educational standards among schools, regions or even between different countries, there are several universal standardized tests. One of the most common test in assessing mathematics and science education is 'The Trends' in International Mathematics and Science Study' (TIMSS). Unfortunately, it has been reported that Saudi Arabia was ranked among the lowest participating nations in 2007 on the achievement sections related to TIMSS (Mullis et al., 2009). In 2011, Saudi Arabia's TIMMS scores remained lower than the international average in science and mathematics subjects (IEA's Trends in International Mathematics and Science Study-TIMSS 2011). Even though, a quarter of the Saudi Arabia's general budget is allocated towards educational improvements with the introduction of new mathematics and science curricula in 2009 and teacher's development programs and workshops (Almannie, 2015). The outcomes of TIMSS data exposed the flaws of the extensive resources and policy commitment, placed by the government on its educators. There is a gap that needs to be addressed in regards to the implementation of new teaching practices, required for STEM implementation. Education in Saudi Arabia remains traditional, due to insufficient teachers' preparations, which resulted in the implementation of inappropriate teaching strategies that have led to Saudi Arabia's substantial ranking in standardized tests, especially in regards to STEM subjects (Almannie, 2015; Badri et al., 2016). Al-Rwathi et al. (2014) Argued that the new mathematics and science curricula depends heavily on teachers' classroom capability and reflected that teachers are not implementing appropriate required teaching strategies.

The newly adapted curricula attempts to make meaningful connections between students' lives and their educational experiences by placing more weight on student-centered learning and understanding concepts instead of relying on memorizing texts. Moreover, the new curricula adopt a constructivist theory of learning that focuses on critical thinking and problem-solving techniques. Previous conducted studies within Saudi secondary schools all demonstrated the lack of critical thinking knowledge within applied teaching strategies among teachers and students. Therefore, Saudi scholars request that any educational reform to the Saudi curricula must incorporate critical thinking (Al-Miziny, 2010; Allamnakhrah, 2013). Further, It is required to take teacher's perceptions into consideration about the planning and development of workshops and programs in structuring and designing of school's curricula and achieving a successful educational reform.

1.3 Significance of the Research Study

A good educational system identifies its country's economic status (Weis et al., 2015). In order to achieve economic growth, education reform is taking place in many countries, especially in developing nations where more focus is attained towards improving the quality and quantity of education. In addition, create and actualize extensive training change programs that can bring about a gifted, information based workforce in accordance with socioeconomic objectives (Mansour & Alshamrani, 2015). The new adjusted mathematics and science curricula in Saudi Arabia has attempted to make meaningful connections between students' lives and their educational experiences. It was achieved by setting more weight on students' centred learning and understanding of concepts instead of relying on memorizing texts. STEM education, in the centre of this study, focuses on the transition from instructor centred passive learning environment towards the implementation of new teaching strategies that are inquiry, student centred and problem-based learning (Pelch & McConnell, 2016). As a way to display inter-disciplinary information, essential learning could incorporate two or more of the four primary controls, distinguished in STEM training. In order to make such implementation, it is important to identify how mathematics and science teachers perceive the shift from traditional teaching strategies to an advance "incorporated" STEM training-learning model. No one can overlook the needs to distinguish how instructors perceive the elements of STEM. There is a desired need of coordinated practices for the success or failure of STEM education implementation in Saudi Arabia.

1.4 Purpose and Questions of the Research Study

The purpose of this research study is to investigate teachers' perceptions and instructional practices of the new mathematics and science curricula as a step towards STEM reform in the kingdom of Saudi Arabia. The aim was to gain an insight on how teachers' perceive, acknowledge and implement new teaching practices required for teaching the new curricula. Therefore, improvements in the standards of Saudi Arabia's educational system in general and the overall quality of its students in the fields of mathematics and science in specific. The gap regarding the failure of importance of teachers' perceptions and views in the literature regarding educational matters can be addressed by taking assistance of pertinent Saudi Arabia's literature to formulate future policy (Oyaid, 2009). Moreover, it also provided new information related to considerable issues to the Ministry of Education (MOE); so that, it can addresses future educational research, reform, policies as well as recommendations. Following are the research questions for the study:

1. What are the major aspects of the new mathematics and science curricula as a form of STEM education implementation in Saudi Arabia?
2. What are the perceptions of teachers on the implementation of the newly adapted science and mathematics curricula?
3. How is the newly adapted mathematics and science curricula delivered in the classrooms, as a form of STEM education?

1.5 Overview of the Research Study

The reseach study has been organized into five chapters excluding bibliography and appendices. The first chapter provides introductory information in regards to the introduction of STEM education in Saudi Arabia through the development of new mathematics and science curricula. Furthermore, discussion on the purpose and significance of the research entailing the research questions has been incorporated. The second chapter provides the review of literature, pertinent to this dissertation along with the theoretical framework that shape up the study. It includes Hurley's (2001) Mathematics and Science Integration Theory, Dugger's (2010) STEM Implementation Theory, The (2012) Next Generation Science Standard Framework (NGSS), Zeidler et al.'s (2005) Socio-Scientific Theory SSI and Berghout's (2011) Islamization of Science Model. The third chapter provides a clear picture of study's design and applied methodology, relating the use of mixed methods design. Additionally, descriptions concerning the context of the research, applied instrumentation including teacher's open-ended interviews, class observational methods, and the distributed questionnaires were included. A justification was provided for recruiting participants, site selection, data analysis of the attained results, the pilot study, ethical considerations, and the limitations of the study. The fourth chapter explains the data analysis of the attained results from both qualitative and quantitative instruments, applied in the study. The final chapter provides a discussion of the research findings, their implications, and conclusion along with recommendations for future educational research.

CHAPTER 2: THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1 Introduction

This chapter presents the foundational theories of the research study that shape up the framework, including Hurley's (2001) Mathematics and Science Integration Theory, Dugger's (2010) STEM Implementation Theory, The (2012) Next Generation Science Standard Framework, Zeidler et al.'s (2005) Socio-Scientific Issues (SSI) and Berghout's (2011) Islamization of Science Model. Furthermore, it includes the review of literature, based on previous research studies, projects, and theories by including essential information. This information is required for the investigation in the context of the new mathematics and science curricula in Saudi Arabia, as a step towards STEM education implementation. The scope of the literature included a theoretical background regarding the diverse cultural forces that shape up the educational patterns in Saudi Arabia. Moreover, it provides an overview on the educational system's quality and current situation along with the major emphasis led on recent reform and adaptation efforts in Saudi's science and mathematics curricula. Finally, the presentation of multiple theories regarding STEM education, its implementation, and relevance to the new mathematics and Science curricula applied in the context of Saudi Arabia.

2.2 The Theoretical Framework

As there are many approaches to incorporate the implementation of STEM into the educational system; each country shares different political, social, and cultural history that affect such implementation. These particular differences are reflected within their educational structures; and thereby, the way STEM can be incorporated. In order to make sense of STEM education implementation confusion, the proposed framework is meant to provide a common perspective for researchers, educators, and curriculum developers. It enables them to identify, discuss, and investigate the ways to incorporate integrated STEM initiatives within the new mathematics and science curricula in Saudi Arabia. The proposed framework entails various views, theories, and models that deal with STEM integration process; and hence, it provides the theoretical framework of this research study.

A theoretical framework usually includes theories and researches from previous findings with a wider range of investigations into a framework that organizes the explanation of a phenomenon under study (Ary et al., 2013). Thus, it also serves as valuable purpose in the development of science. In this research study, the proposed framework contains multiple diagrams. However, the outer part of the diagram has concentrated on curricular reform and subject integration, by proposing Hurley's (2001) Mathematics and Science Integration Theory, Dugger's (2010) STEM Implementation Theory and The (2012) Next Generation Science Standard Framework (NGSS). On the other hand, the intermediate centre of the diagram concentrates on translating theories to relate with the context of the research study and Saudi Arabia's curricular standards. This part of the diagram includes Zeidler et al. (2005) Socio-Scientific Issues (SSI) and Berghout's (2011) Islamization of Science Model.

The centre inner core of proposed diagram included the context of the research study, which is 'New Mathematics and Science Curricula (NMSC)' as a step towards STEM implementation in Saudi Arabia. The objective of the proposed framework is to clarify the existing studies regarding STEM implementation in schools. Moreover, teaching and learning is mainly achieved through the use of discipline-centred curricula to develop a theoretical model of integration to be used within the context of Saudi Arabia (Sedgwick, 2001).

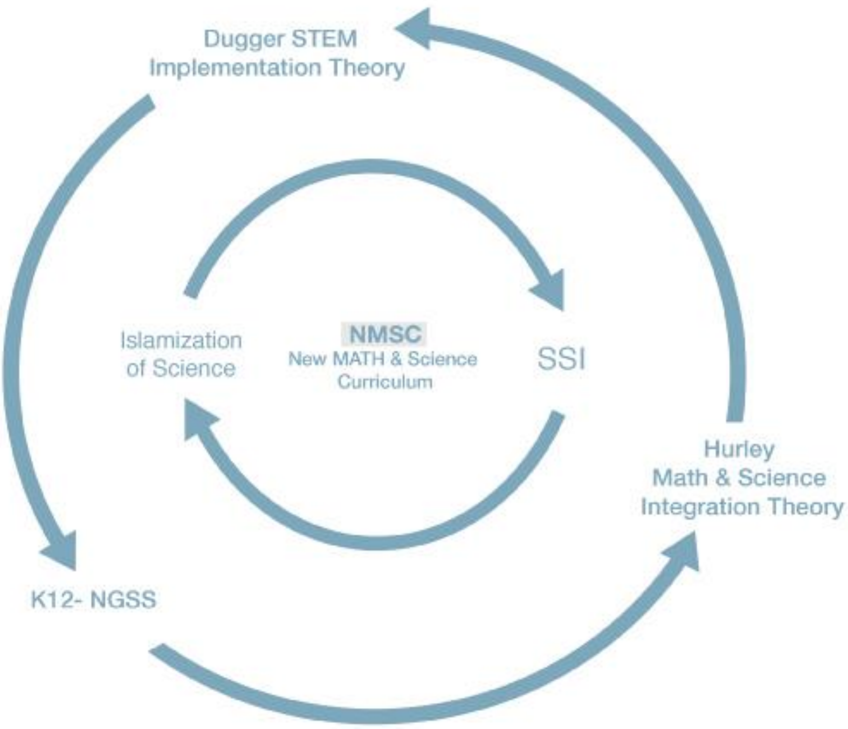


Figure 1: The Mathematics and Science Integrated Framework of the Research Study

Hurley's (2001) Mathematics and Science Integration Theory is the first theory that has been entailed in the outer diagram of the proposed framework. Hurley used the development of five categories to describe subject integration. Sequenced integration is the first category that includes science and mathematics in a combination. Partial integration is the second category that includes particular topics of science and mathematics in a combination; however, rest of the topics are taught individually. Enhanced integration is the third category that entails only one subjects either science or mathematics as a core subject whereas other subjects are taught in a combination. The combination of both subjects' science and mathematics is included in the fourth category that is known as the total integration method. Parallel integration method is the final and last theory Hurley described subject integration through the development of five categories. The first category included the sequenced integration, where science and mathematics subjects are taught in sequence to each other. The second category is throough partial integration, where certain topics in mathematics and science are taught together while the rest are taught separately. The third category is through enhanced integration, where one subject (mathematics or a science subject) is chosen as the major discipline, while the other subject is taught in connection to it. The fourth category is the total integration method, where both subjects are of equal importance and are taught together. Finally, is the parallel integration method, in which both science and mathematics subject are taught concurrently and individually. In this method, it is examined that the occurrence of integrated subjects is modified and; therefore, no major modification has been observed to the actual content of each subject. As teachers assume to restructure the association between the topics of courses to meet comparative subjects throughout the disciplines, more efforts must be required in this category of integration from the teacher's point of view.

Gentry (2016) has demonstrated that there are assorted factors that are required to be considered in spite of the advantages obtained from the interdisciplinary approach. For instance, the implementation of subject integration shall be observed when significant learning is driven to the student's in each content area that is being integrated. As total subject integration, just for the sake of implimeting STEM subject integration may not yield to the same benefits for students. In order for integration to be successful, integrated topics of different subjects should be grounded in the curriculum. This does not mean that every activity must directly relate to curricular standards, but that the overall theme or goal should . This was found to be equivalent to the goals and objectives of the new mathematics and science curricula and the way subject integration should be approached.

Dugger's (2010) STEM implementation theory is the second theory presented in the outer part of the circle in the proposed framework. The theory has described several ways for the applications of STEM. The first stage explains the traditional ways of teaching methods of STEM disciplines as a separate subjects, including Science, Technology, Engineering and Mathematics. Secondly, is to maintain teaching each STEM subject individually with prominence to one or two of the four subjects. It can be deliberated as the most important and prominent method implemented in the United States. Therefore, it must be the main aim of Saudi Arabia's new science and mathematics curricula as a step towards the implementation of STEM education in the Kingdom, where mathematics and science subjects are taught separately using traditional, single-subject approach. Thirdly, is the integration of one of the four STEM disciplines into the remaining three; for example, integrating engineering aspects into science, technology and mathematics. Fourthly, is the integration of all STEM disciplines into a unified curriculum, which is considered as a very challenging task that requires a progressive approach for curriculum. Honey (2014) argued that implementing STEM integration can make the STEM subjects more applicable to students and teachers, particularly concerning its relevance to real-world issues. Therefore, it can increase motivation for learning and enhance students' interest, accomplishment, and diligence. The outcomes are found to be corresponding to the objectives of the new mathematics and science curricula in Saudi Arabia. It may also help to address calls for an effective working environment, which eventually increase the student's quantity in STEM related fields.

The third framework included in the outer part of the circle in the proposed framework for K–12. It included Science Education: Practices, Crosscutting Concepts, and Core Ideas to guide the development of the (2012) Next Generation Science Standards (NGSS). The National Research Council released the NGSS framework with the aim of increasing students' interests in perusing STEM fields within their educational path by presenting new scientific methods to ensure that the students' have enough STEM knowledge to incorporate within their daily lives by the end of grade 12. First, the NGSS framework was built upon the idea of learning science as a developing process. It can be achieved through guiding the students to build upon their existing knowledge during learning to gain logical scientific views of learning and understanding STEM subjects. Secondly, the framework focuses on the reduction of the number of topics within each of the STEM disciplines. It also provides the teacher and students with more time to concentrate on each topic comprehensively, relate topics to real life scenarios, and make the connection among different

STEM disciplines. Moreover, it also increases students' scientific engagement and investigation abilities; therefore, increasing the understanding of core ideas presented. Thirdly, the framework concentrates on the idea of collaboration between knowledge and practice, when designing scientific learning experiences (NAE and NRC, 2014; NGSS, 2013).

Bybee (2013) argued that the Next Generation Science Standard (NGSS) is not deemed as an educational policy for STEM education implementation. However, it provides an explicit description regarding the meaning and purpose; and also entails the developments of instructional material. It further includes essential teaching practices for its implementation. Therefore, Next Generation Science Standards (NGSS) is served as an example of a policy document. The new mathematics and science curricula in the context of this study have been adapted as series of science and mathematics textbooks, produced by the American publishing company McGraw Hill (Al-ghamdi & Al-salouli, 2013; Almazroa & Al-Shamrani, 2015). McGraw-Hill Education designed its curricula's in a way to inspire science to address the Next Generation Science Standards (NGSS) specifications. The McGraw-Hill curriculum attempts to blend science and engineering practices with problem-based learning, literacy and mathematical skills (Meyer, 2015).

Recently, The Next Generation Science Standards (NGSS) have called for more and deeper connections among the STEM subjects, as it includes practices and core disciplinary ideas from engineering. It raised the expectation that science teachers will be expected to teach science and engineering in an integrated manner (Honey, et al., 2014). The NGSS carries the potential to influence new teaching methods, required for teaching and learning the new mathematics and science curricula in Saudi Arabia, as a step towards STEM implimentation . It is influenced by encouraging student's engagement in their own learning, especially in subjects or topics that require the integration between different STEM disciplines. Moreover, it supports the development and implementation of conceptual knowledge and reasoning while teaching STEM subjects.

In the intermediate centre of proposed diagram, Socio-Scientific Issues (SSI) were included to promote a functional degree of scientific literacy (Zeidler et al., 2005). The SSI framework aims to involve students in decision making regarding the current social issues with moral or ethical implications imbedded in the scientific context. Therefore, it is essential to provide students with opportunities for active participation in discussing issues and to examine the solutions in respect to their own lives. As it is possible for certain ethical issues to become embedded to the context of scientific content, and certain nature of science (Zeidler et al., 2005). SSI provides an epistemological context for student's conceptual understanding of important scientific matters; thereby it serves as a venue for the development of character and reflective judgement (Zeidler & Sander, 2010). The SSI also offers a way to explore the nature of science, bridge students and scientific literacy, interdependence of science, society movement, and democratizing science in society; therefore, the promotion of scientific literacy requires curricular attention (Sadler, 2004). Socio-scientific and issues-based teaching help connects between the goal of science education and students' needs. Moreover, fulfilling them with higher order thinking, discussion skills, scientific argumentation, inquiry-based learning, and understanding the nature of science (Nuangchalerm, 2010).

In the context of this study, new strategies for increasing students' interest and knowledge in STEM subjects and their ability to use science outside school are needed. The SSI relates to the new mathematics and science curricula as a way to make science relevant to student's lives as it is required by the Ministry of Education as one of the prime goals and specifications of the new curricula. It has been stated that science and society influence each other in many aspects (Zeidler & Nichols, 2009). Aikenhead (2006) argued that one way to increase students' interest in school science is to bring in a humanistic perspective. The SSI approach places science in a larger social, cultural, and political context focusing on contemporary social issues that require scientific knowledge for informed decision making. In the past years, SSI has become a part of science education reform, curriculum development and the establishment of new educational policies. In this framework, acknowledgement of the Saudi Arabia's society including its religion, culture and beliefs are considered before moving into the domain of traditional science content. It is developed to ensure that science is embedded within the social environment of learners. Hence, making science subjects more relevant could increase student's interest in STEM disciplines, and it also included in the development of students' social responsibility through decision-making (Zeidler et al., 2009). SSI movement focuses on empowering students to consider how science-based issues reflect moral principles and elements of virtue that encompass their own lives, as well as the physical and social world around them (Sadler et al., 2007). Furthermore, the SSI can serve as a useful context for teaching and learning science content. Also, SSI are also positioned as an important driver for addressing citizenship education within science classrooms.

The second theory included in the intermediate section of the proposed framework is Berghout's (2011) framework or model of Islamization. This theory was included in order to ensure that

Islamic perspectives are incorporated within the proposed framework of the research study. Religion is the foundation of the Saudi Arabia's political ideology. Moreover, it is a key area of Saudi Arabia's educational system in which students are taught the interpretation of Islam, known as Wahhabism. It is a movement that was founded 250 years ago by Muhammad ibn Abd al-Wahhab that is reflected throughout the curricular textbooks. Berghout's (2011) framework or model of Islamization was used as an adapted version of the quality management system model with the view of Islamization as a quality process, consisting of input, procedure, output and a response. To ensure the effectiveness of the Islamization process on the entire activity of learning, Islamic perspectives have been incorporated in all parts of the suggested framework. In the Islamization of science framework, Berghout concentrated on fulfilling three essential domains of the learner's advancement including intellectual, psychomotor, and affective domains, with greater emphasis on the affective part in all three domains.

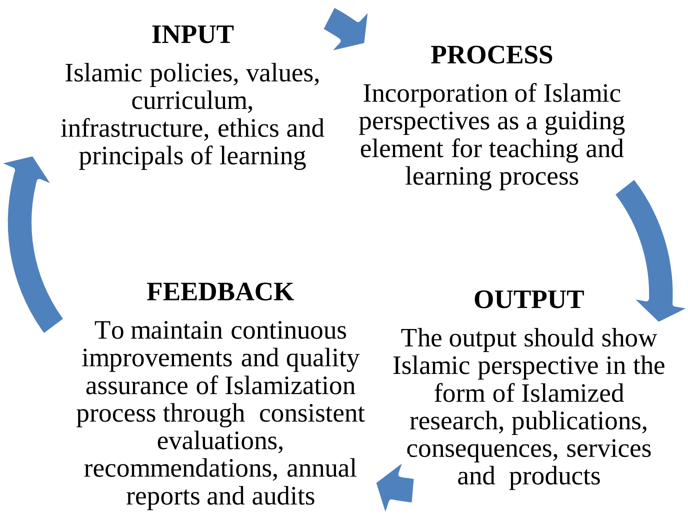


Figure 2: Berghout's (2011) Model of Learning within the Islamic Framework Perspective

Figure 2 has depicted that Islamic policies, curricula, values, ethics and principals of learning are all integrated within the input phase. In a similar fashion, the process phase portrayed Islamic perspectives is incorporated as a guiding element of the processes of teaching and learning. While the output phase demonstrated Islamic perspectives. Moreover, it is important to pay attention to feedback in order to maintain a continual improvements and quality assurance.

2.3 Literature Review

The literature review plays a vital part in any educational research, by conferring on the previous knowledge related research studies that are helpful for the researcher in many aspects. Moreover, it aids in clarifying and defining the concepts and theories related to the topic. Additionally, reviewing previous research assists in identifying suitable methodologies that have proven to be useful for the researcher. It places the researcher in a better position to understand the significance of achieved results (Ary et al., 2013). Likewise, previous research helps the reader to comprehend the themes found within the literature. The objective of the literature review section, in this research study, is to summarize Saudi Arabia's current educational situation in regards to the new mathematics and science curricula. Additionally, to provide a summary of STEM education, including its definition and framework of implementation to make a connection and find relevance with the new adapted mathematics and science curricula. Also, to investigate about its instructional practices as, a form of STEM implementation in Saudi Arabia.

In this section, the literature review was divided into six different areas, based on the research questions and the context of the study. It begins with a preview on the educational system practiced in the Kingdom of Saudi ArabiaIt begins with a preview on the educational system practiced in the Kingdom of Saudi Arabia. It was chosen as the first area of discussion as it is important to understand the history of a culture, in which education reform takes place before analysing the applied educational reformation. Therefore, this area provides background information regarding the various forces that shape up the patterns of education within the Saudi Arabian culture. The second part of the review discussed the quality of current science and mathematics education in Saudi Arabia, which was chosen second as it was important to understand the present circumstances of Saudi's instructive framework and educational policies. Therefore, it characterized the purposes behind its substandard positioning in mathematics and science subjects. The third part of the review covered the implementation of new mathematics and science curricula as a step towards STEM implementation in Saudi Arabia. This section facilitates the process of STEM implementations and curriculum reformation through the improvement of science and mathematics curriculums and its instructional techniques. The fourth part of the review included the Islamic perspective of mathematics and science. In Saudi Arabia, the implementation of any educational material is obligatory, which refers that it must correlate with the Islamic parameter. The fifth area discussed was STEM education to formulate a diagram of STEM definition, significance, favourable circumstances and implementation techniques. Finally, a review on STEM education curricular concept has been proposed after completely understanding the STEM education implementation with regards to classroom and teaching practice.

2.3.1 Education in the Kingdom of Saudi Arabia

In order to analyse the educational reformation of any country, it is essential to understand the history of its culture, in which educational reforms and materials would be implemented. Therefore, this section provides a background regarding various forces that shape the educational patterns within the Saudi Arabian culture in relevance to the topic of this research study.

Saudi Arabia is considered as the largest country in the GCC (Gulf Cooporation Council) (Al- Sadan, 2000). The Kingdom is divided into thirteen regions and follows an education for all policy, where education is free to its citizens from primary school till public university graduation. The Ministry of Education sets the overall standards for the country's educational system, providing over 30,000 schools and educating around 5 million students (Ministry of Education, 2015). The education system in Saudi Arabia has been shaped and used by religious, political and socio–economic forces (Prokop, 2003). Al-Sulaimani (2010) described that all educational matters in Saudi must conform to Shari'a laws and the holy Qur'an, where traditional gender roles shape the teaching careers for both men and women. To explain the reproduction of gender divisions and power relations through education in a traditional Islamic country, El-Sanabary (1994) argued that education in Saudi Arabia is equivalent to the most other Islamic countries, in its structure, and strategies for the reproduction of gender divisions. As the author contends that Saudi education, a miniature of Saudi Arabian culture, has purposefully organized these components and structures as measures for achieving cultural protection and social control.

Three stages are included in the educational system of Saudi Arabia. First stage is the primary school level, comprising of physical education (for boys), home economics (for girls), Arabic, geography, history, Islamic studies, and art, which last for six years. A general elementary school certificate is awarded to students at the end of sixth grade. The second stage includes the intermediate school level that covers most of the classes from primary school and lasts for three years. Lastly, secondary school level is included in the third stage of the educational system, which lasts for three years and students have the option to select a technical or general path. Conversely, mathematics and science are considered as compulsory subjects for students, studying from first grade to tenth grade under a standard curriculum. Afterwards, students are able to select their educational pathway either in science or art subjects for last two years (Ministry of Education, 2015). In the science track, students are obligated to take mathematics, chemistry, physics and biology over two years as well as other common subjects. Traditionally in Saudi Arabia, curriculums of different subjects are taught separately, where minor attention has been given to the interrelationships between the different subjects taught.

Baki (2004) argued that the Saudi government is looking for economic change, in order for such change to occur, the education system needs to be re-evaluated. Preserving society and culture is important, but the extent of preservation needs to be revisited in order for education to prepare both men and women for life in the global economy. In order to process this transformation new goals and reformation in school curricula has been taking place with effective changes in curricula. It has been expanded several times to fulfil the requirement of the society's changing values and economic circumstances. Moreover, globalization carries a significant influence on the educational system in Saudi Arabia, as it contributed to the introduction of many changes and reformation in the Kingdom's educational system and policies (Alyami, 2014). King Abdullah Education Development project is one of the most essential projects of education qualitative development in the history of the Kingdom of Saudi Arabia. This venture provides a complete advancement of education through the development of educational curricula, rehabilitation of educators and creating educational leadership, enhancement of educational environments, enhancement of extra-curricular activities, while focusing on educational objectives and goals. Such objectives and goals radiate from the general principles of education in addition the Kingdom's religious and cultural standing (National Report on Education Development In The Kingdom of Saudi Arabia, 2008).

Over the past twenty years, students have changed, perhaps as a consequence of an innovation rich childhood, students seem to have "distinctive" necessities, objectives, and learning inclinations than students in the past. Such education should include more collaboration and investigation among students and their teachers. The teachers should act more as facilitators investigating and discussing subject's context with their students. Also, display learning rather than telling students what the solutions, procedure, or outcomes ought to be (Claxton, 2007). Furthermore, AL-Abdulkareem (2004) explained three reasons behind the Ministry of Education's efforts in reforming science curricula's. First, was the Internal justification, as current curriculums were designed a long time ago and are irrelevant to modern students, as they do not reflect today's social, cultural, economic and technological conditions and circumstances in Saudi Arabia. Secondly, was the external justification, as the effect of globalization, while all countries are greatly affected by global advancements and developments, Saudi Arabia can no longer stand behind, even if such influence differs from one country to another. Thirdly, was the research and scientific justifications, where the development of manpower and its rehabilitation is a type of investment in a nation's human resources and utilization of the future.

Throughout the past decade, the Kingdom's educational system has gone through a three stage significant expansion. First was the set up stage, includes the introduction of education in the Kingdom. At this stage, the enhancement of education occurred by promoting education to the public with convictions regarding the education. Further, women education and the development of educational systems as well as policies were introduced. In 1953, a major shift in Saudi Arabia's educational system occurred as the Ministry of Education (MOE) became solely responsible for the educational system with an aim to implement the most modern and contemporary educational techniques. It was done through updating curricula and linking it with the social, economic, and scientific process in society (MOE, 1990, p. 5). The second stage was the expansion stage. At this stage, all efforts and resources were allocated to make education opportunities available to everyone including both genders. Hence, the focus was towards increasing the quantity of educational facilities rather than focusing on the quality assurance and educational standards. Today, the Ministry of Education has finally reached the third stage, the quality stage, where more emphases have been utilized towards the quality of education in order to build up a knowledgeable community. It was achieved by focusing on the outcomes, enhancing accountability, and evaluation by using performance indicators of sustainable development approaches (MOE, 1990). Currently, the Ministry of Education aims to achieve the following points in order to enhance the quality of its educational system:

- Firstly, by assigning its students in the focal point of its education process by differentiating teaching for all students.
- Secondly, the advancement of new quality control and motivational frameworks to arrange and coordinate the learning procedure. Additionally, new quality control will be likewise useful to help directorates and schools in meeting learning results and sorting out supervision.
- Thirdly, by conceding freedom to educational directorates and schools to maintain a strategic distance from centralization in dealing with the learning process.
- Fourthly, focusing on schools plans and program by providing them with facilities and

equipment to enhance the overall learning process.

- Finally, assemble possibilities, human and specialized, to oversee education, which will lead the way toward creating schools and accomplishing quality execution. In addition, allowing appropriate authoritative specialist, characterizing objectives for students, and setting up schools that can fulfill these objectives are also certain strategies (MOE, 2015; Mullis, et al., 2016).

This aligns with the Ministry of Education reform movement for introducing new mathematics and science curricula, collaborating with Al Obeikan Research Development Company (Obeikan, 2010) as an adapted series of science and mathematics textbooks produced by the American publishing company McGraw Hill (Al ghamdi & Al-salouli, 2013; Almazroa & Al-Shamrani, 2015). The new adjusted mathematics and science curricula attempts to make meaningful connections between students' lives and their educational experiences, by setting more weight on constructivist theory of learning that focuses on critical thinking and problem-solving techniques (Mullis et al., 2016; Obikan for Research and Development, 2010).

2.3.2 Quality of Current Science and Mathematics Education in Saudi Arabia

This section of the literature review describes the current situation of Saudi Arabia's educational system and defining the reasons behind its substandard ranking in mathematics and science subjects in the light of certain specific studies.

In Saudi Arabia, education is viewed as a key factor for financial and social development, where science and mathematics education has garnished interest like never before (Almazroa, 2013). The new mathematics and science curricula in Saudi Arabia are an adapted version of the curricula, published by McGraw Hill (Obikan for Research and Development, 2010). In mathematics, curricula are based upon adjusted learning by depending on vertical reliance among the educational module, built up for the different evaluations to create psychological understanding and scientific abilities for all evaluations. In particular, this approach relies on inspecting ideas and building subjective aptitudes, creating scientific abilities and methods for acing them, and applying arithmetic consistently to take care of issues from day by day life. In secondary school, mathematics course readings as a rule cover five areas including; Number, Algebra, Measurement, Geometry, and Statistics and Probabilities. Science curricula are composed around writings intended to position the students centrally in the instructing and learning process.

Different exercises are intended for recursive learning, and permit students to take an interest at all levels. The general theory of science course books underscores the significance of the logical technique for examination, reasonable aptitudes (e.g., logical perusing and composing, drawing, and gathering tests), and associating science information with day by day life (e.g., relating science to arithmetic and society, which is considered as a type of STEM implementation). In higher grades, science textbooks incorporates subjects as life, cell exercises, and hereditary qualities. The human body, invulnerable, stomach related, and respiratory frameworks, substantial movement, connections among living beings, vitality, and substances are basic divisions of science (MOE, 2010; Mullis et al., 2016).

In order to assess educational standards among schools, regions or even between different countries, there are several universal standardized tests employed. One of the most common in assessing mathematics and science education is, The Trends in International Mathematics and Science Study (TIMSS). The TIMSS mathematics and science test is developed through the combined efforts among the International Study Centre and mathematics and science educators around the world. It was supported by the International Association for the Evaluation of Educational Achievement (IEA) and administered in the United States by the National Centre for Education Statistics (NCES). The IEA TIMSS is in its sixth cycle and has been conducted every four years since 1995. TIMSS tests are usually taken by students in the fourth and eighth grades to produce a comparison of international education systems in these key subject areas (nces.ed.gov).

Certainly, students' achievement in international assessment tests is influenced by many different variables such as schools, teachers, parents, socioeconomic status, culture, curricula and more (Freguson, 1991; Greenwald, Hedges & Laine, 1996). In 2003, Saudi Arabia scored among the lowest participating nations on the achievement sections of the Trends in International Mathematics and Science Study (TIMSS). It has been reported that eighth grade students ranked 34% lower than the international average in mathematics, and 20% lower in science (Mullis et al., 2004). In 2007, Saudi Arabia students' mathematics performance did not improve, scoring 33% below the average in mathematics and 19% below the average in science (Mullis et al., 2009). In 2011, Saudi Arabia TIMMS scores remained lower than the international standards in science and mathematics of 4th and 8th grade students. The 4th grade students scored 410 in mathematics and 429 in science, while 8th grade students scored 394 in mathematics and 436 in science. The TIMMS scale centre point is at 500 (TIMSS 2011). The outcome of TIMSS data made Saudi Arabia's educational policy makers aware of the points that needed attention for achieving educational improvements and reformation. Moreover, the Saudi Arabian government released in a report that they are aiming to rank within the top 15 countries in TIMMS by 2021(The report: Saudi Arabia 2015). In any case, educational reform changes not only demands significant investments, but also require time to demonstrate results. In the most recent review of the Kingdom's instructional framework, the World Economic Forum's (WEF) "Worldwide Competitiveness Report 2014-15" saw Saudi Arabia's educational positioning slip four spots in contrast with the earlier year. It depicted 24th out of 144 nations, and in 13 out of 14 measures. The WEF report noted that Business pioneers considered that the nature of instruction could be enhanced, particularly for preparing in administration (positioned 78th) and mathematics and science (positioned 73rd).

In 2012, a study conducted a comparison between Saudi Arabian and Taiwanese schools, focusing on mathematics teachers' qualifications, practices, and experiences. The analysis was carried out through the data obtained from TIMSS (2007) results, where Saudi Arabia scored as one of the lowest achieving countries and Taiwan on the other hand, as the highest. Responses of Saudi teachers were compared with corresponding responses of Taiwanese teachers to determine the relationship between mathematic teachers' qualifications, practices, perceptions and students' TIMSS scores. Results revealed that there were significant differences in teachers' preparation for teaching specific mathematics topics, professional development platform and in teachers' perceptions about the effects of schools' overall environment on students' TIMSS scores (Dodeen et al., 2012). In 2013, a similar comparative study was conducted to compare between Saudi Arabian and Singaporean science teachers' experience and instructional strategies. This was achieved by using teacher's questioners as a mean of measurement to address the difference in students' achievements level in TIMSS test scores between the two countries. Results revealed significant differences between 8th grade science teachers in most characteristics regarding their educational background, teachers' preparation, and experiences along with teaching practices in teaching different science subjects. Singaporean teachers were found to be better qualified in using new teaching strategies and had positive perceptions in regards to the implementation of new teaching practices required for teaching STEM disciplines (Al-Shannag et al., 2013).

Ministry of Education in Saudi Arabia has asserted quick actions towards the educational policies, but implementing STEM integration was left void. The headquarters' of the Ministry of Education in Saudi Arabia has now been concentrating on the strategic implementation of mathematics and science curricula in every part of the country. Al Sadaawi (2010) addressed the absence of valid and reliable indicators to monitor Saudi Arabia's educational outcomes over the decades as a substantial disincentive to achievement. Contrary, Al-Ghamdi (2005) argued that the low performance and ranking of Saudi Arabia's students in the International assessment tests was a result of the extended efforts and resources provided for wrong matters. Most efforts and assets were focused on the quantitative issues such as the numbers of facilities, teachers and students neglecting the actual curricula standards and quality of pedagogy.

2.3.3 Development and Implementation of the New Mathematics and Science Curricula

This section provides a description of the Saudi Arabia's educational structure. Moreover, it focuses on teachers' roles in curricular reform and the effect their perceptions carries on their daily classroom practices. Hence, the success or failure of the reform process and the implementation of STEM education.

The Ministry of Education is allocating numerous efforts and resources on new projects to modify Saudi Arabia's curricula, which is based on separate subject design, focusing mainly on textbooks as a sole mean of knowledge (Sedgwick, 2001). Educational researchers have indicated the need to look at curricular reform systemically to comprehend the pathways and barriers to achieve effectiveness (Anderson & Helms, 2001). Furthermore, Alabdulkareem (2004) described that over the past decade, much research in science education has concentrated on reform efforts. Most of the research however, does not provide a complete image of interactions among teachers and curricular developers in an environment that encourages not only collaboration, but also discussion of scientific thinking. In the current environment of reform in science, it is important to examine such interactions. Over the previous decade, it has been learned that the process of educational reform is much more difficult than it has been anticipated. Educational reforms, innovations and large-scale changes are considered as difficult tasks, due to the fact that on a larger scale, reform is about shared meaning. It does not only include individual change, but also social change, which is intrinsically difficult to accomplish. According to Hopkins (1998), formal requirements, structures, and event-based activities have been a major focus of reform strategies. An example for this includes teacher's development programs and workshops, paying least attention to present cultures that requires specific values and practices. Moreover, a framework was proposed by Rogers (2003) for assessing the process of adoption and evaluation of educational materials to promote effective consequences. Five critical steps were entailed in the framework including; knowledge, interest, assessment, trail and implementation. In this framework, if negative feedback were resulted through the evaluation process, then the process would end. If the process does not proceed after the underlying trial then it was referred to “adopt and drop”. Although, there was no precise prescription regarding the sector of educational reform was proposed.

Maroun et al. (2008) has described an efficient framework for increasing the chances of successful reforms, particularly in Saudi Arabia. The framework combined three major dimensions central to educational reform. Firstly, it included socioeconomic environment, where social and economic priorities were translated into feasible educational strategies and related goals. Second is the educational sector operating model, in which upright governance, operating entities, and funding to support educational goals have been emphasized. Third is the educational infrastructure that aided in achieving educational goals; such as the overall quality of teachers and curricula, reliable assessment measures and healthy learning environments. Additionally, Henderson et al. (2012) suggested a few noteworthy issues that ought to be contemplated while advancing instructional change. The significant emphasis of these factors is based on the changes of instructional system made in instructional practice that consequently influence instructional decisions. The first factor incorporates change like a process not an event; therefore, it requires time and patience. Furthermore, awareness of the required adaptation plan is only the first stage in adopting educational materials. It is based on the type of change required, and appropriate strategies that should be selected. In order to facilitate the process of adaptation, different procedures maybe required for altering instructional beliefs. Lastly, viable change systems must consider different components of the instructional structure, for example, instructor feelings, assets and institutional settings.

In Saudi Arabia, the educational system is a central system taking a hierarchy structure, with high authorities in the Ministry of Education and lower authorities in schools. Mathematics and science curricula in the context of this study, is set with relevant material sourced from the Ministry of Education, where teachers have no role in curriculum development nor have the authority to alter or change any topic or subject (Al-Sulaimani, 2010). Alyami (2014) argued that reform concepts and development projects require the acceptance of the affected division. As in education, perceptions of teachers and students affect the success of curricular reform and development. Policy makers believe that change is achieved by changing the structure, but in reality change can only be achieved by changing the subjects involved within the procedure. The success of reform measures in education is threatened, if they are not developed through debate and clarified through participatory democratic processes. Stalling’s (1998) highlighted teacher’s roles in the involvement and interactions of curricular reformation, emphasizing on the importance of understanding the nature of the proposed change to achieve success. However, teachers' perceptions and beliefs that shape their practices in implementing curricular reform are usually neglected. These concerns were presented in many researches regarding education in Saudi Arabia (Bin Salamah, 2001). Han et al. (2015) argued that instructors might not completely grasp new instructional change procedures and actualize them uniquely as expected, such as the case with STEM implementation. Students' content accomplishment, convictions, feasibility toward oneself, and inspiration can be negatively influenced if teachers poorly implement STEM teaching strategies.

Research revealed that teachers' effeciency, experience and educational qualifications were the prime predictors of students' academic achievement (Yala & Wanjohi, 2011; Adeyemi, 2010). In a study to assess the effects of teachers' gender and qualification on secondary students' performance in physics, results revealed that teacher's gender had no effect on students' impact of knowledge, where teachers qualifications on the other hand, was considered as the major influential factor for students academic performance (Owolabi & Adebayo, 2012). Moreover, Kilaha (2010) investigated the effect of chemistry teachers' characteristics on students' performance in Bungoma North District. Results revealed that teachers' qualifications, experience and attitude were more influencial on students academic performance, when compared with the effect of school factors. Consequently, Ugbe (2000) investigated the influence of teachers' qualifications and experience on students' academic performance in a senior secondary school chemistry in Cross River State. Results revealed a significant difference between the performances of students taught by qualified and experience teachers in contrast with students taught by unqualified, inexperienced teachers in chemistry.

Teachers' perceptions and performances have gained an important part within the TIMSS studies and research. In fact, teachers have eventually become the focus of TIMSS, where more emphasis is now allocated on their roles and responsibilities. The focus is directed to achieve three dimension of TIMSS. Firstly, it included the intended curriculum describing the intended mathematical and scientific knowledge for the students to learn from it along with characteristics that influence its development. Secondly, it includes the implemented curriculum, which refers to the curricular initiated and applied by the teachers. Thirdly, is the attained curriculum, which refers to the exact mathematical and scientific knowledge achieved by the students (Al-Shannag *et al.,* 2013).

2.3.4 The Islamic perspective of mathematics and science

Educational policies in the Kingdom of Saudi Arabia radiates from Islam, which is the key record that decides the standards, targets and objectives of education within the region. (National Report on Education Development in the Kingdom of Saudi Arabia, 2008). Despite the critics on the Islamic curriculum being incompatible with the modern western one, Bangura (2004) argued that in both worlds educational perspectives despite their cultural differences complement one another. This section of the literature review discusses the Islamization of knowledge concept, origin and development, in order to obtain an Islamic perspective within the new mathematics and science curricula in Saudi Arabia.

The foundation of Saudi education has relied upon the principles of Islam and sustained integrity of its tradition, despite of the fact that the assorted foreign practices have influenced the education system. Every aspect of educational material is maintained by the Saudi government, as all the curriculum books accessible within and out of the kingdom are controlled by the government. The rationale of the government behind controlling these books is to maintain consistency with Islamic teaching, educational objectives, and intellectual trends of the Kingdom. Stalinsky (2002) has asserted that the interest of school authorities is subjected towards maintaining the textbooks with the Islamic requirements and obstructs the factors that hinder the amalgamation.

Islamization of knowledge (IOK) is considered as one of the most important intellectual movements of the 20th century. It is also one of the most credible and long-standing contemporary Muslim intellectual responses to modernity (Haneef, 2005). Over the past decade, with the ongoing scientific advancements and breakthroughs, Muslim and non-Muslim scholars have realized that today’s scientific knowledge is specific to modern Western civilization in terms of values and concepts. A study has described that this fact influenced Muslim scholars to the principle of “Islamization of Knowledge” (Rehman, 2003). In 1997 the first international conference on Islamic Education was held in Makkah, Saudi Arabia for integrating knowledge into an Islamic perspective by combining Islamic values and ethics in various fields of modern thoughts (Zaidi, 2006; Haneef, 2005). Since then, many developments have taken place advancing the development of the discipline in theory and practice.

The term Islamization refers to the arrangement and composition of changes, intended to enhance individuals and their society by adjusting them to Islamic standards (Ahsan *et al*., 2013). Many reformists share different perspectives and opinions in regards to the meaning and ways of

Islamization of knowledge. Based on the proposed framework, this study concentrated on Berghout's (2011) model, that defined Islamization as a scientific activity, an experimental action of the revival of the scholar and civilizational viability of the Muslims and society. Moreover, emphasis has been given on the importance of referencing back to the Western knowledge in order to ensure and maintain the quality with direction of the whole activity. Meanwhile, other scholars, such as Imad al Din Khalil defines Islamization as a scholarly movement, considering the Islamic idea of life, man and the universe (Ahsan *et al.*, 2013). In a study, Dagor (2005) argued that the project of Islamization requires the re-evaluation of the Islamic history and background along with the development of a new epistemology or theory regarding its methodology, logic, and rationale. Furthermore, Abul-Fadl (1988) described Islamization as a process of transformation and revitalization of the present basic structure of thought and recognition by method of their introduction to a radical evaluation. The radical assessment is directed in the light of an organized game plan of scholarly, enthusiastic and typical qualities acquired from the Islamic custom. On the other hand, Sayed Ali Ashraf (1988), argued that IOK cannot be achieved by adding modern science to old traditional excising ones as, per the thoughts of the author, Islamization of education can only take place if the governments of Islamic countries apply Islamization as an educational policy. It can only be achieved by highly educated academics with an Islamic knowledge background and characteristics. As it is the case in Saudi Arabia, where one of the general educational policies placed by the Ministry of Education is that knowledge and sciences must evolve from Islam and be compatible with Islamic thought (Al-khaldi, 2007).

The Islamization of knowledge (IOK) depends upon two levels. First level is the theoretical phase, which clarifies the measurements, intentions, points, stages and methods for IOK. Second is the implementation phase, where the process of Islamization of different subjects takes place by specialist scholars for each subject (Ahsan *et al*., 2013). Additionally, Tayyebi (2015) described that nearly all the scholars and researchers approach the issue of Islamization in certain ways. Primarily by criticizing the Western-based knowledge and then, by exploring the relevant Islamic parameters. Lastly, by providing the strategy, methodology and epistemology of either an integration of the two perspectives or a reconstruction of the disciplines.

2.3.5 STEM Education

The acronym STEM (science, technology, engineering, and mathematics) has become a major focus of the educational system for achieving global competitiveness (English, 2016; Slavit et al.

2016; Weis et al., 2015). Many programs have adopted STEM education to improve and reform their educational structures to positively influence student's achievements (Johnson, 2013; Zeidler, 2016). On the contrary, the conception of STEM varies among educators, educational researchers, curriculum developers and policy makers (Williams et al., 2015). This section provides an overview of STEM definition, importance, advantages and its relevance to the 21st century educational demands and requirements.

STEM has been perceived and defined uniquely among different educational organizations, and also among different departments within the same organization (English, 2016). Educators have mixed views on STEM as, some view it as a new way of teaching STEM subjects while others view it as a new curricula or program (Hughes, 2009). In a study on STEM education, Herschbach (2011) described it as a way to think about curricular reform, arguing that the absence of a unified perception and meaning of STEM can threaten the overall success of its implementation. Making crosscutting STEM associations is a perplexing procedure, which obliges educators to show STEM content in ponder approaches to make students able to comprehend how STEM information is connected to real-world issues. As of now, crosscutting associations stay verifiable or can miss all together, as clear results should be recognized and measured with respect to how incorporated STEM education can advance students' learning identified with these goals (Stanford, et al., 2016).

STEM education is emerged as an integrated curricular design since 1920s as a part of school programming era (Kilebard, 1987). At that time, educators and curricular developers thought that subject integration would take away intellectual characteristics from the integrated subjects. Therefore, more focus on the development of separate subject's direction was given. Additionally, emphasis was given on making school relevant to student's life experiences. Today, the educational agenda focuses mainly on the separate subject orientation methods, where students are limited by course content restrictions and boundaries. Moreover, academic achievement is evaluated through test results of each independent subject. The focus on making learning relevant to students' lives is fading away, as a result, students are loosing interest in STEM subjects (Herschbach, 2011).

Recently, more interest is allocated towards STEM tegration and implimentaional practices (Kennedy & Odell, 2014). For instance, the STEM Task Force Report (2014), viewed STEM education as being significantly more than an "advantageous combination" of its four disciplines. Rather, it depends on real-world issues and problem based learning that connects STEM four disciplines through a consistent active way of learning and teaching. The Report contended that STEM disciplines should not be instructed in isolation to one another, as they do not exist in separation in the real world or the workforce (Task Force Report, 2014). STEM education is one of the most growing areas in educational reform of the Twenty-first century (English, 2016). Educators are continuously challenged with new teaching strategies and methods required for the success of its implementation (Williams et al., 2015; Lund & Stains, 2015). This is due to the fact that STEM learning does not focus on accomplishing literacy in STEM four disciplines only (science, technology, engineering and math). However, calls for designing STEM instructions that helps students to understand how these four disciplines merge together in order to realize solutions to practical problems and real life challenges (Asunda, 2011).

Educating students in an interdisciplinary approach and coordinating them into a strong learning environment in the light of genuine applications, is the premise of STEM education (Pritchard, 2016; Milner, 2015). An article by Brown et al. (2011) represented the results of a survey that investigated teachers and administrator's perceptions of STEM education. Results concluded that the actual meaning of STEM was not clearly understood among individual participants of the study. Further on, results revealed the lack of clarity of STEM vision even among individuals who admits its importance. Likewise, there was limited proof that STEM education and its teaching strategies were actually implemented within the desired schools, which was concluded as the lack of collaboration found between STEM teachers. In another survey, regarding the perception of STEM, Rodger (2010) implied that most related field professionals lacked the actual understanding of STEM and its implementation. It was then suggested that the first step to advance STEM education and come up with effective educational policies, programs and practices is to clarify STEM's specification and unify its definition.

Numerous researches have been conducted to point out the importance of students' involvement in the classrooms and overcome the international decline of enrolment rates within STEM fields (Lund & Stains, 2015; Asghar, 2012). One of the main reasons that cause students' distractions away from gaining class involvement and productive inquiry is the traditional distinct teaching methods used when science subjects are taught (Coffey et al., 2013; Hartzler, 2000). Educators agree that the most beneficial way of teaching and learning science and mathematics is by using student-centred techniques rather than the old structured lectured ones (Levitt, 2002). Simultaneously, national science education standards are utilizing more inquiry based learning to enhance students' conceptual thinking that is relevant to real life issues. STEM way of learning is an ability that promotes students' critical thinking on how STEM concepts, ideas, standards, and practices are associated with daily life experiences (Roberta, 2015). In 2009, the Obama administration launched the *Educate to Innovate* campaign in order to equip public-private partnerships for the improvement of STEM education within the United States. The former president Obama focused on three major points. The first was to increase STEM literacy to enhance students' critical thinking abilities. Second, was to improve the quality of teaching mathematics and science. Thirdly, addressed the need for the expansion of STEM education and its career opportunities to involve underrepresented groups, including women and minorities (Asunda, 2011).

There are several benefits for using integrated education, known as STEM education in students' educational achievements levels. Research has revealed that integrated curricula provides students with an overall encouraging educational experience through relevant and connected disciplines that are less disintegrated and more relevant with real daily life scenarios. Moreover, it improves the overall level of students' critical thinking and problem solving techniques and therefore, their level of retention. Furthermore, the effective implementation of STEM education assist the students for enhancing their competencies during problem solving, making them self-reliant, logical thinkers, and innovators. Moreover, assistance in terms of technical knowledge is also improved by proper STEM education. Additionally, the integration of mathematics and science subjects has proven to have a positive effect on students' attitude and interest in schools, specifically in STEM disciplines. Various studies have discussed on the importance of STEM education, which is essential to enhance students' encouragement levels of learning and achieving greater educational outcomes (Hurley, 2001; Stohlmann et al., 2012; King and Wiseman, 2001).

Dierdorp et al. (2014) investigated the challenges, faced by the secondary students while recognizing the connection between mathematics, statistics, science subjects, and some professional practices. The study highlighted the importance of research on the matter of curricular coherence between different STEM disciplines. The challenges faced by secondary students in making meaningful requisitions and connections between STEM disciplines are due to the fact that each subject is taught in complete isolation. It means that the teacher acts like the sole source of information and instructional strategies. Hartzler (2000) studied the effect of integrated instruction on students' achievement levels in which thirty individual studies were documented. Results revealed that students, who were taught using integrated curricular programs achieved higher achievement levels in national standardized tests, and state wide testing programs. Additionally, results also indicated that integrated curricular programs have proven its success in teaching mathematics and science subjects in all school grade levels, especially with students who suffered from low achievement levels in STEM subjects. A study has proved that STEM education has improved students' achievements levels along their interest and motivation towards the subjects taught. This successful implementation was due to the integrated instructions of STEM education (Sander, 2009).

Herschbach (2011) described three conditions that should be taken into consideration, when implementing STEM educational way of learning for students to benefit from the integration process. First, the implementation of a coordinated educational module plan unites the topic from various fields of study, to clarify the fundamental interrelationships among STEM disciplines. Secondly, students were presented to the formal structure of the fields of study through learning encounters combining the structural, practical and syntactical structures depending on their knowledge and the utilization of information. Thirdly, students must be engaged with their own learning experience through the use of formal, particular and applicative knowledge. Likewise, Dierdorp et al. (2014) discussed five aspects that are important in order for students to achieve meaningful scientific concepts and contexts. These aspects included; usefulness, it is important for students to acknowledge the purpose to what they are learning. Second is the motivation for students to engage with the context understudy. Third is the application to achieve meaningful education, where students must be able to apply the concepts learned in their daily life issues. Fourth is authenticity that means lessons become more meaningful to students when dealing with relevant and authentic contexts. Finally is connection, including the relationship between different school subjects, where knowledge from different subjects are integrated.

With the continuous research and developments in the field of STEM education, it has been proven through design and evaluation that developed instructional materials and teaching strategies required implementation to enhance students' learning efficiency. On the contrary, there is an apprehension that these instructional approaches and materials are not being adopted properly (Williams, et al. 2015). Stanford et al. (2016) argued that educators are facing difficulties in applying new instructional strategies due to the fact that educator developers tend to rely exclusively on dissemination when proposing new educational materials. This is due to the fact that once educational developers test and evaluate their proposed material, they often tend to disseminate their work via traditional means including journals, conferences and websites. These methods may raise awareness of the topic, but are not sufficient to promote changes in practice. Furthermore, educational developers often focus mainly on developing new instructional materials, not taking into consideration the factors that may influence the adaptation process and its overall success. Such as perceptions and feedbacks of potential adopters (Stanford, et al., 2016; National

Research Council, 2012).

The shortage to successful STEM implementation does not rely solely on the number of students and teachers. But, it is important to concentrate on the quality of teachers, as most primary and secondary STEM teachers are not 100% confident in what they are teaching due to lack of knowledge on STEM subject or its precise teaching ways (Hughes, 2009). Evidence-Based Instructional Practices (EBIPs) are new instructional practices that have been established to endorse students' conceptual understandings and attitudes toward STEM disciplines (National Research Council, 2012). In a study to investigate STEM teachers' implementation levels in respect to new teaching strategies and evidence-based instructional practices (EBIPs) between chemistry, biology and physics teachers. Counting the logical and individual variables impacting the levels of teachers' implementation practices, settled the gap between the developers' vision of an instructional system and the genuine execution of the strategy. Results revealed that even though STEM faculty members were all aware of the EBIPs, only half of them implemented one or more of them in their courses. Which in turn, identified the fact that the levels of adopting STEM instructional strategies remain low (Lund & Stains, 2015).

Professional development is envisioned as an essential device for the reception of research-approved teaching strategies and a noteworthy concentration of numerous systematic reform activities (Henderson et al. 2011). Despite the proven advancements of reformed teaching methods in students' educational outcomes, especially in STEM disciplines, teachers in higher educational institutes are hesitant to adopt these new strategies. This is due in part to teacher development programs which have not proven their success in promoting the transition from instructor- centre passive teaching techniques towards new student centred and active learning methods (Pelch & McConnell, 2016). STEM represents an urgent need for curriculum adjustment and the modification of traditional teaching and learning techniques. Zeidler et al. (2005) described ten best teaching practices teachers should follow to achieve a successful mathematics and science integration process, hence, STEM education. The authors described that teachers should act more as facilitators rather than the main source of information. Also, to encourage students' hands on learning, concentrating on the use of cooperative learning, critical thinking and problem solving techniques. Moreover, during class, teachers should depend heavily on questioning, assumptions and discussions. Further, it has been added that mathematics and science classes should be based in inquiry, student centred inquiry, where assessments are included with in the class. Additionally, more attention should be focused on the integration of technology.

It has been proven that STEM educational activities give teachers the chance to focus on concepts that are naturally connected between different STEM subjects. Berlin and White (1995), recommended different teaching approaches that can benefit the process of STEM education or subject integration today. First, teachers should focus on students' prior knowledge, try to organize and build upon the existing knowledge to connect relative concepts and themes. Second is to create alternate information to include interrelationships of ideas and procedures. Third is to be able to comprehend that achieved knowledge is a circumstance or context specific. Fourthly, to empower information to be progressed through class discussions and relevance to real life scenarios. Finally, comprehend to students that knowledge is socially developed after some time (Berlin & White, 1995).

Even though, there has been an increase in the number of STEM contributions, as many schools are moving towards implementing different forms of STEM and subject interventions (Kelley & Knowles, 2016). However, STEM is yet considered as a challengeable task, as there stays little concurrence about what STEM schools ought to look like in practice, and even about what "STEM" really is in the operational setting of K12 instruction (LaForce et al., 2016). Moreover, due to the lack of its solidifying perception and implementation framework, there are many ways to formulate a STEM program and no specific curriculum model to follow and apply. The implementation of reformed institutional changes require the adoption of reformed instructional approaches. However, this process is considered as socially and logistically challengeable, due to the standards of practice and organizational structures especially in STEM fields, where each discipline share its own set of standards and curricular requests (Hora, 2012). Three considerations must be taken into account when designing, developing or reforming a curricula, which includes the society, its students, and the subject of matter (Tyler, 1950). Therefore, there is a need to enhance the overall understanding of these instructional practices and decision making across all STEM disciplines to achieve effective application of instructional reform practices. Instructional reform efforts should focus more on the implementation techniques including raising awareness, interest, practice and application of these strategies rather than focusing mainly on its advertising (Lund & Stains, 2015).

2.3.6 Implementation of STEM as Curricular Concept

Integrating subjects and connecting disciplines, as in STEM education, have been emphasized throughout past studies, especially in respect to the integration of mathematics and science curricula (Herschbach, 2011; Sander, 2009; Hartzler, 2000). The recognition of the similarities between the two disciplines has increased the number of studies within this area. The uniformity in the field of their application and mutual approaches towards problem solving has been considered an important reason to perform researches in this field. Each country shares a different political, social and technological history; therefore, possess different views on its educational system, specifically in regards to STEM education and the technological use (Cutucache et al., 2016). In Saudi Arabia's educational system, minimal attention is given to the interrelationships between the different taught subjects within the curriculum. STEM has the characteristics of promoting an integrated curriculum design, where subjects are taught in relation to one another (Herschbach, 2011). Research studies reviewed in this section helped in examining the implementation of STEM and its effect on teachers' perceptions, classroom practices and students' outcomes.

STEM education proposals are commonly found in the United Kingdom and the United States of America; however, they have not been appropriately introduced nor considered of great preference in other countries. On the other hand, these other countries in educational context followed their lead, as the Commonwealth countries tend to follow the United Kingdom and Europe. The Asian countries tend to follow the technological educational developments in the United States (Williams, 2011). Likewise in Saudi Arabia, the new mathematics and science curricular textbooks are adapted versions of the American educational company McGraw-Hill (Al ghamdi & Al-salouli, 2013; Almazroa & Al-Shamrani, 2015). Despite the fact that the idea of STEM education has been envisioned in the United States since the 1990s as a way of strengthening mathematics and science curricula. Today, several decades later, its exact implications are still unclear (LaForce et al., 2016; Tofel-Grehl & Callahan, 2016). Herschbach (2011) illustrated two ways to integrate STEM within school curricula. Firstly, it includes the correlated curriculum pattern approach, where each subject retrains its separate identity with the addition of correlation and organization among topics within individual subjects. The challenge is related with the required coordination among teachers who are teaching different STEM disciplines, in addition, the need of reorganization of subjects' topics to meet the requirements of the coordination with the other associated subjects. The second method is the broad field pattern approach, which is considered a radical move towards integration, as all four disciplines are integrated into a unified curriculum. The main challenge of this approach is creating an effective organizing framework for instruction, which is difficult to maintain through an integrated curriculum design. Vasquez et al., (2013) described four different forms of STEM subject integration. First, through disciplinary form of integration, where concepts and skills of STEM subjects are taught separately in each discipline.

Secondly, through multidisciplinary integration, where concepts and skills of STEM disciplines are taught separately. Thirdly, through interdisciplinary coordination where firmly connected ideas and attitudes are found out from at least two controls with the point of expanding students' information and instructive abilities. Finally, through trans-disciplinary integration, where knowledge and skills gained from at least two trains in the interdisciplinary way of integration are connected to real-world issues and projects.

Vasquez et al., (2013) mentioned STEM subject's integration in forms similar to what was described earlier by Drake's (1998) three integration directions. However, the only difference was that Vasquez et al., (2013) added one more direction to the integration process, the addition of disciplinary form of integration. Drake (1998) described the curricular integration theory through three directions. First, the multidisciplinary approach, where students are expected to make an association with respect to a point or an issue that has been instructed among various branches of knowledge in various classes. Secondly, the interdisciplinary approach, where students are expected to apply their knowledge from different subject areas, as subjects are connected to a greater extent than a theme or an issue. The focus wasw on interdisciplinary content and skills. Thirdly, the trans-disciplinary approach, in which students are required to focus on real-life issues, and have the ability to connect these issues to social, political, economic, international, and environmental concerns. Furthermore, Jacobs (1989) described several ways to integrate curricula among which parallel design of discipline was the one common method. In this method, only the appearance of the integrated subjects are changed, and no alteration is done to the actual content of the subjects. Teachers are supposed to reorganize the course's topics in a way to meet similar fields within the disciplines. Jacob's perspective of subject integration is also similar to Drake's multidisciplinary model. Both models agree on the same theme, the rearrangement of topics sequence in the integrated curricular to make connections among different disciplines.

In a study, Kiray (2012) developed a new mathematics and science integrated curricular model called "The Balance Model", which reflects the significance of balance in the process of integration that is suitable for the Turkish educational background and culture. The aim was to keep the contents and standards of the integrated mathematics and science curricular the same as their original values. In a study, Kiray (2012) developed a new mathematics and science integrated curricular model called "The Balance Model", which reflected the significance of balance in the process of integration that is suitable for Turkish educational background and culture. The aim was to keep the contents and standards of the integrated mathematics and science curricular similar as their original values. Seven dimensions were reflected with the help of the balance model, including; content, skills, teaching, learning process, affective characteristics, measurement, and assessment. Studying and comparing these dimensions with the previously developed ones, along with findings from previous research helped in developing the newly integrated scientific and mathematical model in Turkey. Introduction of STEM as an educational reform in turkey is considered to be critically important for its economic competitiveness, despite the fact that there have been some critics in regards to teachers' educational levels in teaching STEM disciplines. Turkish teachers were not fully prepared to implement new teaching strategies that are required for the success of STEM implementation. In a study by Corlu et al. (2014), the authors introduced a STEM educational model that was designed through the investigation of previous research on STEM education, curricular integration, teaching knowledge and the Turkish educational reforms. Their major focus was towards the importance of integrated teacher's knowledge to successively move their schools from the traditional way of teaching and learning to an integrated model that promotes innovative teaching and learning required for the success of STEM education implementation process (Corlu et al., 2014).

The genuine capability of STEM education reform lays in the chance to influence change in instructor practice. In a review to survey generally utilized inductive teaching strategies, including, inquiry learning, problem-based learning, extend based learning, case based educating and disclosure learning. The authors highlighted shared traits and particular contrasts and research surveys on the adequacy of each technique. It was concluded that despite the differences of the strength of evidence initiated in each method, inductive methods were consistently found to be more effective than, traditional inferential methods. These methods helped in attaining a comprehensive range of learning consequences (Prince & Felder, 2006). Meta-analysis of integrated curricular research demonstrated higher achievements and accomplishments of students when taught with an integrated curricular approach (Hartzler, 2000; Becker & Park, 2011). Studies conducted within the field of STEM education helps in informing STEM educational stakeholders on identifying best teaching practices that were required for the implementation of STEM education, along with determining barriers to its success. Therefore, a conceptual framework has been considered as a valuable tool to aid in building a research agenda, and to analyse the full potential of its implementation (Kelley & Knowles, 2016). Kennedy and Odell (2014) suggested that in order to achieve successful STEM educational programs, the following points should be taken into consideration: first, minimum integration of engineering and technology into mathematics and science curricular. Secondly, to promote the use of scientific inquiry and engineering designs to facilitate difficult mathematical and scientific instructions. Thirdly, the use of collaborative approaches while teaching and learning STEM subjects, in order to connect students and educators with STEM fields. Fourthly, is to provide a multi-perspective view in regards to the topics understudy. Fifth is the incorporation of different educational strategies, and finally, the incorporation of suitable technological methods to enhance the overall learning experience.

Knezek et al. (2013) studied the effect of hands-on project activities on students' perceptions and content knowledge of STEM within six different middle schools in the United States. Findings confirmed students' increased knowledge in STEM fields and an improvement in their creative tendencies and perceptions about STEM subjects and careers. Moreover, a qualitative study investigated elementary teachers' perceptions regarding the new applied science curricula in Saudi Arabia (ALGhamdi & Al-Salouli, 2012). Eight of the science teachers were interviewed, not only to understand their perceptions, but also to study the effect of their beliefs on their classroom practices. Findings revealed that the new curricula's interactive and group-oriented activities have increased enjoyment for teaching and learning science, moreover, lead to higher achievement and understanding of scientific concepts among students. A similar study was conducted to understand teachers' perceptions and classroom practices regarding STEM integration. Wang et al. (2011) used a multiple case study as a form of qualitative research on three middle school teachers. The study was conducted after the completion of a yearlong professional development program on STEM integration. Findings emphasized the importance of problem solving techniques as a key component to integrate STEM subjects. Moreover, findings have addressed teachers' needs for more content knowledge in their STEM integration, and highlighted the effect of teachers' perception on their classroom practices. It evaluated that the teachers' different perception of STEM is the reason behind the different ways STEM is implemented within classrooms.

Despite the positive effect of STEM on students' achievement and content knowledge, incorporation of STEM should be approached with caution through a gradual long-term plan. Many factors including political, social, cultural, economic and religious issues make school curricular structures rigid and resistant to change. In a study to investigate attitudes toward science among students in 4th, 7th, and 10th grades and their parents. Results revealed that students with parents holding positive orientations toward science are more likely to sustain positive attitudes toward STEM, where the establishment, in adulthood, may specifically influence the routes the up and coming era of students interacts with science (Mihelich et al., 2017). Other barriers that face a successful implementation of STEM includes; rigid structures of school curricular, standalone subjects that are taught in complete isolation to one another along with educational department's agendas and requirements (Kelley & Knowles, 2016). Moreover, the use of the end of the year exams as a sole assessment process. Nonetheless, many possible benefits of STEM education can be provided to concentrate on teaching practices, efficacy and strategies required for a successful implementation (Stohlmann et al., 2012). A successful integration of mathematics and science subjects is dependent heavily on teachers' understandings, content knowledge, and perceptions on the integration process. Many teachers face some difficulties in teaching their own subjects. This leads to integrate other subjects that can be challenging and may leads to miscommunication, which to a degree can effect transmitted information to the students (Stinson, et al., 2009).

The challenges of STEM implementation have been demonstrated in the form of integrated circular design, indicating the grounded historical subject's curriculum system over the past few decades in France (Lebeaume, 2011). The integration of the structured scientific curriculums has been restricted with the demonstrated deep-rooted organization. Pitt (2009) described the challenges included in the implementation of STEM education in schools, describing it as a problematic approach, because of the absence of a unified definition of the accurate meaning of STEM and the absence of an implementation framework. The absence of information on whether STEM should be educated as a discrete subject or as a way to deal with instructing as part subjects. Pitt described that even if it was possible to integrate STEM subjects into a unified curricular. It is still unrealistic to expect its success especially in higher school levels, due to teachers' qualifications, as it is impossible for secondary school teachers to be equipped with all required knowledge from different STEM subjects. The only way for the integrated approach to be successful is to involve the team teaching technique in the organization. The team teaching technique include the implications of timetables, and special training programs for teachers, still, this technique has bit of complexities and is impossible to achieve.

In the proposed research, the aim is to understand the concept of STEM integration within Saudi Arabia's newly adapted mathematics and science curricula. This aspect has been achieved through investigating teacher's perceptions and the new applied instructional practices required for its success.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter provides a justification of the research design and chosen methods including a fair description of the research study approach, site, sampling, participants selection, applied research instruments, ethical considerations and analysis techniques. Appropriate methodology has been entailed to justify the objective of the research study, which is to investigate teachers' perceptions of the new mathematics and science curricula as a step towards STEM implementation in Saudi Arabia. Williams et al. (2015) described that gathering information on instructional practices is an imperative stride in arranging and sanctioning important activities to enhance undergraduate science instruction. This aspect can be achieved by investigating the new instructional practices, required by the Ministry of Education for the implementation of the new mathematics and science curricula in Saudi Arabia. The chapter is divided into main sections and subsections. The first section provides a general description of the research study's approach, methods applied and chosen paradigms. The second section describes the research's context, while the third section provides a full description on site, sampling and participants' selection. Furthermore, the fourth section entails discussion on the applied research instruments for qualitative and quantitative approaches, ethical considerations, and analysis techniques.

3.2 Research Approach

This section identifies the research study's design, which is based on a mixed method approach, including methods applied, paradigms, chosen instruments and data analysis used for the research at hand, while providing justification for the researcher's choice.

Educational research can be defined as the application of a scientific approach, where researchers learn useful information that is valuable to study educational process and its problems (Tuckman & Harper, 2012). Methodological approaches are usually classified as either qualitative or quantitative. The quantitative research uses objective measurements in a controlled setting to gather numerical data that are used to answer the research questions or hypothesis. On the other hand, qualitative research uses different forms of inquiries that focus on understanding a social phenomenon from the perspective of human participants in natural settings. Data collection in the qualitative methods focuses on describing, discovering, classifying, and comparing with previous results and conducted researches (Ary, et al., 2013; Tuckman & Harper, 2012).

The particular manner, in which a teacher utilizes a set of curricular materials, depends on many factors including the nature of the adapted materials, teacher's perceptions, qualifications, and knowledge. Moreover, it also depends upon students' reactions towards new-implemented curricula. In this research study, a mixed method design was chosen as a suitable method to investigate teachers' perceptions and applied instructional practices of the new mathematics and science curricula as a step towards STEM implementation in Saudi Arabia. It was achieved to improve the standards of Saudi Arabia's educational system in general, and the overall quality of its students in the fields of mathematics and science subjects in specific. Here, both the qualitative and the quantitative methods were applied to enhance the overall strength of research, making the achieved results and future recommendations more reliable and significant (Creswell, 2013; Teddlie & Tashakkori, 2009; Creswell & Plano, 2007; Onwuegbuzie & Leech, 2004; Driscoll et al., 2007, Johnson et al., 2007).

Mixed methods design is becoming increasingly common in the educational research field; as it provides a more complete understanding of the research problem. It compliments and mitigates the weakness of using either approach by itself (Onwuegbuzie & Leech, 2004; Driscoll et al., 2007, Johnson et al., 2007). The emergence of mix method as a third methodological type of research in the social and behavioural sciences is not considered as new, and had begun since the 1980s (Tashkuri & Teddli, 2003). For several decades, researchers have been using mixed methods in their research, referring to it by using different terms as multi-methods, integrated, combined, hybrid, and mixed methodology research (Creswell & Plano, 2007). Furthermore, Creswell defined mixed methods research as *"an approach to inquiry"* as it collaborates both the qualitative and quantitative methods within the same research (Creswell, 2008).

For a long time, there has been a continuous debate among educational researchers regarding qualitative and quantitative methods, describing them as being directly opposite to each other. Opponents of quantitative research described it as a reductionist approach; while critics of the qualitative methods described it as non-scientific approach. Gradually, it has reached to their intensions that both methods are not considered as opposite approaches in research, and were finally viewed as complementary rather than adversarial (Ary et al., 2013). Different views on mixed methods exist, depending on the researcher itself and the nature of the research understudy (Hanson et al., 2005; Fraenkel et al., 2015). Onwuegbuzie and Johnson (2004) described that the researcher becomes more flexible and holistic throughout the applied investigational techniques when combining both quantitative and qualitative methods. It qualified the researcher to investigate further into the data set and get a deeper understanding of the research problem by using one method to verify and compliment the findings of the other. Furthermore, it enhanced the understanding and analysis of significant findings in educational evaluations. A key feature of using mixed methods research is that it provides the methodological multitude that positively improves the research, when compared with a single method research (Teddlie & Tashakkori, 2009).

In this mixed method research study, a sequential exploratory design was used with the rationale of investigating teachers' perceptions on the implementation of new mathematics and science curricula. It was done by expanding and elaborating the findings of qualitative data with the input of numerical quantitative results. Ivankova et al. (2006) asserted that the research goals and objectives along with the particular design of each phase must be identified and taken into consideration to find preference of a certain method. In the proposed study, the priority was placed on the qualitative data as the goal of this study was to rely as much as possible on participants' views and perceptions to understand *"what and how the new mathematics and science curricula is implemented in the classrooms"*. This aspect was best analysed through qualitative procedures; such as in-depth interviews with participating teachers, teaching high school mathematics and science subjects, and through classroom observational methods (Yin, 2003). Moreover, five open-ended questions were included at the end of the distributed questionnaire, to gain a wider range of participant's views, perspectives, and instructional practices in regards to the new mathematics and science curricula and its relevance to STEM education implementation practices.

Firstly, , it is entailed to the uniqueness of research topic. Being one of the first studies on STEM education conducted in Saudi Arabia, it was of great benefit to use both methods. Therefore, it resulted in increasing the possibility to overcome the lack of research within this area of study.

Secondly, to enhance the overall strength of the research study, as the qualitative analysis would be helpful in revealing unique in-depth information and reasoning regarding teachers' perceptions about the application of new science and mathematics curricula. The quantitative analysis on the other hand, would encourage educational policy makers regarding the significance of STEM implementation. Moreover, it also aids in building hypothesis, assumptions, and future educational recommendations in regards to the implementation of STEM education in Saudi Arabia.

Thirdly, collecting data from both qualitative and quantitative methods provides an opportunity to determine the degree to which teachers' perceptions from the qualitative instruments applied, congregates with teachers conceptualizations of those same beliefs and perceptions. Hence, responses gained from the distributed questioners.

Fourthly, results achieved from the quantitative method by the use of a cross sectional questionnaire, would be helpful to generalize the qualitative results making them more relevant and of high importance to the Saudi society as a whole (Creswell, 2003). The qualitative part of the study was unique to Jeddah, which consisted of only eight participants, mostly females. While the quantitative data on the other hand, was taken from 13 different regions across Saudi Arabia, consisting of 543 participants from both genders, to ensure the validity of the results from both genders.

Fifth reason was to achieve data triangulation as described by Greene et al. (1989) and Yin (2003). It was approached by seeking corroboration of findings through the usage of qualitative evidence as teacher's interviews, class observational methods, and the open-ended questions found at the end of the distributed questionnaire; therefore, it provides multiple measures for the same phenomenon. Triangulation is also recommended to increase the validity of research and to eliminate bias as every research method by itself carries its shares of limitations.

Sixth reason was the researcher's objective to eliminate bias. Lincoln et al. (2011) described qualitative research as *"fiction, not science, and that these researchers have no way to verify their truth statements."* This is due to the fact that in qualitative research, the researcher's prejudgment and bias can be introduced throughout the analysis and findings. Therefore, the collaboration of quantitative analysis did not only compliment and generalize the results, but also gave it support by eliminating bias. In the case of quantitative methods, multiple-choice questionnaires, as a mean for gathering quantitative data, has been criticized for their lack of validity and of being weak instruments (Aikenhead & Rayan, 1992). According to Johnson and Onwuegbuzie (2004), major limitation of quantitative results is that researchers do not fully understand what information can be found through statistical significance testing. This as a result makes it more difficult for policy makers, especially in the educational fields, to base their decisions, policies, and recommendations on numerical non-descriptive data. Therefore, the interpretation of using qualitative and quantitative methods helped in making the analysis of the results more comprehensible.

Finally, the use of mix methods assisted in the evaluative emphasis process of the newly implemented mathematics and science curricula. As participating teachers were able to express their perceptions and applied instructional practices in regards to the new curricula quantitatively and qualitatively, which was achieved by the use of multiple means, including semi-structured interviews, class observational methods, and cross sectional questionnaires.

Ary et al. (2013), argued that quantitative and qualitative research comes from different philosophical assumptions; therefore, it affected the way researchers approach their research problems and the way they collected and analysed their attained data. In this mixed method research study, a paradigm for each method was used and analysed separately in two different views as each method remained distinct from the other (Sandelowski, 2000). The choice of paradigm in a research sets down the objective, motivation, and expectations of the research under process. Therefore, proposing a paradigm at the beginning of a research creates a baseline for choosing the methodology, applied instruments, literature review, and the research design (Mackenzie & Knipe, 2006). In this research study, a humanistic paradigm was chosen in qualitative phase to grasp teachers' subjectivity, perceptions and true views in regards to the newly implemented mathematics and science curricula, along with its required teaching practices (Miller, 2015). In general, qualitative results can be considered as a window for the researchers to help them understand the social reality experience of the topic understudy from the participants' point of view (Ary et al., 2013). On the contrary, a post-positivism paradigm was chosen for the quantitative approach, to achieve scientific and common sense reasoning obtained from the numerical statistical results; therefore, be able to claim what will cause the achieved outcomes (Sharp et al., 2011). Positivists believed that general principles govern the social world as they do through objective procedures, researchers can discover these principles and apply them to understand human behaviour (Ary et al., 2013). Positivism is normally considered as a customary logical strategy, which includes theory testing and target information assembling to accomplish discoveries that are systemic, generalizable, and open to replication by different scientists.

In the methodological part of the research study, the qualitative method was first applied using basic interpretative studies. Basic interpretative research is considered as the most simple and common form of qualitative research. Moreover, it provides a descriptive analysis through the use of different forms of qualitative measures as interviews, observational methods and document analysis (Ary et al., 2013). The qualitative measures of this research study, were collected through the use of high school mathematics and science teachers' semi-structured open-ended interviews, class observational methods, and five open-ended questions included at the end of the distributed questionnaire. The purpose behind using basic interpretative research was to understand how high school mathematics and science teachers perceive events, processes, and activities, while implementing the new mathematics and science curricula in the classroom as a step towards the implementation of STEM education in Saudi Arabia. The research study focused on using personal open-ended interviews with participating teachers to gain a deeper understanding of the major aspects of the new mathematics and science curricula. Moreover, classroom observational methods were applied in order to comprehend how the new mathematics and science curricula as a step towards STEM implementation are delivered in the classroom. Furthermore, participants' responses at the end of the distributed questionnaire helped gain a wider and deeper perception on the implementation of the new mathematics and science curricula as a step towards STEM implementation in Saudi Arabia. In the quantitative phase of the research study, a cross sectional questionnaire was distributed for gathering and analysing the perceptions and convictions from a larger group of high school science and mathematics teachers, that are familiar with the new mathematics and science curricula in Saudi Arabia (Rea & Parker, 2012; Fraenkel et al., 2015).

According to a study conducted on the implication of data analysis, it has been stated that the analysis of exploratory design is always conducted separately with the help of parallel mixed analysis (Johnson & Onwuegbuzie, 2004). The analysis of the qualitative phase of the research study was approached using Krathwohl's (2008) three main stages. Firstly, through familiarization and organization of the results; secondly, through coding and recoding of achieved data; and finally, through summarization and interpretation of the outcomes (Krathwohl, 2008). However, in addition to the three main steps, a diagram was created at the end of each method to summarize attained results. The statistical means of the quantitative phase was analysed using descriptive statistics SPSS (Rea & Parker, 2012).

Johnson and Onwuegbuzie (2004) argued that three conditions should be taken into consideration to conduct a parallel mixed analysis. Firstly, the analysis of both the qualitative and quantitative data should be done separately. Secondly, no part of the analysis of both the quantitative and qualitative methods should build upon the other during the data analysis stage. Third, no integration or comparison between the findings of the two methods should be done until both sets of data analysis have been fully completed. Johnson and Onwuegbuzie (2004) described the purposes of using parallel mixed analysis either with a quantitative or qualitative base, is to achieve triangulation, complementarity, and initiation within the research findings. The purpose of using parallel mixed analysis in this research study were consistent with the purposes of using mixed methods design when conducting a research as it was stated earlier (Greene et al., 1989).

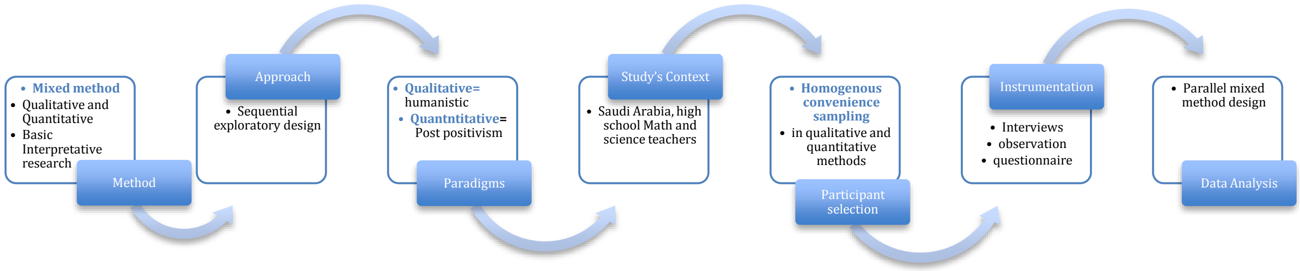


Figure (3) Stages of research study's approach and methods

3.3 Context, Sampling and Participants Selection

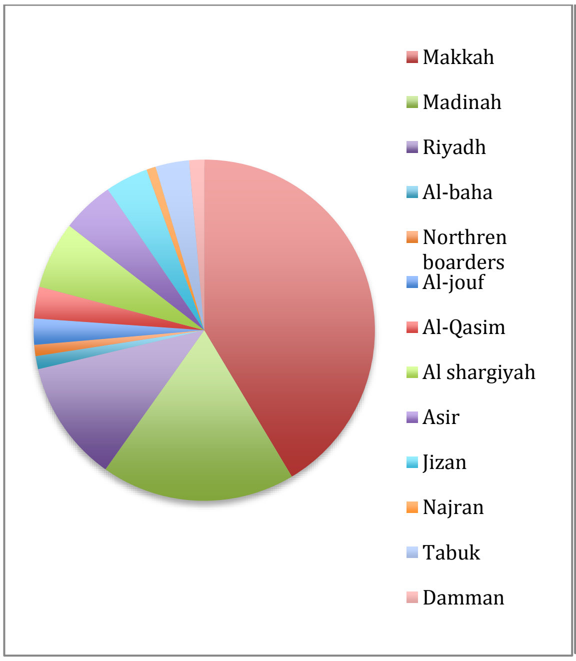
The context of this research study is in light with the Kingdom of Saudi Arabia (KSA) by the use of mixed methods design to investigate highschool mathematics and science teachers' perception on the new mathematics and science curricula as a step towards STEM implementation. Depending on a homogeneous sampling for the qualitative and quantitative parts, the researcher selected similar cases to describe a subgroup in depth, rather than from all members of the population (Glesne, 2011). Moreover, it is also used to ensure that the required data achieved is related to the scope of the research understudy (Onwuegbuzie & Collins, 2007; Patton, 2002; Fraenkel et al., 2015). Participants' selection was based on teachers' willingness to take part in the study; selection was specific to science and mathematics teachers, teaching new mathematics and science curricula higher grades (grades 11 & 12), applied from the Ministry of Education as a step towards STEM implementation in Saudi Arabia.

The qualitative part was unique to Jeddah, Saudi Arabia, based on a homogenous conveience sampling. The selection of this area was based on the researcher's accessibility to potential study participants and information, as the researcher lives there. Participants' selection was based on teachers' experience in teaching both, the previous and the new mathematics and science curricula in Saudi Arabia. Eight high school teachers participated in the qualitative part; four of which were selected for the semi-structured open-ended interviews and another four for the classroom observational methods. It was achieved to gain a deeper and wider perspectives of research's objective from different angles; and therefore, growing a clearer picture on teachers' perceptions of the new mathematics and science curricula in contrast with its implementation practices in the classrooms and eliminate bias. Participants were selected from four different schools, from which one school was comprised of male students only, and the other three were all female student schools. From each participating school, one science teacher and one mathematics teacher were nominated by their schools as suitable candidates to be included in the qualitative part of the research study.

Four teachers were interviewed; including three female teachers teaching mathematics, physics and biology, and a male teacher teaching chemistry. Baker et al. (2012) argued that a small number of interviews might not enable researchers to compare particular groups or to consider frequency distribution. On the contrary, Brannen and Nilsen (2011) described that the most important issue in deciding on the number of qualitative interviews depends on the purpose of the research, type of addressed research questions, and the proposed methodology. Based on the objective of this study, where the aim was to investigate teachers' perceptions and classroom practices in regards to the new mathematics and science curricula; only four teachers teaching different subjects including mathematics, biology, chemistry and physics were interviewed. This was achieved in order for the researcher to gain in-depth information on each subject, be more observant, and able to build a convincing analytical narrative that is based on richness, complexity, and detail for each individual subject taught.

Turner (2010) argued that in many times, depending on the scope of the research, interviews are coupled with other forms of data collection, to provide the researcher with a well-rounded collection of information for analyses. In the observational part of the methodology, another four high school teachers, teaching STEM subjects (chemistry, biology, physics, mathematics) were observed. The reason behind observing different participants than the ones interviewd, is due to the fact that the researcher's objective was to observe mathematics and science classes under natural settings and investigate teachers applied instructional practices. Furthermore, it was ensured that participants are not implementing teaching practices that are equivalent to the research topic based on their interviews, and therefore eliminate bias. However, due to Saudi gender segregation policy, all classroom observational methods were conducted in the all female participating schools. It was due to the fact that the researcher is a Saudi female, she was not granted access to all male school facilities. Moreover, since the researcher is not a part of the Ministry of Education research panel, video tape recording of boys' classes were also not granted; therefore, the researcher had to depend solely on observing four female teachers, within the three participating all girls schools in Jeddah.

The quantitative part of the research study, consisted of 543 highschool mathematics and science teachers. Sample selection was decided on by using 10% of the target population, including male and female highschool mathematics and science teachers, teaching the new mathematics and science curricula within the 13 different regions of Saudi Arabia, to ensure the validity of the results from both genders. Furthermore, it was also ensured that different subgroups are represented in the sample according to their presence in population (Muijs, 2011). According to the Ministry of Education's 2012-2013 Summary Statistics on General Education In K.S.A, (Ministry of Education Report, 2013), the sample should be around 600 male and female teachers teaching high school mathematics and science subjects within the different regions in Saudi Arabia; but only 543 were suitable for analysis. 60 samples were excluded from the analysis due to missing data, teachers teaching subjects other than mathematics and science. Moreover, some teachers were teaching elementary levels, where the focus was on highschool curricula. The illustration for participants distribution in Saudi Arabia, along with the male/female ratio was proposed using a pie-chart (figure 4). The illustration has shown that 58% participants were female teachers, while 42% were male. The alpha level used in determining sample size is 0.01, as, it is considered acceptable in most educational research (Kotrlik & Higgins, 2001).



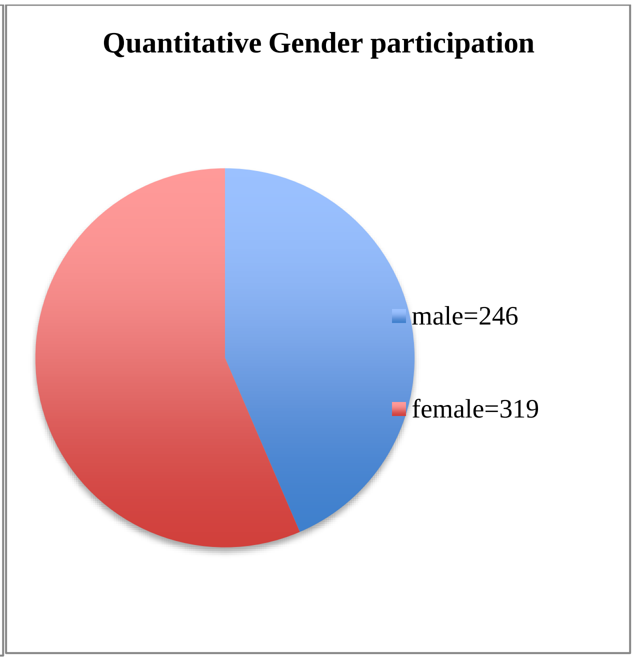


Figure (4) Quantitative sample: participants gender and regional distribution

3.4 Instrumentation

This section intends to provide operational definitions for the key features of instruments applied using mixed methods design. The purpose is to elicit a rich and deep understanding of teachers' perceptions, in respect to the new mathematics and science curricula, as a step towards STEM implementation in Saudi Arabia. Based on the particular design, three instruments related to qualitative and quantitative methods were discussed. First aspect was the semi-structured face-to-face interviews with participating mathematics and science teachers. Secondly, classroom observational methods; and thirdly, the cross sectional questionnaire. Data collection of the research study was chosen within the scope of the research topic and in relevance to the literature review and proposed framework, with the aim of providing appropriate answers for following the research questions:

1. What are the major aspects of the new mathematics and science curricula as a form of STEM education implementation in Saudi Arabia?
2. What are the perceptions of teachers on the implementation of the newly adapted science and mathematics curricula?
3. How is the newly adapted mathematics and science curricula delivered in the classrooms, as a form of STEM education?

3.4.1 Interviews

Interviews have been considered as the most popular form of qualitative methods as it provides authentic information of participants' personal experiences and perceptions of a certain matter (Melles, 2005). Interview questions in qualitative studies usually focuses on participants culture, perceptions, experience, understandings, systems, meanings and problems studied in order to investigate plans, intentions, roles, behaviour and relationships of participants regarding the research topic understudy (Tuckman & Harper, 2012). Therefore, interviews are perceived as a powerful tool when gaining insight into educational issues, by understanding personal experiences of involved individuals and provide more in depth responses (Seidman, 2013; Crabtree and Miller, 1999). There are three forms of interview designs; first are the informal conversational interviews; secondly, the general interview guide approach; and thirdly, the standardized open-ended interviews (Turner, 2010). In relation to the research topic and the nature of the research questions, the researcher developed semi-structured interviews, based on an open-ended style of questioning. Semi-structured interviews are considered as the most effective and convenient means of gathering information (Kvale and Brinkmann, 2009) as it enables participants to provide responses in their own terms and language. Therefore, revealing important and often hidden aspects of human and organizational behavior (QU & Dumay, 2011). Furthermore, semi-structured interviews involve prepared questioning, guided by identified themes in a consistent and systematic manner to help direct interviews toward the scope of the research. Additionally, it is also used to ensure that similar thematic approach is applied during interviews (QU & Dumay, 2011). In this research study, the semi-structured instrument consisted of nine open-ended questions, designed to investigate mathematics and science teachers perceptions and classroom practices in regards to the new mathematics and science curricula, as a step towards STEM implementation in Saudi Arabia (check appendix 1). The purpose of conducting the semi-structured interviews was to provide teachers with the opportunity to describe and elaborate the connection between their perceptions about new mathematics and science curricula as a step towards STEM implementation, with their daily applied classroom practices. Providing participants a place to voice their opinion freely allowed the researcher to build future recommendations for Saudi Arabia's educational policy makers and curricular developers, to improve the standards of Saudi Arabia's educational system in general, and the overall quality of its students in the fields of mathematics and science in specific.

In order to maintain the quality of an interview, Shensul et al. (1999) suggested three principles; first was maintaining the flow of the interview's questioning and participants' responses; secondly was to maintain a positive relation with the participants; and and thirdly to avoid interviewing bias. In this research study, the researcher took the role of the interviewer. Moreover, interviews were guided by the same main questions as all participants were asked the same questions in the similar order. Furthermore, the questions were worded in an open-ended format; the open-ended nature of the addressed questions allowed participants to contribute in shaping the discussion and feel free to share their perceptions, experiences, and attitude in regards to the subject matter (Bogdan & Biklen, 1998). Additionally, it allowed the researcher to gain access to participants thinking; including aspects influencing their perceptions in a way that cannot be accessed using other modes of data collection (Luft & Roehrig, 2007). In order to confine any potential for biasing the interviewees' remarks and to avoid influencing participant's answers, the interviewer took the position of an uninvolved member during all interviews, as the interviewer read the questions as worded in order to minimize any unintentional influence. Moreover, participants answered were recorded exactly as they explained it. Further, the interviewer focused on providing neutral explanations when the participants needed further clarification. Finally, the researcher created a summary report with the objective to interpret the data obtained from the participants, to eliminate any unintentional input from the researcher.

Each interview lasted around forty-five minutes to an hour, as an appropriate time to conducting interviews as described by Glesne (2011). Participants were briefed prior to interaction with the research topic, rationale and objectives along with necessary clarifications that could accurately influence the success of the interview. The interview questions were first developed in English, then translated into Arabic, as it is the first language in Saudi (check appendix 2). In order to ensure the accuracy and validity of the translation, and to make sure that the meanings were not lost in translation (Kapborg & Bertero, 2002) two certified translators were asked to assist (Simon, 2011). Appointments were requested ahead of time through verbal agreements using phone calls with intended school principals. Four teachers were interveiwd; three of them were female teachers teaching mathematics, biology and physics from three different female schools in Jeddah, Saudi Arabia. Each interview was held within the school premises and lasted for about forty-five minutes. The fourth interview however, was conducted with a male highschool teacher teaching chemistry. Due to gender segregation policy in Saudi Arabia's schools, the interview was conducted over the phone after granting the schools's principle permission. Methods used for documentation and later analyses, included note taking and audio tape recording (DiCicco-Bloom & Crabtree, 2006). Unfortunately, the researcher was only able to record one interview, which was conducted with the chemistry male teacher on the phone, as most participants rejected the idea of recording their voices, despite the fact that it was described to them that they will remain anonymous.

In order to test the trustworthiness of open-ended interview questions, a panel of educational experts; including educators and teachers were asked to judge the translation, context, and validity of the developed instrument. Three educational experts assisted in reviewing the questions, including a science education professor from Dubai, a school principle from Jeddah Saudi Arabia, who also has a previous 25 years experience of teaching mathematics in Saudi, and a retired Biology teacher with 22 years of teaching experience in Saudi Arabia. Furthermore, a trial interview was conducted with a female science teacher, teaching 11th grade chemistry. The interview was held within the premises of one of the participating schools in Jeddah, Saudi Arabia, and lasted for approximately one hour. The interview was conducted in Arabic as it is the first launguge used in Saudi Arabia, the trial consisted of thirteen questions and later edited down to nine questions. It was done to increase the convenience of participants included in process, and structuring the interview to match the objective of the research study. Some of the questions were deleted from which one example includes *"In your opinion, if you were asked to compare between the old and the new mathematics and science curriculum which would you promote and why?"*

Also, additional adjustments to open ended questions were made, which included clarifying words, removing spelling and grammar errors, and cancelling the overlapping questions. Moreover, rearrangement of the sequence, grouping, and contents of some questions took place to implement an easier flow and to make the questions more relevant with the scope and objective of the research study. For an example "*Were you or your fellow mates offered any sort of Teachers' development programs or workshops to prepare you to teach and implement the new math and science curriculum? How important is it for teachers?"* was modified to *"As a teacher, were you offered any sort of Teachers' development programs or workshops for preparation to teach and implement the new mathematics and science curriculum? How important do you think is it for teachers?"*

3.4.2 Classroom Observations

In the proposed research study, the main focus of classroom observational methods was to describe whether teachers' perceptions has aligned with the applied teaching practices in regards to the implementation of the newly adapted mathematics and science curricula as a step towards STEM implementation in Saudi Arabia. Moreover, formulating an in-depth study for each individual participant in order to conclude the research question "*How is the newly adapted mathematics and science curricula delivered in the classrooms, as a form of STEM education?*" Classroom observational methods were conducted by the researcher within the participating schools in Jeddah, Saudi Arabia. Four schools participated in the qualitative part of the research study as it was described earlier; one was an all male school, while the remaining were all female. Due to gender segregation policy in Saudi Arabia, only three schools were included in the class observational method. It was due to the fact that the researcher conducting the classroom observational methods was denied access to the all male schools, as the researcher is a Saudi female. Moreover, the research is not under the Mininsrty of Education research panel, video tape recordings were also declined. Therefore, classobservational methods were unique to the three all female schools in Jeddah, Saudi Arabia. Classroom observations of the biology and chemistry teachers were conducted from the same school, while the physics and mathematics classes were each from a different school.

Erickson (2012) described that the best possible way to investigate a new curricula and its educational practices is through observing classroom discourse and pedagogy. Tofel-Grehl and Callahan (2016) described that the best path to understand STEM education implementation within STEM schools lays in the study of classroom discourse. As the authors described instruction and classroom dynamics as critical variables in student outcomes. In this research study, four different high school teachers were observed, teaching chemistry, biology, physics and mathematics. The primary focus of the classroom observations was to investigate teachers' application of the new instructional practices required from the Ministry of Education, to teach the new mathematics and science curricula as a step towards the implementation of STEM. Classroom observational methods were purposefully conducted during participants' STEM integration lessons by the use of an observational checklist that was developed by the researcher, with relevance to the scope of the research topic and the nature of the research questions. The observational checklist included two sections. The first section was to investigate applied teaching strategies to address the following question; "*how well did the teacher cover the following teaching approaches in the classroom?"* This was approached through the observation of the following subdivisions; Lesson opening, quality of teaching, mode of instruction, relating taught subjects with students' daily life issues, and making connections between different STEM subjects when teaching. The second section included the observation of the overall learning environment in the observed mathematics and science classrooms.

The classroom observational method was applied to investigate all activities and interactions between participating teachers and their students, to monitor their interactions with the activity (Merriam, 2009). As the format of the lesson plans varied significantly among teachers teaching different STEM subjects (mathematics, physics, chemistry and biology), the number of classroom observations was also varied depending on the coverage of each STEM subject and chapter, each class was 45 minutes long. In chemistry, a total of six classes were observed for the same teacher teaching 11^{th} and 12^{th} grade students. Topics covered, included the ionic and covalent bond, which was covered in two classes. Alkaline battery topic, was covered in two classes; and the hybridization chapter was also consisted of two classes. In biology, a total of five classes were observed for the same teacher teaching 11^{th} and 12^{th} grade students. Topics covered included Bird anatomy chapter, which consisted of two classes including one in the Laboratory; the circulatory system chapter was covered in three classes. In physics, three classes were observed for the same teacher teaching 12^{th} grade students; topics covered included the Quantum theory, Kinetic energy and Newton's first law. In Mathematics, five classes were observed for the same teacher teaching 11^{th} and 12^{th} grade students; topics covered included Pascal theory, binomial theory, Polar coordination, resume limits and tangent and velocity. The reason behind choosing to observe more that one chapter in each subject was to ensure that the researcher gathered enough evidence that are suitable for analysis and the investigation of applied instructional practices.

In order to achieve trustworthiness of developed instrument, a pilot classroom observation took place with a female mathematics teacher teaching 12th grade, in one of the participating schools in Jeddah, Saudi Arabia. The observational trial assisted in focusing on the required observational techniques and note taking, with regards to the scope of the research topic. The trial helped in clustering the observational checklist. Some of the columns were deleted and more emphasis was given on observing the subject integration among the topic taught and STEM subjects. For example, the observational checklist was re-organized into two sections. The first is to investigate new applied teaching strategies required for teaching the new mathematics and science curricula as a step towards STEM implementation. The second, was to observe the overall learning environment in mathematics and science classrooms. Instead of three sections: A) Teaching strategies: How well did the teacher cover the following teaching approaches in class, B) teachers qualifications and C) Learning environments.

Additionally, in the revised observational checklist, more focus was attained towards testing students' input and involvements, and on the relation between the taught subject and real life scenarios. Moreover, in order to eliminate bais, the researcher took the position of a silent uninvolved member during all classroom observational methods, as no interaction was made with the teacher or any of the students during observed classes. The researcher was observing the classes with the aim to add knowledge and not pass judgement on the observed settings, as everything was recorded as it occurred. Further, the researcher adapted the two column field note taking strategy, as described by Hammer et al. (2009). In the observational checklist, the researcher used two columns for taking classroom notes, one column to report the indicators for classroom teacher and students interactions, while the other column was used for writing personal thoughts and comments (Appendix 3). By that, the observer's personal comments and thoughts are separated from the actual observational facts.

3.4.3 Cross Sectional Questionnaire

Appropriate instrument development is fundamental for a questionnaire in order to accurately measure its intended subjects for its intended demographics (Williams, et al. 2015). In this research study, a cross-sectional questionnaire was developed as a suitable form of method to gather data. The developed questionnaire contained a series of multiple questions with five open-ended questions at the end. The researcher generated the questions in relevance to the scope of the research topic, literature review, theoretical framework and the nature of the proposed research questions. Moreover, with relevance to the targeted group of participants, their demographics were also taken into considerations (Rattray & Jones, 2007). Research revealed that teachers play a key role in academic reform, and on students' educational outcomes. Scholars have suggested various factors related to teachers' characteristics, affect the academic performance of students in STEM courses, such as their qualification, age, experience, and gender (Etsy, 2005). In order to investigate teachers' perceptions on the new mathematics and science curricula and its implementation practices, as a step toeards STEM education in Saudi Arabia, five demographic variables that might carry an effect on teachers, were taken into consideration. Including teachers' gender, nationality, years of teaching experience, educational qualifications and subjects taught.

By the use of a homogenous convenience sampling (McMillan, 2004; Glesne, 2011), a onetime questionnaire was distributed among different schools in Saudi Arabia, to analyse the perceptions of a large group of participants. The group included high school mathematics and science teachers, teaching the new mathematics and science curricula implemented in Saudi Arabia (Rea & Parker, 2012; Fraenkel et al., 2015). Furthermore, it was also used to understand applied teaching strategies required for teaching the new mathematics and science curricula and its relevance to teaching practices required for STEM education implementation. Hanson et al. (2005) described questionnaires as a valuable tool to understand how education is functioning in a certain area by capturing useful snapshots of educational efforts. When conducting a survey, it is very important for the researcher to give weightage and potential to every question and use them as pieces of puzzle that could make up the educational landscape (Tilak, 1992; Cohen, Manion & Morrison, 2013). There are many advantages of using questionnaire as a mean of gathering data in educational research. It is anonymous and can encourage greater honesty of responses from participants. Moreover, questionnaires can be more economical in terms of money and time, as they are relatively quick to complete. The data provided by the questionnaire can be easily analysed and interpreted by the researcher *(*Henerson et al., 2005; Rattray & Jones, 2007).

Despite the previous advantages of using a questionnaire as a mean of gathering quantitative data, it also carries its share of limitations. This depends on the way that polls are not adaptable and can't investigate nor promote any thoughts or remarks that a respondent makes. Besides, composed reactions might constrain for a few people who may communicate all the more effortlessly orally (Hanson et al., 2005). Moreover, capturing teachers' perceptions of a wide topic as STEM education through limited multiple choices can be challenging. Additionally, participants' background differs from the researcher's, which makes it difficult to comprehend participant's exact veiws regarding the objective of the research study. Also, each participant may comprehend the questions differently from what is intended by the researcher. Therefore, the questionnaire was developed with the addition of five open-ended questions at the end, to minimize the limitations of the developed questionnaire and maximize its benefits. This would help gain a more in-depth response and give the participants a place to voice their perceptions freely and clearly (Rattray & Jones, 2007). Moreover, several points including; confidentiality of participants, rights to withdraw at any time, potential of the research to improve participant's educational situation and the degree of threat or sensibility of the developed questions were carefully taken into considerations by the researcher (Cohen, Manion & Morrison, 2013).

The cross-sectional questionnaire contained a selection of forty two items (check appendix 4), as described by De Vaus (2002) within a suitable range of questions in a questionnaire. It mostly contained close-ended questions with five open-ended questions at the end. All questions used within the questionnaire constituted to the nature of the research questions and the data of the research understudy (Creswell, 2013). Due to the uniqueness of the research study, the quantitative measurement of the subjects' responses to the research questions required the development of the instruments by the researcher. The questionnaire was designed into five sections. The first section involved an overview of the demographic information of participants including gender, years of teaching experience, nationality, subjects taught and teachers' educational qualifications. The second section covered teacher's background including how teachers are prepared to teach the newly applied mathematics and science curricula as a step towards STEM implementation in Saudi Arabia. Further on, the third section was related to the perceptions of teachers regarding to the objective of this study. The fourth section comprises of teaching the new mathematics and science curricula within the classroom, it includes teacher's preparedness, collaboration, development, the new curriculum efficacy as well as the challenges and barriers. The fifth section on the other hand, consisted of five open-ended questions that were analysed as a form of a qualitative method. The open-ended questions were only included in the manually distributed questionnaires as the aim was to facilitate the online process for the participants from the 13 different regions in Saudi Arabia. The manually distributed questionnaires were distributed to male and female highschools in Jeddah and Al-Madinah cities in Saudi Arabia, due to convenience factors, as it is where the researcher and her family lives.

The developed questionnaire may be in the initial image of the three middle sections, which had been prepared in the form of multiple-choice questions. Based on the objective of the research study, each dimension of questions included partial sets of variables. In the first section, questions 6 to 18, the aim was to investigate teachers' awareness and preparedness levels to teach the new mathematics and science curricula. Therefore, participants were offered the following options: 1= not prepared, 2= somewhat prepared, 3=well prepared and 4= very well prepared. The second part, including questions 19 to 29, aimed to investigate the emphasis of the new mathematics and science curricula on teachers' implementation practices. Options included; 1=no emphasis, 2=minimal emphasis, 3=moderate emphasis and 4=heavy emphasis. In the third section, questions 30-39, the objective was to investigate the delivery of the new mathematics and science curricula in the classroom, options included; 1=no opinion, 2= disagree, 3=somewhat agree and 4= strongly agree.

Lozan et al. (2009) described that one of the primary considerations, when designing an educational questionnaire was the scale development. As educational scales and instruments are commonly used to measure opinions, personality traits, self-efficacy, school organization and other phenomena affecting the educational process. However, there has been an on going debate on the use of midpoints on Likert scale when designing a questionnaire. Tsang (2012) identified the major issues behind this debate by dividing these concerns into two major factors. First was the methodological factor, on whether or not midpoints affect the reliability and validity of the research. The second factor included epistemological issues, regarding how researchers are able to know the meaning of the responses into midpoints that they intend to measure. Tsang (2012) proposed that the use of a scale with midpoints is appropriate for educational research in light of the fact that such an incorporation may not really affect the validity and reliability of the results. Additionally, abstain from compelling respondents to choose a direction. Nevertheless, the author described that in order to minimize the limitation of using midpoints when developing a questionnaire, few restrictions should be taken into consideration including; cautious utilization of options labels, clear definition of the midpoints, the consideration of "N/A" choices in a Likert scale, and the expansion in scale affectability.

Johns (2005) favoured the usage of 4-point scales when developing a questionnaire, to secure validity of the developed instrument; and later on, the achieved results. In the developed questionnaire, participants were provided with four options to choose from. A careful examination was taken into consideration when developing the questions as a mixture of both positively and negatively worded options were proposed in all the three middle sections of developed questionnaire. It was distributed through the following options in the form of *"strongly agree or* *disagree, not prepared and very well prepared, no emphasis and heavy emphasis"* to minimize the threat for biases (Rattray & Jones, 2007). Furthermore, the use of neutral options or mid points on the scale were also offered in the form of "*minimal emphasis, somewhat agree, somewhat prepared"*. Forcing agreement or disagreement through eliminating a mid-point or neutral option within the proposed options can force participants to claim "*no opinion"* when they actually have one. It is due to the fact that some respondents have no bases for choosing between agreement and disagreement; therefore, providing a neutral option that can be used as a safe choice in order to avoid unpopular viewpoints that can latter on, affect the results of the research (John, 2005; Williams, et al. 2015). Adding to that, participants' responses were later translated into numerical data to form statistical analysis.

Table (1) Expressing items of the developed questionnaire for each dimension, in the three middle sections in the form of multiple choice

Questions	**Dimensions**	**Questionnaire Answer Options**			
		1	**2**	**3**	**4**
Questions 6 to 18	Teacher Background	Not prepared	Somewhat prepared	well prepared	Very well prepared
Questions 19 to 29	Teachers' perception	None	Minimal emphasis	Moderate emphasis	Heavy emphasis
Questions 30 to 39	Teaching New Math and Science Subjects in a Classroom	No opinion	Disagree	Somewhat agree	Strongly agree

Due to the fact that the context of the research study is based on Saudi Arabia, where Arabic is known as the first language, a translation of the instrument into Arabic was required to ensure the validity and accuracy of the distributed questionnaire (appendix 5). Two of the criteria were taken into account for translating the instrument. First criteria was related to the correlation of Arabic and English language's meaning. Second was related to the clarity of the translation offered to the participants (Fraenkel et al., 2015). The Arabic version was tested using two different professional translators in order to ensure the sense of the items had not been lost in translation. The first translator used alot of difficult scientific terminologies that made the survey seem complicated and rigid. The second translator on the other hand, did minor modifications to facilitate the translation by using simpler wording. This would help in creating an easier flow, making it easier for the participants to accurately respond. Moreover, a back translation of the Arabic version of the questionnaire was achieved in order to confirm that no meaning was lost in translation (check appendix 6).

3.5 Pilot Study

A pilot study is an essential element included in the study design and is considered as a valuable tool that assists in elucidating the research's statement, inquiries and proposed questions (Glesne, 2011). Even though, conducting a pilot test may not guarantee the success of a research, it increases the chances of success by providing valuable insights of the research methods and the instruments designed and applied. Pilot studies are also known as feasibility studies, which have been considered as a mini version of a full-scale study (Teijlingen & Hundley, 2002).

In order to ensure the instrument's appropriateness for the context of the research study, research questions and the targeted population, the instrument should be assessed to determine whether it was useful to obtain the target or not (Williams, et al., 2015). The purpose of the pilot study is to test the quantitative part of the research, the developed questionnaire, its' appropriateness to the subjects in terms of clarity, validity and reliability in order to gain confidence in the produced results (Lancaster et al., 2004; Baker, 1994: Al-Ghanem, 1999; Williams, et al., 2015). Rattray and Jones (2007) explained that considerable pilot work is required in order to refine wording and content. In this research study, the objective behind piloting the developed questionnaire, was to confirm that the questionnaire was able to collect the information necessary to meet the objective of the research study, and to ensure the relevance of the items. It also determines the time required for answering the questions when applied to the basic study sample.

An Excel spread sheet was used for data capturing, while percentage and numbers were used to interpret attained data. Moreover, a cross tabulation was used to determine association of the achieved results. The pilot study was prepared through the consultation of experts within the field of the research, and by the review of the associated literature. In this research study, the piloting of the developed questionnaire was achieved in two steps. Two experienced educators in Saudi Arabia helped in reviewing the layout of the questionnaire including translation, clarity, wording issues, relevance to the research topic, and the quality of the developed questions (Simon, 2011). The second step was done by piloting the questionnaire in a sample of sixty teachers from both genders, teaching higher grades mathematics and science subjects, using a homogeneous convenience sampling. Sample size of the pilot study was decided by using 10% of the 600 participants required for the quantitative part of the research study, as it was described earlier in participants' selection. The cross-sectional questionnaires were distributed manually among different high schools of both genders in Jeddah, Saudi Arabia (Kotrlik & Higgins, 2001).

To test the trustworthiness of the applied instrument as a mean of gathering data, the developed questionnaire was tested for its validity and reliability through the use of multiple tests. Tavakol and Dennick, (2011) described validity and reliability as two fundamental elements in assessing the development of a questionnaire. Moreover, they clarified that the trustworthiness of an instrument is allied with its validity, where an instrument cannot be valid unless it is considered as reliable. Validity is an assessment to investigate whether an instrument measures up to its objectives. In this research study, the validity of the developed questionnaire was ensured through the use of construct validity test, using the approximation discrimination approach.

Reliability on the other hand, is concerned with the ability of an instrument to measure consistently when measurements are repeated using the same tools under the same circumstances (Tavakol & Dennick, 2011). The researcher calculated the reliability coefficient achievement test through the application of two different tests. First, through the use of Cronbach's alpha coefficients test, known as the most popular test to measure reliability (Tavakol & Dennick, 2011; Rattray & Jones, 2007). Secondly, by the use of Kuder-Richardson 21 test, as an imitative test to Cronbach's alpha, also known as a measurement of internal consistency (Kuder & Richardson, 1937).

3.5.1 Validity of the Developed Questionnaire

3.5.1.1 Construct validity by approximation discrimination approach

Mann-Whitney U test is a non-parametric test that is utilized to analyze two sample means from the same population, and is used to test whether the two sample means are equivalent or not. In this research study, Mann-Whitney U test was carried out to determine if the variables were acceptable as independent constructs that could be sufficiently distinguished from each other. In addition to the fact that the U test is designed for small distributions, including both homogeneous and heterogeneous sampling (Creswell, 2005). In order to calculate the U statistics, combined set of data is first arranged in ascending order with tied scores receiving a rank equal to the average position of those scores in the ordered sequence. In this section, the researcher conducted an approximation discriminatory, where the sample (n=58) is rearranged in a ascending order according to the total score achieved by each of the participants in response to the total score for the questionnaire grades. After that, the researcher identified the top 27% of scores (n =29 members), and the lowest 27% of the grades (n= 29 members). Finally, a comparison was done between the scores of the two groups using the test Mann-Whitney U. The table below demonstrates the values of (U) between the low and high scores on the achievement test.

Table (2) Values of (U) between the low and high scores on achievement test

Dimensions	Group	No	Average	Total	U Value	Z Value	Level of significance
	High score	29	12.50	100.0		-	
	Low score	29	4.50	36.00		3.401	
	High score	29	12.50	100.0		-	
	Low score	29	4.50	36.00		3.398	
	High score	29	12.50	100.0		-	
	Low score	29	4.50	36.00		3.542	
	High score	29	12.50	100.0		-	
	Low score	29	4.50	36.00		3.470	

From the above table, the level of statistical significance was 0.001 for all paragraphs. It means that there are statistically significant differences between individuals' high responses and low responses in all the paragraphs of the test. Which in turn, reassured the validity of the test.

3.5.2 Reliability of the Developed Questionnaire

3.5.2.1 Using Cronbach's Alpha Coefficient

Tavakol and Dennick (2011) described Cronbach's alpha test as one of the most important concepts used in the evaluation and assessment of a questionnaire. When conducting a quantitative research through questionnaire as a means of gathering data, it is important for the researcher to apply Cronbach's alpha test to add validity and accuracy to the developed questionnaire. Furthermore, the test used inter-item correlations to determine if constituent items of the questionnaire are measuring the same domain as it is based on the variations of the questionnaire's questions. Moreover, it is used to clarify the extent of heterogeneity between the vertebrae tests. Therefore, the researcher calculated the reliability coefficient for the three main diamensions of the questionnaire separately and then calculated the alpha coefficient for the total score of the test. Table 4 below, shows the values of Cronbach's alpha coefficient for each dimension and for the total score test.

Table (3) Cronbach's alpha coefficient for each dimension and for the total score test

Dimensions	Statement	Alpha	Average correlation

		coefficient	dimension
Teacher Background	14	0.773	0.562
Teachers' perception	10	0.876	0.591
Teaching the New Math and Science Subjects in a Classroom	10	0.743	0.556
Total Score for the exam	34	0.896	0.578

It was illustrated from table 3, that the reliability coefficient values for the achieved results of each dimension ranged between (0.773-0.896). This appeared stable when compared with the average dimensions links, which on the other hand, ranged between (0.502-0.591). Moreover, it was also demonstrated that the calculated reliability coefficient of the total score of the applied test was (0.896). Rattray and Jones (2007) described that if the items show good internal consistency, Cronbach's alpha test score should exceed (0.7) for newly developed questionnaires and (0.8) score for a more established one. This aligned with the achieved Cronbach's alpha test score, which indicated a high level of internal consistency for the study's scale; therefore, can be considered as a good reliability that is acceptable to conduct the research.

3.5.2.2 Kuder-Richardson 21 test

The researcher further used Kuder-Richardson 21 test, to reassure the stability and reliability coefficient test of the developed questionnaire, in accordance to the following equation:

$$\text{KR21} = \frac{(M-N)M-V2N}{V2\ (1-N)}$$

Table 5 represented the coefficient, which was 0.86 for the Kuder-Richardson 21. The coefficient eventually confirmed the high level of internal consistency for the questionnaire developed. Thus, it assured the use of questionnaire developed in qualitative study for gathering relevant data to acquire the aim of study.

Table (4) The Mean value , Standard Deviation , Variation and Kuder-Richardson 21 coefficient for dimension and total score of the test

Dimensions	Statement	Mean	Standard Deviation	Variation	Kuder-Richardson 21 coefficient
Teacher Background	14	4.78	2.36	5.56	0.62
Teachers' perception	10	4.93	2.25	6.72	0.77

Teaching the New Math and Science Subjects in a Classroom	10	4.98	2.34	6.89	0.78
Total Score for the exam	34	25.06	8.06	64.96	0.86

Results achieved from the pilot study through the use of different tests assured the validity and reliability of the developed questionnaire; therefore, it can be considered as an applicable tool for gathering quantitative measurements involved in a study. Moreover, it was proven that the developed questions or items included within the questionnaire were appropriate for the scope of the research study and relevant to the nature of the research questions. The only shortage concluded lied under the fact that the most teachers were not familiar with the term STEM, so a small paragraph as an introduction was added at the beginning of the distributed questionnaire. It helped in fully describing the meaning and insuring accuracy of the achieved results.

3.6 Data Analysis and Procedures

Based on Johnson and Onwuegbuzie (2004) study on using parallel mixed analysis, the analysis of the qualitative data first took place through an ongoing process. The process included preparing, organizing and interacting with the attained data at multiple levels (Creswell & Plano, 2007). This was approached through following Krathwohl's (2008); three main stages of analysing qualitative results. However, in addition to the three main steps by Krathwohl, a table was included at the end of each qualitative method including; participants' interviews, class observational methods and four open questions found at the end of the distributed questionnaire, in order to summarize achieved results.

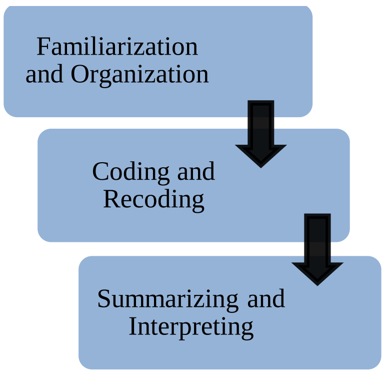


Figure (5) Krathwohl's (2008) method followed to analyse the Qualitative data

The following paragraphs briefly discussed the analysis of the qualitative data achieved in this research study, based on Krathwohl's (2008) three steps of qualitative analysis. Stage one is known as familiarization and organization, in which obtained results are familiarized and organized during analysis. In this stage, the researcher had read and reread interviews, observational checklists notes, and open-ended questions to become familiar with the achieved results. After that, the researcher put the open-ended questions into an organized form and completed the notes of the interviews. The analysis of observational checklist notes and the open-ended questions found at the end of the distributed questionnaire were done by same procedure. Furthermore, the researcher also read and reread the notes again and took additional comments while reading.

Stage two refers to the coding and recoding of data. In this stage, the researcher identified the main categories and themes of the attained notes that were achieved from the qualitative instruments applied. After familiarizing the results, coding involves clustering them into relevant themes of the research, which is to investigate teachers' perceptions and instructional practices of the new mathematics and science curricula as a step towards the implementation of STEM education in Saudi Arabia. Moreover, coding and recording is also helpful to achieve aspirations and verification of the barriers, which were required in the implementation of STEM within the Saudi curricula.

Stage three is generally known as data analysis. In this stage, summarizing and interpreting data is the most important perspective of the qualitative analysis. Furthermore, the researcher had to present the massive amount of attained data in an understandable and organized manner. Thus, a table was created to summarize the shared points found in teacher's interviews, class observational checklists, and teachers' responses to the five open-ended questions, included at the end of the distributed questionnaire. It was achieved to put the summary of the key issues in accordance to the developed theme of the study.

On the other hand, the statistical means of the quantitative data were analysed using descriptive statistics in the quantitative part of the study; such as percentages, group means, modes, frequencies, T- test of differences and F-test of analysis of variance (ANOVA) by using the Statistical Packages for Social Science (SPSS 22.0) to perform the data analysis (Muijs, 2011). Data analysis began with data cleaning and descriptive statistics for the rate of investigating teachers' perceptions and classroom practices regarding new mathematics and science curricula as a step towards the implementation of STEM education in Saudi Arabia. Furthermore, the examination of the differences among the five demographic variables, including participants': gender, years of teaching experience, nationality, educational qualifications and the subject taught.

3.7 Ethical Considerations

In this research study, ethical considerations were carefully evaluated in order to protect the dignity of the participants in specific and the validity of the research study in general.

- Verbal agreements through phone calls with school heads were granted in the qualitative part of the research study, to allow access to their school premises for conducting interviews with participated teachers and observe mathematics and science classes. Moreover, in the quantitative part, E-mails were sent to different schools to grant permission to distribute the cross sectional questionnaire among highschool mathematics and science teachers (appendix 7 and 8).
- In the qualitative part of the research study, a clear verbal agreement was established with participants prior to their participation in order to clarify their roles, obligations and responsibilities required from both sides.
- In order to guarantee confidentiality and anonymity, all participating subjects were assured that any data collected from them will be held confidential as each participant will be referred to a number instead of using his or her original identity (Fraenkel & Wallen, 1993).
- Deception was avoided by fully informing qualitative participants with the aspects of the research that might influence their willingness to proceed, as all addressed questions and concerns were fully described and taken into consideration (Fraenkel et al., 2015).
- All participants were granted the freedom to withdraw from the research at any time.
- Significant differences within the research population including cultural, social, religious and gender factors, were taken into consideration in the planning, conducting and reporting of the research (Onwuegbuzie & Collins, 2007). For an example, when interviewing the male chemistry teacher, due to religious and cultural factors, the teacher wasn't comfortable in meeting face to face with the female researcher, therefore, a phone call interview was arranged. Moreover, due to cultural regulations, observational methods were all conducted in female schools.
- Research techniques that may carry negative social consequences were carefully considered, addressed and minimized. In the qualitative part of the research study, participants were not comfortable to audio record their the interviews, nor video record the observed classes, therefore, the researcher depended solely on note taking.

CHAPTER 4: DATA ANALYSIS AND RESULTS

4.1 Introduction

The previous chapter outlined the methodological approaches that were used in this research study. In this chapter, findings of the research study were fully presented and analyzed. The purpose was to investigate teachers' perceptions and instructional practices of the new mathematics and science curricula as a step towards STEM reform in the Kingdom of Saudi Arabia. In order to achieve the objective, the research study followed a mixed method design. The instruments applied included semi-structured open-ended interviews and class observational methods in the qualitative part of the research study, and a cross-sectional questionnaire in the quantitative part. Data attained was analyzed in order to answer the following research questions:

- What are the major aspects of the new mathematics and science curricula as a form of STEM education implementation in Saudi Arabia?
- What are the perceptions of teachers on the implementation of the newly adapted science and mathematics curricula?
- How is the newly adapted mathematics and science curricula delivered in the classrooms, as a form of STEM education?

Due to the fact that the research study followed a parallel mixed analysis design, attained results from the qualitative and quantitative parts of the research study were separately conducted and analyzed. This was achieved in order to avoid integration and comparison between the findings of the applied two methods, as described by Johnson & Onwuegbuzie (2004). Therefore, in this chapter, results were collected by qualitative instruments including: mathematics and science teachers' open-ended interviews, class observations, and the five open-ended questions. The quantitative part of the results was obtained through the cross-sectional questionnaire.

4.2 Qualitative Analysis

4.2.1 Teachers Interviews

Based on a homogenous convenience sampling, participants' semi-structured open-ended interviews were conducted with four different participants, teaching high school mathematics and science subjects from four different schools in Jeddah, Saudi Arabia. The interview section included a male chemistry teacher, and three female teachers teaching mathematics, physics and biology. All participating teachers had the experience of teaching the old and the new mathematics and science curricula in Saudi Arabia, as it was a requirement from the researcher. In this section, nine open-ended questions were listed along with each participant's responses, which were based on their own educational backgrounds, perceptions and personal teaching experiences. Data analyses of the open-ended interview results were achieved using Krathwohl's (2008) three main stages. First, through familiarization and organization of teachers' responses. Secondly, through coding and recoding of the attained results and finally, through summarization and interpretation of the achieved results. Moreover at the end, a table was created to summarize teachers' responses in regards to the nine open-ended interview questions.

Q1) Are you familiar with the concept "STEM education", if yes please describe it for me?

Not all interviewed teachers heard of the 'STEM' title; however, after describing the meaning of the term it was apparent that most participants were familiar with its concept. The physics teacher was the most familiar with STEM, as she was able to give a complete definition of its implementation, purpose and objectives. Further, the teacher described that finding relevance between different STEM subjects when teaching, and relating given topics to students' lives is a requirement from the Ministry of Education when teaching the new curricula". Moreover, she added: "Most schools in Saudi Arabia do not focus much on STEM implementation or subject integration when teaching, the concept STEM is familiar to me due to my own personal experience. This was due to my participation in Bricks for Kids, an educational program that stands for fun for education. In this program, kids used Lego blocks to define different themes, for an example the illustration of museums and the different forces of nature. Further, in this program, kids were introduced to engineering without noticing, through building different modules". Likewise, the chemistry teacher added; "The new curricula focuses more on relating assigned topics with students', making it relevant to their daily lives more than the actual integration process between different STEM disciplines". While the biology teacher explained: "All of us teachers within different fields of science subjects have annual visits from the Ministry of Education, in order to make sure that we are applying the new student centered teaching techniques and are following the new curricula's goals and objectives. On the other hand, we are not questioned much about subject integration or the implementation of STEM". Further, the mathematics teacher highlighted the importance of STEM integration, saying "We cannot separate mathematics from other STEM subjects, especially physics and engineering, as all subjects are related like a chain reaction if you cut one part out, you lose the reaction".

Q2) Do you believe that the new mathematics and science curricula is a step forward in Saudi Arabia's educational reform and a step towards STEM implementation? Explain.

In this question, most participants shared positive views in regards to the new mathematics and science curricula being a form of educational improvements in Saudi Arabia. Moreover, most participants agreed to the challenges required in order for the new curricula to meet its objectives and achieve educational success. The physics teacher explained, "The new curricula is more advanced in terms of the information included and the level of coordination among subjects, including the sequence of its topics. Moreover, the new curricula introduced the integration of technology, even though it is still considered as limited and at its early stages". Further, the teacher added; "In terms of the integration of engineering especially with physics, we are still far behind, more focus and training is still required. In the work simple machine chapter for example, if more concentration on engineering occurred, the chapter would have been more enjoyable for both the teacher and the students". The biology teacher commented, "When implementing any new reform or system, people must carry different views, depending on their backgrounds and experiences. However, when it comes to educational reform, in general, I say yes, the new curricula is much more advanced in term of its overall structure and its concentration on students' outcomes and engagement in their own learning. Furthermore, the new mathematics and science curricula is now more relevant with the educational standards of other advanced countries as in the United States and Great Britain. But in respect to STEM implementation this is not enough. Take biology for instance, I believe that the new curricula needs reorganization of its chapters, as STEM can only be achieved effectively if science curricula's were reorganized with coordination of topics between different science subjects. For an example, chapter one in biology relates to chapter 7 in chemistry and so on". Adding to that "Teaching the same topic from different angles and perspectives, facilitates the overall learning and teaching experience for both the teachers and their students". Moreover, the teacher added; "Linking taught subjects to students' lives is one of the new curricula's major specifications. For example, when I was teaching the Bird Anatomy chapter, I had to compare birds' bone structure and its organs with human anatomy, pointing out similarities and differences in shape, composition and functions in order to make it more relevant and personal to students; hence, increasing their interest and input in the classroom. Another important focus is the implementation of the new instructional practices, including students' engagement in their own learning and the encouragement of group work. For an example, when studying the human anatomy, I showed students a video of the human skeleton, after that, students were divided in four groups of five, in order to analyze the video by summarizing certain points; the first group to finish was required to explain the lesson to the rest of the class". Likewise, the chemistry teacher mentioned that the new curricula is a positive step in Saudi Arabia's educational reform that was long awaited; stating that "The new required teaching practices that focus on students' involvements and engagements in their own learning is considered as an evolutional change in education, when compared with old teaching instructional methods. Since education in the Arab world was initially introduced, teachers were viewed as a sole source of knowledge and information. However, in present times, their roles have transformed to facilitators, as students are now more indulged in their own learning. To me, this is a major aspect when it comes to STEM implementation, I cannot say that the new curricula is fully meeting its objectives yet, but with time and more training I'm sure it will". The teacher further described, "When the given topic is related to a real-life scenario, students become more interested and feel the connection with the topic, which makes it difficult for them to forget or neglect new information, especially if it is related to their life or health circumstances. Students involvement through discussions and hands-on activities increases their interests of the given topic and therefore, with the subject of matter, which in turn, is considered as a major part of the educational reform objectives". In regards to STEM implementation the teacher added, "When teaching the new curricula, no serious integration within STEM subjects is implemented, connection is only made when it is relevant to the topic. STEM implementation is not yet considered as a requirement from the Ministry of Education, connections between different STEM subjects are applied as an extra effort from the teachers". The teacher further explained, "I often go back to biology and physics teachers to assist me with questions and concerns in some chapters, which to me is an indication that there is a form of subject integration depending on the topic or chapter at hand".

The mathematics teacher responded with a statement saying, "I believe that group-work activities and student engagement in own learning, is a step towards educational reform. The new curriculum is a form of STEM education even though a lot of teachers and students might not notice it yet. You cannot separate mathematics from other STEM subjects, in general, mathematics is related more with physics and engineering, for example; the Molar concentration chapter is mainly chemistry. Before I started the chapter, I had to go through the definition and characteristics of the molar concentration chapter in chemistry to facilitate students' understanding of the meaning of the topic. Another example is calculus, as it is mainly physics" adding to that, the teacher confirmed that linking mathematics to real life scenarios has increased students' interests in her classroom. Further, she emphasized that the new curricula is better than the old one, in terms of its' content and subjects distribution. Yet, more focus is required for the implementation of STEM education and subject integration in specific, and the whole learning and teaching experience in general, which can be achieved by the following points:

- Improving the overall standards of teachers, including their knowledge and instructional practices through professional development programs.
- Unifying the exams from the Ministry of Education, or the application of national unified exams, in order to prepare students in Saudi Arabia for international standardized tests.
- Not giving the teachers the full authority to teach the new curricula without supervision on their daily applied instructional practices, assigned home-works and on the configuration of exams".

Q3) Do you have the experience in teaching the old curricula? If your answer is yes, did you experience differences in your coursework and instructional approaches required for the implementation of the new curricula when compared with the old one?

Though the researcher requested that all nominated participants have experience in teaching both the old and new mathematics and science curriculums, this question was asked to make sure that the researcher's request was met. In one of the interviews conducted with a female biology teacher, this question revealed that she had only been teaching for three years and hence has not had the experience of teaching the old curriculum. The researcher then ended the interview and scheduled another one with another biology teacher.

All interviewed teachers were able to identify differences between the old and the new mathematics and science curricula in terms of the actual content and its' required teaching practices. The physics teacher favored the new curricula, explaining that: "In the new curricula, at the beginning of each chapter, the objectives of the lessons are clearly stated. As teachers, we are required to follow these objectives and use them as a framework to guide us in preparing and structuring different lessons. Nevertheless, one of the negative points of the new curricula, is the presence of some non-explicit information categorized, where sufficient effort is required to define and organize information that is hidden between the lines". Similarly, the chemistry teacher described some of the challenges he is facing when teaching the new curricula, stating, "Teaching the new curricula requires more effort and knowledge from my side. As teachers are challenged not only in our ability to carry a class using new active learning, student-centered teaching techniques, but are also to be informed about other STEM subjects as well. Moreover, the new curricula adds excess load on teachers when compared with the old one, as it requires teacher's knowledge and experience to read information that are found between the lines and be able to clarify them to students. Further on, build upon previous lessons and student's general knowledge. The old curricula on the other hand, was more detailed, as the information was organized and distributed in a coherent uncomplicated way". Adding to that, the teacher explained, "Implementing new instructional practices including student-centered teaching techniques, requires not only teaching experience, but also more time in class. In order to improve the new curricula, topics and information of chapters must be reorganized, as some chapters must be reduced to allow students to be fully engaged in their learning experience". The mathematics teacher on the other hand, explained, "The new mathematics curricula is stronger in content, as it focuses more on the basics of mathematics through new engaging teaching techniques, that increases students' interest and encourages classroom engagements. The only shortage is the translation of some items found in the assigned mathematics textbooks". Adding, "When teaching the new curricula teachers must be qualified and highly experienced, most teachers need training and are not ready yet, when facing difficulties most teachers tend to go back to their comfort zone, applying old instructional methods and skipping the parts that requires the assistance and coordination of other STEM teachers".

Q4) In your opinion, in the new curricula does the Ministry of Education aside from connecting mathematics and science subjects to real life scenarios, focus on STEM implementation or subjects integration in their annual visits?

Most mathematics and science teachers indicated in their answers that the new curricula focuses more on students' engagements, and puts more weight on the relevance of subjects to students' daily lives. However, STEM implementation and the integration of its subjects are approached within that process. The physics teacher explained that the Ministry of Education focuses mainly on the new active learning strategies and new student-centered teaching techniques, where teachers are supposed to act as facilitators and help guide their students to reach the information by their selves. Adding to that, the teacher explained, "Minimum emphasis is concentrated towards the implementation of STEM education or subject integration between physics and other different science subjects". The biology teacher described that part of their teaching requirements assigned from the Ministry of Education, is to make taught subjects relevant to student's lives while encouraging their engagement and continuous inputs. As the teacher further explained, "In the assigned textbooks, at the beginning of each chapter, there is a subtitle under the introduction titled "relevance to real life"; where all given information and examples are obtained from real life scenarios. This section was not included in the old curricula's textbooks, nor was it a part of the Ministry of Education inspections". Further the teacher stated, "It is obvious that sometimes it is mandatory to make a connection or build upon information from other STEM subjects, depending to the topic area of each class. Some connections are given within the assigned textbooks and some are based on teacher's knowledge, qualifications and teaching techniques. For example, when referring back to anti antigens and the chemical components of the blood in biology, at the same time, chemistry students were learning about the ionic bond, so it is really up to the teacher to make the connection". In chemistry, the teacher added, even though he favors the implementation of new instructional practices, he still finds the new curricula challenging to teach. Despite the fact that STEM implementation is not a part of the Ministry's direct requirements, it is still required in order to achieve the new curricula's educational goals and objectives. He further explained, "Not all of us teachers are familiar with the title STEM, still we are all aware of its meaning, I often ask my fellow teachers to support me in some of the information related to their fields. For example, in the battery chapter, I relied on the physics teacher to assist me with information regarding electron transportation, so I can be well-prepared and able to answer all questions addressed to me by the students". However, in mathematics, the teacher disagreed noting that not all teachers and students are aware of STEM integration concept. "Not all teachers are prepared or knowledgeable enough in this part, and students are just following their teacher's path, if the teacher do not fully understand the process of subject integration or STEM education, how can the students? In education, the teacher holds the key to curricula's reformation success, without teacher's support educational improvements cannot be successful".

Q5) Do you believe teachers are qualified to teach the new mathematics and science curricula? Explain the challenges that faced you as an instructor.

In respect to teacher's qualifications to teach the new mathematics and science curricula, teachers shared mixed views. In biology, the teacher stated, "In this school we have three biology teachers, I believe all of us are qualified and well-informed in teaching the new biology curricula, in terms of its content and are aware of all new teaching requirements and methods". On the other hand, the physics teacher disagreed, as she described teachers as unqualified in teaching the new physics curricula, highlighting two challenges; first is the language barrier, where most teachers are not familiar with the meaning and pronunciation of most English scientific terminologies included in the new curricular textbooks. Secondly, is the challenge of implementing new instructional practices required for teaching the new mathematics and science curricula, as teachers tend to refer back to their old teaching methods. Further, the teacher added, “When the new mathematics and science curricula was first introduced, it created a huge gap for both the teachers and the students, as it was very challenging for us teachers to build new information with students having no base. For an example, in 10th grade, in the vector analysis chapter, I had to explain mathematical topics that students were not introduced to before, in order for the students to be able to understand the given chapter. However, today after several years of application, students and teachers are now more comfortable with the new curricula’s specifications. For example, Newton’s law is introduced gradually with expansion to students in 7th grade, then further in 9th grade and later with extension in 10th grade.

Likewise, the chemistry teacher agreed as he explained; “Most teachers are not capable or qualified enough to teach the new chemistry curricula. It requires more effort from the teacher’s side in terms of using new teaching strategies and acquires more knowledge to verify hidden information for students. Moreover, relating topics with other relevant STEM subjects is very challenging”. Adding to that, “In order for these new teaching practices to be effective, it must be applied from student’s early educational stages and not introduced suddenly in higher levels”. Similarly, the mathematics teacher agreed by saying “Not all teachers are qualified nor prepared to apply new required instructional practices, regardless of whether they have participated in teachers development programs and workshops or not. As these workshops concentrate on proposing new teaching techniques and methods, without practicing its implementation. Also, it does not focus on the actual curricula’s requirements or individual teachers’ strengths and weaknesses. In these workshops, teachers must be trained and treated like students, in order for them to be fully informed and qualified on implementing new instructional approaches”. The teacher added, “I have 27 years of teaching experience, this long period helped me master my profession as a mathematics teachers and be able to link and build upon mathematical information from different levels. Moreover, notice the similarities of topics with other STEM subjects”. Further, the teacher added, “Engaging students in their own learning and the application of new student-centered teaching techniques requires time, knowledge, and experience that are not common among all teachers. It is very challenging to teach the new curricula, find relevance with other STEM subjects, plus engage students in every step of the way. It requires time, as the curricula is long and condensed. The Ministry of Education specified seven classes per week for mathematics, in our school, I requested two more classes in order for me to be able to achieve curricula's requirements and objectives, but then again that's not the case in other schools."

Q6) As a teacher were you offered any sort of Teachers' development programs or workshops as a preparation to teach and implement the new mathematics and science curricula? How important do you think is it for teachers?

It was concluded from the participant's different answers that teachers were not all required or obligated to enroll in workshops or teachers' developing programs before teaching the new mathematics and science curricula. In biology, the teacher stated, "I do not deny the importance of teachers' development programs and workshops, I believe it is the most effective tool to curricular reform success and a window for teachers to learn how to apply new different teaching techniques. Despite that, I have been teaching high-school biology for a couple of years now, so far I was not obliged to enroll in any courses or workshops. Many teachers in this school have attended one or even more workshops and they all benefited from it". The physics teacher had a different response saying, "I was obligated to enroll in a teachers development program offered by the Ministry of Education before teaching the new physics curricula. In fact, the workshops were introduced in two different phases. In the first phase, the workshops concentrated on describing the new curricula's specifications including its content, objectives and the gradual distribution of its topics, with no emphasis on required instructional practices. In the second phase, the workshops concentrated on the presentation of new instructional practices required for teaching the new curricula, including the introduction of active learning." The teacher further explained, "Most workshops consisted of five days, and depended mainly on verbal discussions and lacked implementation practices". The chemistry teacher explained, "Yes, I took a course on the presentation of new instructional practices required for teaching the new mathematics and science curricula, the Ministry of Education is offering a lot of different courses in this area, so are the schools. But it is up to the schools to send their teachers and enroll them in these workshops, in order for them to increase their teaching and learning standards". The mathematics teacher on the other hand, shared a different view, as the teacher explained, "Yes I took a workshop, but it was poorly organized and to tell you the truth most of us attending teachers did not benefit much from it".

Q7) What do you think are the major aspects of the new mathematics and science curricula, that are considered as a step towards implementing STEM education in Saudi Arabia?

In this question, teachers shared similar positives reviews in regards to the new mathematics and science curricula as a step towards educational reform, and the implementation of STEM education in Saudi Arabia.

The physics teacher described several aspects in the new physics curricula that were not included in the old one, these aspects included:

1- The organization of the chapters and the topics included within each chapter. For example, in the layout of the "Movement and Force" chapter at the beginning, a general description of the chapter was provided, its relevance to real life circumstances, the main objectives of each topic included within the chapter, an image for the students to visualize, summarize and facilitates new information and finally, key words.
2- The summary found at the end of each chapter, to help students organize the chapter's main thoughts and build upon information.
3- The new curricula is more research oriented
4- The new curricula is relevant to students' real life situations and circumstances

The biology teacher pointed out three characteristics of the new science curricula that to her was proof that educational reformation in Saudi Arabia is going through the right direction:

1. Relating subjects taught to students' real life scenarios.
2. Relating subject taught (biology) to other science subjects.
3. The new curricula's textbooks contain a lot of images that facilitates students' understanding, especially in the case of biology.

Further, in chemistry the teacher described other characteristics offered by the new curricula that were not included in the old one, such as:

1. The presence of a large variety of revision questions found at the end of each chapter of the assigned textbooks, which varied in strength and style.
2. The inclusion of a summary at the end of each chapter, including the chapter's key points to helps students organize their thoughts, be able to revise and build upon their previous knowledge.
3. In chemistry, in each chapter there is a real life experiment that students must do in order to help facilitate the understanding of the topic. Moreover, emphasizes the involvement of students.

In mathematics; however, the teacher highlighted the fact that mathematics unlike other science subjects is considered as rigid and difficult, which makes it very challenging for the teacher to engage students in every step of the way. Nevertheless, the new curricula challenges students by proposing complex problems that are related to real life scenarios. Furthermore, the numerous exercises given at the end of each chapter are considered as an excellent addition to the mathematics curricula's textbooks. The exercises given are varied in their level and style, which helps students practice beyond the confines of their books; therefore, be more familiarized with international exam questions.

Q8) What is your overall conclusion on the newly implemented mathematics and science curricula?

Despite the fact that most participants shared mixed views and feelings in regards to the new mathematics and science curricula, they were all optimistic that this educational reformation is a positive step in Saudi Arabia's educational improvement levels in general, and students' outcomes in STEM subjects in specific. The physics teacher explained, "I have experienced in teaching both the new and the old curricula, even though the new curricula is stronger in its content and more advanced in its implementation techniques, some chapters that were of importance to students were compromised. For an example, the "Percentage of Einstein Matter" in the old curricula was one chapter; however, in the new curricular textbook it was shortened". The biology teacher stated "Relating and mixing information from the different STEM subjects is new, us teachers find it challenging. On the other hand, we cannot deny that the new curricula is a step forward in our educational standards when compared to the old curricula and its applied teaching methods". The chemistry teacher added, by certain adjustments to science textbooks, the new curricula opens the door to educational reformation that Saudi Arabia was thriving for, for many years. The mathematics teacher added that in mathematics, the new curricula is strong and well-organized, but there is a gap between teachers performance and the actual curricula, saying, "I believe that the new mathematics curricular content is more advanced than the potentials of its teachers" as the teacher further described that this can be avoided and minimized by further curricular mapping, and the restructuring of teachers' development programs and workshops.

Q9) Do you have any additional comments that you would like to share?

The biology and chemistry teachers had nothing to add. However, the mathematics and physics teacher shared some important notes. The mathematics teacher explained: "Improving the overall process of learning does not depend solely on coming up with a new curricula. In order to improve our educational standards, schools must rely on outside exams that are given from someone other than the teacher who is teaching the topic, so both the teacher and the students can be encouraged to put more effort to improve. I believe that there will be no improvements in education as long as the teachers do not improve, as I believe they hold the key to academic success. Moreover, I believe that there are too many holidays during the semester, which carries a negative effect on students learning". Further on, the physics teacher added; "I believe that the new curricula is a form of STEM education, as it requires the integration of different subjects and topics while teaching. The down side is that the Ministry of Education does not consider STEM as part of the new curricula's major requisites. In order to properly introduce and implement STEM education as a part of the Saudi Arabia curricular agenda, the Ministry of Education should rely on qualified, experienced and well-trained teachers to reorganize curricular chapters to be more coherent and relevant with each other. Moreover, focus on increasing the integration of engineering especially in mathematics and physics subjects. Furthermore, encourage the infusion of technology while teaching different STEM disciplines". Adding to that, the teacher explained. "Investing heavily on different international educational companies to transform the new curricula to a STEM oriented one is not the answer to educational reform, as local teachers are the best candidates that understand the country's core educational conditions, issues and obstacles that face educational reform distributions as the implementation of STEM education".

Table (5) Key responses of participants during interviews

Interview Question	Summary of Results
As a teacher are you familiar with the concept "STEM education"	Mathematics and science teachers shared mixed views on STEM subject integration process and meaning.
Do you believe that the new mathematics and science curricula are a form of STEM education?	The new mathematics and science curricula, a form of STEM education in Saudi Arabia through the following specifications: 1- STEM lessons immerse students in hands-on inquiry and open-ended exploration 2- STEM lessons involve students in productive teamwork 3- STEM lessons focus on real-world issues and

	problems. 4- STEM lessons allow for multiple right answers and reframe failure as a necessary part of learning 5- Minimal introduction to the integration of technology
Do you have experience in teaching the old curricula? If your answer is yes, did you or your fellow mates experience differences in your coursework and instructional approaches that are required in the implementation of the new curricula when compared with the old one?	Participants agreed that the new curricula is better than the old one, pointing out to the following points: • Focus on achievement gaps. • Improve preparation for college. • Foster more engaging practical science instructions. • Requires the implementation of new instructional practices • Changes in curricula's content • Relevance to the real world • Role of educators have transformed to facilitators.
In your opinion, in the new curricula does the Ministry of Education aside from connecting math and science subjects to real life scenarios, focuses on STEM implementation (STEM subjects integration) in their annual visits?	• MOE focuses more on students engagement in their own learning • Relevance to students real life situations • Minor integration between different STEM subjects • STEM way of teaching and learning, all we need is reorganization of curriculum textbooks with more relevance, coherence and integration between different STEM subjects.
Do you believe teachers are qualified to teach the new math/science curricula? Explain the challenges that faced you as an instructor.	Participants shared mixed views, but mostly agreed to the fact that teachers are not fully qualified in terms of knowledge and practice to implement new instructional practices required for teaching the new mathematics and science curricula, and the implementation of subject

	integration between different STEM disciplines.
As a teacher were you offered any sort of Teachers' development programs or workshops as a preparation to teach and implement the new math and science curricula? How important do you think is it for teachers?	• Teachers development programs and workshops are available, but not mandatory • Need of restructuring and organization of workshops • The workshops need more implementation practices.
What do you think are the major aspects of the new mathematics and science curricula that are considered as a step toward implementing STEM education?	• Relevance to real life situations • Minor relation between STEM subjects • More images and illustrations included in textbooks • Summery at the end of each chapter with key points • The variety in the level and style of revision questions found at the end of each chapter • Contains a lot of real life examples • The new curriculum is more research oriented. • More relevant to the 21st century requirements and requisites.

4.2.2 Classroom Observational Results

Observing instructors teaching practices applied in their classrooms plays a significant role in enhancing students learning in different STEM disciplines (Smith et al., 2013). In this section, the researcher relied on an open-ended observational protocol where the researcher attended classes, took notes, and commented on students' involvements and interaction within the classroom by the use of a developed observational checklist. The observational checklist included two sections, the first section was to investigate applied teaching strategies, through the observation of the following subdivisions; Lesson opening, quality of teaching, mode of instruction, relating taught subjects with students' daily life issues and making connections between different STEM subjects when teaching. The second section included the observation of the overall learning environment in the observed mathematics and science classrooms.

Within each observational section, results were further classified into two parts; the first part entailed the observations regarding science subject's classes including physics, biology and chemistry. On the other hand, the second part included mathematics class's observations. Data analysis of the observational method was achieved using Krathwohl's (2008) three main stages. The first stage was attained through familiarization and organization of observed facts. The second through coding and recoding of attained data and finally, through summarizing and interpreting of the achieved results. At the end, a table was created to summarize the shared points between different subjects observed in the class observational checklist.

4.2.2.1 Teaching Strategies

In this section, the researcher investigated applied teaching strategies, in order to address the following question. Based on the developed observational checklist, "*how well did the teacher cover the following teaching approaches in the classroom?*" This was approached through the observation of the following subdivisions; Lesson opening, quality of teaching, mode of instruction, relating taught subjects with students' daily life issues, and making connections between different STEM subjects while teaching.

1-Lesson Opening

Most science teachers started their classes with a recap on the previous lesson, as a revision to freshen up students' memory. The objective was to build upon and connect new information. Different approaches were observed; some teachers started their classes with open-ended questions regarding previous lessons or students' general knowledge from other STEM disciplines as a way of implementing active learning. Others, encouraged class discussions through the use of clicker questions.

Example 1: In chemistry, the teacher was comfortable in involving students and encouraging class discussion and argumentation. In the observed class, the teacher called students by their first names to answer questions from previous lessons, as the definition of the partial formula and the structural one, and the differences between them. In a different class the teacher asked students to define the ionic bond and did a quick revision on the topic before introducing the covalent bond.

The teacher was encouraging students' participations, as she began her classes with a question about the phenomenon under study to ease the introduction of the new topic or chapter.

Example 2: In physics, the teacher started the class using clicker questions, as she called students by their first names to answer questions regarding the previous lesson, concerning the meaning, law and uses for the Quantum Theory. Here, the teacher was listening to and discussing student's different answers. Moreover, partial integration with chemistry was observed when the teacher asked the students to define the hydrogen atom, through class discussions. It was presumed that the hydrogen particle is an iota of the compound component hydrogen and that the electrically nonpartisan molecule contains a solitary decidedly charged proton. A solitary adversely charged electron bound to the core by the Coulomb constrain. After that, the teacher described the electric field of the hydrogen atom using a classical coulomb potential. Therefore, linking it to the lesson under study, the quantum theory.

Some teachers started their class with a review on students' previous general knowledge attained from different STEM subjects to connect and relate to the new topic or chapter, as a way of implementing active learning and involving students in their own learning.

Example 1: In chemistry, the teacher asked the students about the definition of hydrocarbons and where they are naturally found. Students were able to identify hydrocarbons as organic compounds consisting of hydrogen and carbon atoms from previous chemistry classes. Moreover, the teacher was capable to lead a class discussion on where they are naturally found. Students gave different examples including crude oil and different natural gases. In another class, in order to encourage students involvement, when introducing the covalent bond, the teacher asked the students about different elements that are found naturally combined or in pairs, students gave different examples as CL_2*,* H_2O*,* CO_2*,* O_2 *and so on. Here, through class discussions, students were able to define the covalent bond as a chemical bond that involves the sharing of electron pairs between different atoms in order to reach a stable balance.*

Examples 2: In biology, the teacher started the class using open-ended questions including the description of different heart diseases such as heart attacks, strokes, high and low blood pressure *and so on. These questions lead to an enthusiastic class discussion, which facilitated the introduction to the circulatory system chapter including its components, roles and deficiencies.*

Teachers managed to provide a fair introduction to the topic at hand using different instructional techniques to encourage students to think about what they know and why they know it. They did so by starting the classes using open-ended questions, or by using a statement to encourage debates and class discussions, or by the telling of a story, or even by the integration of technology as visual aid.

Example 1: Some science teachers used a statement to open the door for class debate and discussion, as in biology, in the circulatory system chapter, the teacher started the class with the following statement, "Not all blood is the same and every human has a different blood type". Here, students were excited to share their information regarding different blood types, as they were able to explain how human blood is grouped into four types: A, B, AB, and O. Where each letter refers to a kind of antigen or protein that is found on the surface of red blood cells. Further, one of the students was able to give the following example: The surface of red blood cells in Type A blood, has antigens known as A-antigens. In this class, Students' were provided with opportunities to demonstrate their conceptual understanding of the topic at hand through class conversations and debates among students and between students and the teacher.

Example 2: Analyzing and interpreting data from scientific investigations using visualization or the integration of technology as a tool for analyzing and locating patterns including power point presentations and illustrations of images and scientific patterns. As in biology the teacher used a projector to view an image of the inner body of a bird in order to facilitate the introduction of the chapter "bird anatomy". In another class, the teacher used different images of the heart muscle, to explain how the arteries and veins transport blood from the heart to the body and the way back, to facilitate the introduction to the circulatory system chapter.

Example 3: By the telling of a story, to encourage students' interest in the subject matter, as in physics the teacher started the class with a short story regarding the problem with ordinary mechanical theory and the reason behind coming up with the quantum mechanical theory referring *back to Albert Einstein, who's work laid down the foundation for modern quantum mechanics as he referred to this as the "no-spooky-action-at-a-distance".*

- **Mathematics Subject**

The Mathematics teacher started the class with a quick review on the previous lesson, as a revision to freshen up students' memory to build upon and connect new information. Different approaches were observed as a way of implementing active learning and students' engagements through the encouragement of class discussions. In one class, the teacher started the class with an open-ended question regarding the previous lesson, while in another class, the teacher started the class by writing an equation on the board and asked students to come up and try to solve it.

Example 1: The teacher was comfortable in engaging students and encouraging class discussion and argumentation as a way to ease the introduction of the new topic. In the attended class, the teacher asked students by their names to discuss the meaning of "Compatibility and their uses" to freshen up students' memories in order for them to build upon and connect with new information. Here students' were provided with opportunities to demonstrate their conceptual understanding of the topic and process their skills.

Example 2: In another class, the teacher gave a full revision on the previous lesson "Pascal's triangle" by asking one of the students to come up to the board and do an exercise using Pascal's law before the introduction of the binomial theorem. The teacher applied in class practices in order to elicit, build upon and evaluate students' knowledge and understanding of the previous lesson prior the introduction of the Binomial theorem. Moreover, to evaluate students' ability to perform a given task, make sense of the problem and persevere in solving it.

The teacher provided a fair introduction to the topic at hand depending on students' argumentation and comparison with previous lessons. This was achieved through engaging students' in mathematical investigations with varying degrees of guidance from the instructor, as a way of implementing active learning and involving students in their own learning.

Example: In the Binomial theorem class, the teacher presented a quick introduction to the topic, but depended mainly on a comparison between the new topic "Binomial theorem" and the previous one

“ Pascal’s triangle”. The teacher started the class by proposing an equation on the board asking students to solve it using Pascal’s triangle law from previous lesson. Here students were required to make sense of the problem and persevere in solving it, after multiple tries and continuous class argumentations, the teacher solved the problem by introducing the Binomial theorem law. Further, students were given an example on how to solve an equation using both Pascal’s and the Binomial theorem, and when and why it’s appropriate to only choose one. This was done to encourage students to construct viable arguments and critique the reasoning of others. In this class, students were engaged in their own learning by allowing them to make predictions, test a theory, and locate patterns and correlations. Students were able to explain the meaning of the given problem and seek for possible solution entry points.

2-Quality of Teaching

- **In Science Subjects**

In general, science teachers seemed confident and qualified to teach assigned subjects, as they possess the potential to facilitate given information and answer all addressed questions through the use of different instructional practices. In the attended classes, most of the teachers encouraged students’ engagements, argumentations, debates and class discussions as a form of implementing active learning.

Example 1: In chemistry, students were required to interact with the teacher through continues argumentations and class discussions. This was achieved by responding to the teacher’s open-ended questions of previous chemistry lessons and other STEM disciplines. In the hybridization class, the teacher asked the students if all electronic fields were equal in their shapes and energy, and asked students to explain their answers, as a way to encourage students to think about what they know and why they know it. Here, minimal integration with physics was observed, as students were able to define electric fields as fields of force that act from a distance, where the force is applied by the effect of a charged object on another oppositely charged object.

Example 2: In physics, students were provided with opportunities to demonstrate their conceptual understanding and process skills through their participation in continuous class discussions and explanations about the course’s concepts, among students or between students and the instructor. In the attended class, the teacher concentrated on students’ inputs and explanations as the meaning *and definition of light, its history and the role photons play. Students were able to define photons as an elementary particle of all forms of electromagnetic radiation including light. While light on the other hand, as an electromagnetic radiation within a certain portion of the electromagnetic spectrum. Another example is the definition and characteristics of Quantum physics when compared with basic physics. Students were able to discuss their differences, defend their explanations and formulate evidence.*

In the attended classes, science teachers possessed the ability to implement new instructional practices, which were required for teaching the new curricula. This was achieved through the implementation of hands on class activities, including worksheets and building modules, as it was observed in the following examples.

Example 1: In chemistry, the teacher encouraged students to build models in order to develop explanations about natural phenomena; hence, the hybridization process. In the attended class, students were challenged to draw the fields of the atoms of the methane molecule, clarify the areas containing the electrons and demonstrate the hybridization process while defining the different types of interventions that happened within the last field. This was achieved to evaluate students' understanding of the course's concepts, and the ability to perform a given task. Further, in another class, students were asked to build a methane module using balloons and pens. In these classes, students' were provided with opportunities to demonstrate their conceptual understanding and process skills in regards to the hybridization process.

Example 2: In physics the teacher distributed handouts in order to keep students engaged and make it difficult for them to layoff. At the end of the class, the teacher challenged the students by proposing the idea of building a module that moves using the theories they learned, based on the fact that when light falls, electrons are liberated and therefore applying a stream.

In the attended science classes, teachers encouraged students to work in groups; therefore, enhancing students' argumentation, reasoning and problem solving techniques, as a way of implementing active learning and student-centered instructional practices.

Example 1: In physics, the teacher distributed handouts, students were writing, discussing and working with their assigned partners the whole time as they were divided into groups of two to solve problems and different exercises in the kinetic energy section.

Example 2: In biology, in the circulatory system chapter, students were asked to work in groups to measure and asses their blood pressure; further, they were required to discuss the attained readings and be able to define the systolic and diastolic numbers achieved. Students' were able to define that the systolic number is the reading on top, while the diastolic number is the reading found at the bottom. Moreover, each group was required to represent, discuss and explain a different case of blood pressure. In this class, the level of conversation about the course's concepts among students or between students and the instructor was enhanced, as students were excited and involved in their own learning. Moreover, students were offered the opportunity to work with real-world context.

In the attended science classes, teachers were able to use investigative strategies while teaching, as a way of interpreting new instructional practices required for teaching the new curricula.

Example 1: In biology, the teacher applied investigative strategies through continual class discussions. In the bird anatomy section, students used the laboratory for experiment-based tasks. In the laboratory, students were divided into two groups, each group was handed a chicken. Students were granted the opportunity to explore and analyze different parts of the chicken freely. Further, in order to evaluate students' understanding of the course's concepts and their ability to perform a given task, the teacher asked questions about different organs and parts as the heart, kidneys, liver, stomach and intestine and students were supposed to find it.

Example 2: Minimal integration of technology was observed, in the chemistry class, as the teacher preferred to use a video (flash) to describe the steps of the hybridization process in the methane molecule. In another class, it was used to describe the components of the alkaline and dry battery in order to facilitate and summarize the description of electrons transportation.

- **Mathematics Subject**

In general, the mathematics teacher was confident and qualified to teach the assigned subject, as the teacher was able to facilitate given information and answer all addressed questions using different teaching techniques.

In the attended mathematics classes, the teachers encouraged students' engagements, argumentations, reasoning and class discussions as a way of interpreting active learning and students' involvements in their own learning as it was observed in the following examples.

Example 1: In the attended class, the mathematics teacher wrote a problem on the board and asked the students to try to solve it using Pascal's law, students were all trying, but none came up with the correct answer, after an open class discussion on how to solve the problem, the teacher referred back to the topic at hand "the Binomial theorem" and when it was appropriate to use it. Here, students were required to construct viable arguments and critique the reasoning of others.

Example 2: In the polar coordination class, the instructor was posing questions to the class as a whole and receiving individual student responses. In the attended class, the teacher started by writing a problem on the board and asking students by their names on how to solve it and why solve it that way. Students were required to make sense of the given problem and persevere in solving it.

In the attended mathematics classes, teachers encouraged students to work in groups to enhance students' argumentation, reasoning and problem solving techniques, as a way of implementing active learning and students centered instructional practices.

Example 1: Students were assigned in groups of two, each group was required to solve four different problems distributed to them by the teacher through printed handouts, and the first group to finish was parsed with a bonus mark. Students were discussing their options freely with each other and the teacher, as they were able to construct viable arguments and critique the reasoning of others.

Example 2: In the integration chapter class, the teacher used four different instructional practices:

1- Started the class with a problem that students can relate to. For an example, when the teacher was discussing matters applied to calculate the distance integration accounts, the *teacher started the class with a problem that students can relate to form their life, as using a land area, which is located between two un-parallel streams.*

2- Lead an open discussion with students on how to solve this problem or equation "calculating the distance integration" from their previous knowledge.

3- Presenting required steps to solve the problem.

4- Start with explaining the topic its meaning and uses and at the end reach the correct way to solve the problem using information and equations given within the lesson.

3- Mode of instruction

- **Science Subjects**

In most attended science classes, teachers were following an inquiry-based learning approach (IBL) as it was observed in the following examples.

Example 1: In biology, in most attended classes including; the circulatory system, the respiratory system and the execratory system, the teacher started the class with an open-ended question for the students to answer. Students' answers were based on their previous general knowledge, or from earlier biology lessons. Starting the class with an open-ended question encouraged argumentation and class discussion, which enhances students' scientific practices and reasoning for explaining a natural phenomenon. Moreover, provides the students with the opportunity to extend and apply knowledge to new situations and relevant contexts. One of the given examples was asking the students the meaning of high and low blood pressure, its defects and the differences between them. Another example was, what are the components of the circulatory system? Here students were encouraged to demonstrate their conceptual understanding through in class conversations about the course's concepts among students and between students and the instructor.

Example 2: In chemistry, the teacher often depended on open class discussions as an introduction to the new topic; thus, encouraging students' involvements in their own learning. For an example, the teacher started the hybridization chapter by asking questions that gradually lead to the topic of interest, as are electronic fields equal in their shapes and energy? After students gave in different answers and opinions, the teacher then described the differences the E-fields share in their energy and shapes. Therefore, highlighted the need for hybridization before getting into the topic. Here, *students were engaged in scientific investigation of the hybridization process with varying degrees of guidance from the instructor.*

Example 3: In physics, when studying the Quantum theory of the photoelectric effect, the teacher led a class discussion by asking students to discuss the problem with the ordinary mechanical theory. Moreover, when teaching, the teacher kept repeating the same point in different ways using different examples to make sure students grasp the information and understand the given laws and equations.

In the observed classes, most science teachers were able to lead their classes using different investigative strategies as a way of applying new student-centered techniques that focus on improving students' critical thinking and problem solving.

Example 1: In chemistry, the teacher encouraged students to participate in class activities to analyze and translate data from scientific investigations, in order for them to be able to develop explanations about a natural phenomenon regarding the topic at hand. Moreover, enhance their ability to locate patterns by using a range of tools for analysis. This was observed in several classes where the teacher asked the students to assemble modules that represent the topic of interest, and engage students in their own learning. In 11^{th} grade, students were asked to assemble a hybridization module using cardboards and colors and illustrate outside examples. In another class, students were required to represent the methane structure with an angle of 109.5 using pens and balloons. Moreover, in 12^{th} grade, students were divided into four group of five to manufacture a battery model, using cardboards and aluminum foil; the first team to finish was praised with a bonus mark.

Example 2: In biology, the teacher managed to involve students in their own learning through the application of hands-on class activities. Moreover, engaged students in a scientific investigation with varying degrees of guidance from the instructor. In the observed class, students were divided into groups of two, each group was required to measure their blood pressure and explain whether it was within the normal range, high, or low. Further, students were asked to analyze, compare and discuss their results. Here, students' were provided with opportunities to demonstrate their conceptual understanding, process skills and behaviors towards the circulatory system chapter.

Most science teachers are dependent on the assigned curricular textbooks as a primary source of knowledge, rather than an additional instructional method.

In all attended science classes, it was concluded that despite teachers' minimal integration of technology, that was applied through the use of video flashes and images from the Internet and outside sources. Science teachers mainly depended on the assigned textbooks in teaching, giving class exercises, homework and exams.

- **Mathematics Subject**

Most observed mathematics classes were based on problem-based learning (PBL). Here, the teacher often started the class by representing an equation on the board and asked the students to solve it, whether independently or as a group. These ways of thinking provided students with the opportunity to make predictions and to locate different patterns or correlations. Thus, it abled them to make sense of the problem at hand and persevere in solving it.

Example: The teacher managed to lead the class using investigative strategies, concentrating on students' involvements and improving their critical thinking and problem solving techniques. For example, to introduce the Binomial theorem chapter, the teacher proposed the following problem on the board, if $(A+B)^2 = A2+ 2AB+ B2$, $(A+B)^8=?$

4- Relate taught subjects with students' daily life

- **Science Subjects**

In most attended science classes, teachers managed to relate assigned topics to students' making it relevant to their daily lives, as a requirement for teaching the new science curricula. The following examples demonstrate the relevance between the topic at hand and students' daily life experiences.

Example 1: In physics, in Newton's first law chapter, in the moment of inertia class, the teacher presented a real life example to make it easier for the students to relate to the new topic. The teacher asked the students, "When you are sitting in the car, and the car suddenly stops, how will your body react?" Through class discussions students agreed that their body would move forwards then backwards. The teacher replied that this is exactly what the moment of inertia means. Then she *started the class with the following definition, the determination of inertia or mass angle is a measure of the body's resistance to changes in its rotation rate, as the symbols I and J are sometimes measured in units of (kg m^2). Here, students were provided with an opportunity to place their thoughts, reasoning and explanations of a natural phenomenon. Moreover, formulate evidence based on data and examine further ideas with their teacher.*

Example 2: In biology, due to the nature of the subject, the topics observed were interesting and relevant to students' lives: The anatomy of birds, the human circulatory system including blood pressure and different blood types. In most classes, the teacher kept referring to medical conditions that are caused by the malfunction of blood circulation. Providing examples as heart attacks, strokes and blood pressure. Students were sharing different medical cases of their family members in relation to the topic, as they were able to extend and apply previous general knowledge to new challenging situations and relevant contexts.

Example 3: In a biology class, each student was asked to write down their blood type along with their parents' to see whom they inherited their blood type from. Moreover, the teacher integrated a bit of genetic engineering, as she gave students a brief introduction that relates to the inheritance of blood types, and how from DNA analysis we can find genetic series. Further, how these blood types can help solve different life and criminal cases. Students couldn't wait to share stories about how some crimes are solved by the use of DNA analysis, whether from television shows, movies or stories they read in the newspaper. In this class, the instructor managed to relate contents of the class to exciting real-world examples.

Example 4: In biology, in the bird anatomy section that was given in the laboratory, when one of the students asked about the smell that came out of the chicken's corps. The teacher freely started describing the process of decomposition of the body, comparing it with the smell of human corps and the reason behind burying the bodies. This also lead to a discussion of the mummification process, the teacher described how in ancient Egypt, and now with animals they have to take out all the organs and described the steps required to preserve the body and prevent the smell. Here, the instructor managed to relate assigned contents with relevant real-world examples.

Example 5: In chemistry, the teacher managed to link the assigned topic, the hybridization process, including the need for the elements to receive and make connections with other elements, with real world examples that students could relate to. Here, the teacher linked the hybridization process to when a person wants to welcome guests to stay over, and the preparations required to prepare extra rooms and try as much as possible to accommodate most guests.

Example 6: In another chemistry class, the teacher facilitated the understanding of the covalent bond between two Cl2 elements, by saying that every person has a goal in life. As students' your goal is to graduate and go to college, the Cl element goal is to have 8 electrons; therefore, it does not mind sharing an electron with another Cl element and form a covalent bond, becoming Cl2 in order to reach its goal.

Example 7: In chemistry, when studying about alkaline batteries, the teacher kept referring back to the batteries found in the supermarkets and what battery lasts longer and which is better to buy.

- **Mathematics Subject**

In mathematics, the teacher was able to link mathematics with students' lives by giving problems to solve and examples obtained from real life cases.

Example 1: When the teacher was discussing matters applied to calculate the distance integration accounts, the teacher started the class with a problem that students can relate to, for an example; A land area, which is located between two un parallel streams. The reason behind using real life examples in mathematical rigid problems was to help students make sense and visualize the given problem; therefore, persevere in solving it.

Example 2: In another class, the Binomial theorem chapter, the teacher managed to describe the relevance of the chapter to real life scenarios, for example, the importance of Binomial Theorem in the architecture industry and in the design of infrastructure. As it permits engineers, to calculate the significances of the projects; therefore, deliver an accurate estimation of the total cost and the time required for building. Moreover, for contractors, it is considered as a very important tool to help ensure that the costing project is competent enough to deliver profits.

5- Making connections between different STEM subjects when teaching

- **Science Subjects**

Minor connections were made between different STEM subjects according to the topic of interest and teachers' qualifications and ability to make these connections, as it was observed in the following examples.

Example 1: Integration between physics and biology. When studying the meaning of multiple thresholds, the teacher asked the students, what a threshold means? One of the students answered: it's a door step, the teacher agreed, but then asked them where they heard that term scientifically before, another student replied, in biology "The alarm threshold in nerves". The teacher then started to compare between the meanings of threshold in both biology and in physics as an introduction to the class topic. Another example of integration with biology was observed in the lenses applications class, where lenses installations and functions were compared to those of the human eye.

Example 2: In biology, minor connections were made with mathematics and physics, first connection observed was in measuring and calculating the diastolic and systolic pressure, and secondly, when referring back to mercury's density and specifications. In another class, a connection was made with chemistry as the chemical components of blood and anti antigens in the circulatory system chapter.

Example 3: In biology, the teacher was well prepared and knowledgably equipped not just in the field of biology, but also in other STEM subjects, for an example when describing the hybridization process in biology, the teacher gave the students a brief revision on the entire topic and how it relates to the hybridization process between domains in chemistry.

- **Mathematics Subject**

Due to the nature of mathematics, minimal connections were made between mathematics and other STEM subjects. Most connections were made according to the topic of interest and teachers' qualifications and ability to make these connections. Most integration was achieved with physics as it was observed in the following examples.

Example 1: In the subsidiary section, the teacher characterized its importance with material science and building, as she portrayed to students that in spite of the way that the idea of Derivative is at the center of Calculus and present day arithmetic. The meaning of the subsidiary can likewise be drawn nearer in two diverse ways. One is geometrically as a slope of a curve and the other one is physically as measuring the rate of progress.

Example 2: In the chapter of resume limits the teacher started the class with a general description of the topic linking it to other STEM subjects by describing to the students how measuring the resume limits arises naturally not only in mathematics, but also in many problems in physics and engineering as the existence of the tangent to the curve.

Example 3: In the tangent and velocity chapter, at the beginning of the class, the teacher asked the students to define instantaneous velocity based on what they have learned in physics. Students were able to recall its definition, as the velocity of an object at a single point in time and space as calculated by the slope of the tangent line. Moreover, most given exercises in class were related to physics.

Example 4: In the logarithm chapter, the teacher managed to describe the importance of logarithms and their usefulness in solving exponential equations, not just in mathematics, but also in other STEM subjects. Some examples of this were included in physics as in measuring sounds using decibel measures, measuring earthquakes using Richter scale and in measuring the brightness of stars. Moreover, its relevance with chemistry in measuring the pH balance.

4.2.2.2 Learning environment

This section included the observation of the overall learning environment in the observed mathematics and science classrooms.

1- Classroom environment

- **Science Subjects**

The amphitheater style and layout of the attended science classes gave the teacher a central position, as all students were able to see and hear clearly. Moreover, all classes were well organized, clean and spacious as it was easy for the students to maneuver. Furthermore, laboratories were also well organized, as everything was labeled and all safety precautions were taken into consideration.

Example 1: In physics, the layout of the physics laboratory where physics classes were given contained two rows in an amphitheater style where everyone can see and hear the teacher clearly. The two rows were facing the teacher, the board and the table where all the modules are distributed. Laboratory equipment and instruments were available, labeled and well organized, which made it easy for the students to handle.

Example 2: In biology, the layout of the class consisted of four groups of five, where the teacher was standing in the middle, behind her was the board and the projector screen with easy access to the laboratory behind. In the laboratory, when studying the anatomy of the chicken, students were comfortable as all equipment and instruments were labeled and easily accessible.

Example 3: The chemistry class was organized into four groups of five were the teacher and the board were located in the middle, behind was the chemistry laboratory, which was fully equipped with all required elements and resources. All equipments and elements were clearly organized and labeled. Moreover, all safety precautions were taken into consideration.

- **Mathematics Subject**

The amphitheater style and layout of the mathematics class gave teacher an appropriate position where all students can see and hear her clearly. Class was organized, clean, and spacious, as it was easy for the students and teacher to maneuver. The board used was big and clean, visible to all students. Seating arrangement was done in four groups of five; in another class it was two by two.

Table (6) Key points found in class observations

The Theme	Science class observations	Mathematics class observations	Observational comments
Lesson Plan	• Revision of previous lessons • Build upon existing knowledge and	• Revision of previous lessons • Fair introduction to the new topic	Lesson opening included: • Review of previous lesson • Review of students’

	connect with the new topic • Fair introduction to the new topic		general knowledge • Open-ended questions • Telling of a story • Argumentation, debates and class discussions
Quality of Teaching	• Students' involvements through class discussions and open debates. • Implementation of hands on activity • Encourage group work • Use of investigative strategies	• Students' involvements through class discussions and debates • Encourage group work • Use of investigative strategies	New applied instructional methods included; • Investigative strategies • Hands on activities • Group work • Debates and class discussions.
Mode of Instruction	• Inquiry based leaning (IBL) • Investigative strategies • Student centered • Improve critical thinking and problem solving • Use curriculum book as a main source of info	• Problem based learning (PBL) • Student centered • Improve critical thinking and problem solving • Use curriculum book as a main source of info	Mathematics and science teachers encouraged: • Students' critical thinking and problem solving techniques • The use of investigative strategies while teaching.
Relevance of subject to real life scenarios	Most topics were always related back to real life examples and scenarios where students were easily connected and involved in their own learning	Due to mathematics being rigid containing mostly numbers and equation, teachers tried as much as possible to link the examples to real world context, to make it easier	Relevance of taught subjects to students' lives.

		for the students to relate and use mathematics in their lives.	
Connection with other STEM Subject	Minor connection was made between different science subjects. More connection was made between biology and chemistry due to the relevant nature of the two subjects	Minor connections with other STEM disciplines were observed. Most connect was made with physics due to the relevance between the nature of both subjects.	Minor connections were made according to the topic and subject taught.
Classroom Environments	Well organized, spacious and well equipped.	Well organized, spacious and well equipped	School facilities and classrooms of attended classes are suitable for STEM implementation practices.

4.2.3 The Open-ended Questions found at the End of the Distributed Questionnaire

This section entailed a representation of participants' responses gathered from the five open-ended questions included at the end of the distributed questionnaire. The aim was to investigate teachers' perceptions of the new mathematics and science curricula as a step towards the implementation of STEM education in Saudi Arabia. Moreover, to investigate new instructional practices applied as a requirement for teaching the new curricula. The open-ended questions were only included in the manually distributed questionnaires, which were distributed to male and female high schools in Jeddah and Al-Madinah cities in Saudi Arabia, due to convenience factors, as it is where the researcher and her family resides.

The reason behind excluding the five open-ended questions from the online version of the questionnaire was to facilitate the process and encourage more participants to respond. 169 questionnaires were manually distributed, out of which 75 responses were selected depending on the suitability. This was due to the fact that most participants viewed the open-ended questions section as optional, where most questionnaires had some missing data. Moreover, some participants did not provide justification to their answers, as they only responded with a yes or no answer. The five open-ended questions section included the following:

- As a teacher are you familiar with the concept “STEM education”?
- Do you believe that the new curriculum is a form of STEM education?
- What are the challenges facing teachers in teaching the new mathematics and science curricula as a form of STEM implementation/ subject integration into schools?
- Do you believe that the new curriculum is an improvement to the standards of education in Saudi? Please answer with yes or no and explain.
- From an educational point of view, which do you think is more beneficial to students, the old or the new mathematics and science curricula?

Data analysis of the five open-ended questions included at the end of the distributed questionnaire was achieved using Krathwohl’s (2008) three main stages. First, through familiarization and organization of participants’ answers. Secondly, through coding and recoding of the results, and finally through summarization and interpretation of the achieved results. At the end, a table was created to summarize participants’ responses to each open-ended question.

Table (7) Responses to the questionnaire’s 5 open-ended questions

The Question	The Results
As a teacher are you familiar with the concept “STEM education”	Due to the paragraph included at the beginning of the questionnaire, as an introduction to the meaning of STEM education, participants were able to describe the following: • STEM lessons immerse students in hands-on inquiry and open-ended exploration • STEM lessons involves students in productive teamwork • STEM lessons focus on real-world issues and problem solving. • STEM lessons apply rigorous mathematics and science content to students learning. • STEM lessons allow for multiple right answers and reframe failure as a necessary part of learning
Do you believe that the new curriculum is a form of	Most teachers agreed on the fact that the new curriculum

STEM education?	can be considered as a form of STEM education through the following points, on ways to achieve familiar with the concept "STEM" • Need sufficient and efficient training on using new required instructional practices • Understanding change process. • Cooperation and teamwork such as curriculum, technicians and laboratories and physical capabilities • Organizational structure development of the new curriculum. • A biology teacher described that when teaching, the integration of mathematics, physics, chemistry and technology is required.
What are the challenges facing teachers in teaching the new mathematics and science curricula as a form of STEM implementation/ subject integration into schools?	Barriers to change described by participants included the following: • Poor instructional design • Lack of teachers' training • Insufficient quality and knowledge of teachers • Lack of communication among teachers and educators • Lack of recognition • Lack of encouragement • Tendency of the Arab students to learn through the traditional instructional approaches • Students resistance to change • Time constrains, where the curriculum is condensed and long • Lack of schools facilities, resources and equipment, especially in public schools • Minimal integration of technology • Lack of parents influence and home support • Lack of a clear framework for application

	• Large students numbers in each class, especially in public schools where applying student centered instructional practices can be challenging • The challenge of subjects integration • The absence of unified assessment forms for the students and teachers
Do you believe that the new curriculum is an improvement to the standards of education in Saudi?	Most participants agreed to the fact that the new curriculum if applied correctly, is a step forward in Saudi Arabia's educational standards. Several points were addressed including: • The new curriculum puts more weight on students inputs • The introduction of new teaching practices • Suitable for the new generation • Emphasizes research and experimental learning • Prepares students the 21st century requirements and work force • It is more simplified and relevant compared with the old curriculum • Relevance to students lives • Encourages students involvements in their own learning • Enhances students' confidence, motivation and self-efficiency • Emphasizes students interest in STEM subjects
From an educational point of view, which do you think is more beneficial to students the old or the new mathematics and science curricula	Most participants agreed to the fact that the new mathematics and science curriculum is better that the old one, due to the following characteristics: • The old curriculum depends on old traditional teaching methods that are not suitable for the 21st century

	• The new curriculum holds the line on high expectations. • The new curriculum focuses on achievement gaps. • The new curriculum improves students' preparation for college and work force. • Fosters more engaging science instructions • Relevance to students' lives • Engage students in their own learning

4.3 Quantitative Results

In the quantitative part of the research study, a cross-sectional questionnaire was employed to collect data from teacher's responses. Further, the descriptive and inferential statistical analysis was achieved, including: demographics, t-test and ANOVA test.

4.3.1 Teachers' Cross Sectional Questionnaire

In this section, the purpose of the cross-sectional questionnaire was to investigate teachers' perceptions of the new mathematics and science curricula as a step towards STEM implementation in Saudi Arabia. In order to analyze the data, statistical package for social sciences (SPSS) version 22.0 was used. The data cleaning and subsequent analysis was performed in order to analyze the perceptions of a large group of science and mathematics teachers, teaching high school students the new mathematics and science curricula within different regions of Saudi Arabia. This was attempted by a onetime questionnaire (Rea & Parker, 2012; Fraenkel et al., 2015) using a homogenous sampling (McMillan, 2004; Glesne, 2011). The questionnaire distributed reported and analyzed the acquired data for answering the research questions:

- What are the major aspects of the new mathematics and science curricula as a form of STEM education implementation in Saudi Arabia?
- What are the perceptions of teachers on the implementation of the newly adapted science and mathematics curricula?
- How is the newly adapted mathematics and science curricula delivered in the classrooms, as a form of STEM education?

In the questionnaire, 543 participants were included, which consisted of both male and female teachers. The participants were those teaching high school mathematics and science subjects within different regions of Saudi Arabia. Data analysis began with data cleaning and descriptive statistics for the rate of investigating teachers' perceptions of the new mathematics and science curricula as a step towards STEM education implementation in Saudi Arabia. A frequency distribution was generated for each question in order to allow visual inspection for out-of-range data, missing values and input errors (Creswell, 2005). In this research study, fifty cases were excluded and not imported into the SPSS due to factors that can affect the validity of the research study's results. It included missing data responses from teachers teaching different subjects other than science or mathematics, respondents teaching mathematics and science subjects in primary levels. Furthermore, unreliable answers were found in the questionnaire. An examination of the differences among five demographic variables, including: participant's gender, years of teaching experience, nationality, educational qualification and the subject taught were applied.

4.4 Descriptive Statistical Analysis

In this research study, the cross-sectional questionnaire contained a selection of 42 items, which were categorized into five sections. The first section involved an overview of the demographic information of participants including gender, years of teaching experience, nationality, subjects taught and teachers' educational qualifications. The second section covered teachers' background that entailed how teachers are prepared to teach the newly applied mathematics and science curricula as a step towards STEM implementation in Saudi. The third section presented teachers' perception in regards to the emphasis placed on the newly implemented mathematics and science curricula on students' learning outcomes. The forth section, encompassed teaching the new mathematics and science curricula in the classroom including teachers' preparedness, collaboration, development and efficacy of the new curricula, and any challenges that the industry faces. The fifth section on the other hand, consisted of five open-ended questions that were analyzed as a form of qualitative method.

The three middle parts of the developed questionnaire aimed for investigating teachers backgrounds, perceptions and finally, teaching the new mathematics and science curricula within the classroom. Mean scores (M) and standard deviation (SD) were used to report the answers for these questions among 34 statements. Participants five demographic variables were considered in each part of the questionnaire including: participants' gender, years of teaching experience, nationality, educational qualifications and the subject taught. An independent sample t-test was used to test the statistical significance for participants' gender and years of teaching experience.

Whereas, a one-way ANOVA was used after all ANOVA assumptions have been attained and achieved to determine the statistical significance for participants' nationality, educational qualifications and the subject taught. The conventional 2-tailed 0.05 level was used throughout the current research study, as it is considered acceptable in most educational research (Kotrlik & Higgins, 2001).

1-Rate of awareness of the major aspects of the newly implemented mathematics and science curricula, as a step towards STEM education implementation in Saudi Arabia.

The major aspects of the newly implemented mathematics and science curriculum were demonstrated by endowing four options to the participants based on the perceptions of teaching. These perceptions were notified further to explore the implementation of the new required practices. The intended options provided to the participants were 1 = Not prepared, 2= somewhat prepared, 3= Well prepared, 4= Very well prepared. The mean scores and standard deviation for the rate of awareness of the major aspects of new mathematics and science curricula are revealed in table 8. The perceptions of new mathematics and science curriculum are demonstrated for questions 6 to 18.

Table (8) Rate of awareness of the major aspects of the new mathematics and science curriculum used (N = 543)

Teacher Background	**Awareness**	
	M	SD
6) Develop students conceptual understanding of taught subject	2.28	1.27
7) Provide deeper coverage of fewer science/math concepts	2.59	.56
8) Make connection between science/ mathematics with other subjects	2.44	0.61
9) Lead a class of students using investigative strategies	2.48	0.65
10) Encourage students' interest in mathematics and science subjects	2.31	0.70
11) Use assigned textbook as a source rather than a primary instructional tool	2.12	0.73
12) Connecting taught subjects with students daily life issues	2.53	0.62
13) Manage a class of students engaged in hands on/ project based activities	2.60	0.60
14) Teaching the new mathematics and science curriculum	2.47	0.65
15) How prepared are you in teaching lessons that appropriately combine STEM	2.56	0.63

subjects		
16) Apply new student centered teaching techniques	2.63	0.57
17) Using teaching approaches that focuses on improving students critical thinking and problem solving	2.45	0.68
18) Making connections between different STEM subjects when teaching	2.50	0.66

The findings of table 8 have shown teachers perceptions towards the new mathematics and science curricula in Saudi Arabia. Findings have revealed that teachers were able to implicate new teaching practices required for teaching the new mathematics and science curricula. Level of preparedness varied among different participants, none of the participants chose the not prepared option. Based on the mean scores achieved, it was revealed that teachers were well prepared in applying new student centered teaching techniques (M=2.63). Managing a class of students engaged in hands on project based activities (M=2.60). Providing deeper coverage of fewer mathematics and science concepts (M= 2.59). Making connections between different STEM subjects when teaching (M=2.50). Connecting taught subjects with student's daily life issues (M=2.53) and in teaching lessons that appropriately combine STEM subjects (M=2.56).

When teaching the newly implemented curricula it was revealed that teachers were somewhat ready to apply new teaching instructional practices that focus on improving students critical thinking and problem solving techniques (M=2.45). Teaching the new mathematics and science curricula (M=2.47). Lead a class of students using investigative strategies (M=2.48). Moreover, based on the lowest mean scores achieved, it was shown that teachers were not entirely ready to use assigned textbooks as a source rather than a primary instructional tool (M=1.63). Develop student's conceptual understanding of taught subject (M=2.28) and encourage students' interest in mathematics and science subjects (M=2.31).

Table (9) Rate of awareness of the new mathematics and science curriculum used by Demographic Variables (N = 543)

Teacher Background	**Awareness**	
	M	SD
Gender		
Male (n=168)	2.67	1.29
Female (n=375)	2.78	1.20
Years of teaching experience		
1 – 16 (n=356)	2.09	.54
> 16 (n=187)	3.98	.73
Nationality		
Saudi (n=400)	1.89	.50
Egyptian (n=70)	1.98	.79
Jordan (n=30)	1.76	.53
Other (n=43)	1.82	.64
Qualification		
Bachelor's degree (n= 324)	1.41	.51
Masters (n=150)	2.15	.39
Other (n=69)	2.16	.39
Subject taught		
Mathematics (n=205)	2.29	1.21
Chemistry (n=128)	2.31	1.21
Biology (n=100)	2.30	1.21
Physics (n=110)	2.31	1.21

The above table, table 9 demonstrated the descriptive statistics on the rate of awareness of the newly implemented mathematics and science curricula in regards to the five selected demographic variables. In respect to gender, table 9 has shown that the awareness level of both males and females group was closely associated in their preparation of making connections between different STEM subjects when teaching. The mean score between male and female group was 2.67 and 2.78 respectively. In regards to participants' years of teaching experience, it was concluded from the mean score that teachers with experience greater than 16 years, were more capable in applying new instructional practices. Moreover, shared positive perceptions on the level of awareness in making connections between different STEM subjects when teaching the new mathematics and science curricula, with a mean score of (M= 3.98) when compared with teachers with fewer years of teaching experience (M= 2.09). Furthermore, in respect to teachers' nationality, all teachers groups closely rated their awareness level of making connections between different STEM subjects when teaching, as the mean scores ranged between 1.76 and 1.89. From the findings, it was observed that teachers with higher educational degrees, when teaching the newly implemented mathematics and science curriculum mostly made the connections between different STEM subjects. The mean score was higher among teachers possessing a master's degree (M=2.15) and other certificates (M=2.16) as compared to teachers possessing a bachelor degree (M=1.41). Table 9 has illustrated that the mean scores for the subject taught was closely ranged between 2.29 and 2.31.

Table (10) T-test Table for the Group Difference on participants Gender and Years of teaching experience

Variable	Df	T	P	Mean Diff	SD Diff
Rate of awareness of newly integrated math and science curriculum used/gender	543	85.148	1.69	3.63	.20
Rate of awareness of newly integrated math and science curriculum used /Years of teaching experience	543	1.46	0.03	3.40	1.64

Table 10, illustrates the rate of awareness among participants with respect to their gender and years of teaching experience. Findings have shown that there was no differences found between participants gender and the rate of awareness of newly implemented mathematics and science curricula (t = 85.148, p > .05). On the contrary, in regards to participant's years of teaching experience, the *t*-test indicated that there was statistical differences between the two groups: t = 1.46, $p < .05$. As results revealed that teachers with higher teaching experience > 16, were more capable and qualified on teaching the new mathematics and science curricula along with their abilities to implement new required teaching practices when compared with teachers with lower experience.

Table (11) ANOVA Table for the Group Difference on participants' Nationalities

Variable	SS	Df	MS	F	P	η2
Between groups	9.932	3	3.311	2.191	.263	.088
Within groups	814.503	539	1.511			
Total	824.435	542				

Table 11 has shown the findings obtained from the ANOVA analysis showing the mean scores of four groups of participants nationalities; Jordanian, Saudi, Egyptian and others. ANOVA test indicated that there were no statistical differences at α=0.05 among the four groups mean scores on the affect of participants' nationality on their level of awareness in teaching the new mathematics and science curricula (F= 2.191, p > .05).

Table (12) ANOVA Table for the Group Difference on teachers' Qualifications

Variable	SS	Df	MS	F	P	η2
Between groups	57.136	3	19.045	2.719	0.03	0.44
Within groups	3775.199	539	7.004			
Total	3832.335	542				

In respect to participants' qualifications, results revealed that teacher's with master and other degrees showed the largest two mean scores across participants' qualifications, while mean scores of teacher's with bachelor's degree showed the least groups. In addition, the ANOVA test indicated that there were statistical differences between the mean scores on participant's qualification awareness in teaching the new mathematics and science curricula: $F= 2.719$, $p < .05$.

Table (13) ANOVA & Tukey Test for the Group Difference on participants' subject taught

Variable	SS	Df	MS	F	P	η2
Between groups	57.136	3	19.045	2.719	0.03	0.44
Within groups	3775.199	539	7.004			
Total	3832.335	542				

Multiple Comparisons						
					95% Confidence Interval	
					Lower Bound	Upper Bound
	Chemistry	-.010	.059	.065	-.16	.14
	Biology	-.033	.061	.021	-.19	.12
	Physics	-.060	.054	.064	-.20	.08
	Math	.010	.059	.034	-.14	.16
	Biology	-.023	.069	.030	-.20	.16
	Physics	-.051	.063	.038	-.21	.11
	Math	.033	.061	.021	-.12	.19
	Chemistry	.023	.069	.030	-.16	.20
	Physics	-.028	.065	.040	-.20	.14
	Math	.060	.054	.054	-.08	.20
	Chemistry	.051	.063	.030	-.11	.21
	Biology	.028	.065	.040	-.14	.20

Table 13, has shown the ANOVA findings for participant's subject taught awareness. The results have illustrated statistical significant difference between the mean scores on participants subject taught awareness (F= 2.719, p < .05).

The significant differences illustrated from the ANOVA tests were identified from Tukey test for teacher's perception and subjects taught. The results of multiple comparisons have shown that there were statistically significant differences between teachers perception in mathematics and biology subjects (p=0.021). Significant differences were found between biology with chemistry

(0.030) and biology with physics (0.040). Moreover, significant differences were found between chemistry and mathematics (0.034) and between chemistry with physics (0.038).

2-The rate of the implementation of the new science and mathematics curricula

The rate of the implementation of the new mathematics and science curricula was determined by providing the participants with four different options to report their opinion in regards to the newly implemented science and mathematics curricula. Options included were as follow: 1= No emphasis, 2= Minimal emphasis, 3= Moderate emphasis and 4= Heavy emphasis. Table 14 shows the mean scores and standard deviations of STEM adoption through questions 19 to 28 of the developed questionnaire.

Table (14) The rate of participants' implementation of the new science and mathematics curricula (N = 543)

Teachers' perception	Rate of Implantation	
	M	SD
19) Students interest in mathematics and science subjects	2.75	1.00
20) Aid in learning basic concepts in mathematics and science subjects	2.53	0.86
21) Aid in learning important terms and facts of knowledge	2.68	0.94
22) Prepare students for future study in these fields	2.28	1.06
23) Learn how to communicate ideas in mathematics and science subjects effectively	2.67	0.93
24) Prepare students for standardized tests	2.26	1.51
25) Learn about the relation between STEM subjects	2.61	1.01
26) Connect mathematics and science subjects to students daily life issues	2.78	0.99
27) Make a connection between STEM subjects in problem solving	2.39	1.03
28) Effect on students' critical thinking and problem solving	2.73	0.95

Table 14 has shown the responses revealed by participating teachers with respect to the newly implemented mathematics and science curricula in the classroom. Findings have shown that all participated teachers agreed on the fact that there was some degree of emphasis on the learning and teaching process while implementing the new mathematics and science curriculum, as non-chose the no emphasis option.

Participants rated the implementation of the new mathematics and science curriculum as moderate emphasis on the following aspects, where the highest mean scores were achieved through connecting mathematics and science subjects to student's daily life issues (M= 2.78). Moreover, on students interest in mathematics and science subjects (M= 2.75) and on students' critical thinking and problem solving techniques (M= 2.73). Further, moderate emphasis was also achieved in the following points: Aid in learning basic concepts in mathematics and science subjects (M=2.53), Aid in learning important terms and facts of knowledge (M= 2.68). Learning how to communicate ideas in mathematics and science subjects effectively (M= 2.67) and in learning about the relation between different STEM subjects (M=2.61).

The lowest mean scores were achieved through the following points: participants rated the implementation as minimal emphasis on preparing students for standardized tests (M=2.26), for future study in the fields of mathematics and science subjects (M= 2.28). Further, in making a connection between different STEM subjects in problem solving (M= 2.39).

Table (15) Teachers' perceptions by Demographic Variables (N = 543)

Teachers' perception	**Implementation**	
	M	**SD**
Gender		
Male (n= 168)	3.41	1.55
Female (n=375)	3.29	1.53
Years of teaching experience		
1 – 16 (n=356)	3.39	1.58
> 16 (n=187)	3.76	1.49
Nationality		
Saudi (n=400)	2.43	1.57
Egyptian (n=70)	2.28	1.52
Jordanian (n=30)	2.47	1.56
Other (n=43)	2.45	1.45

Qualification		
Bachelors (n= 324)	3.39	1.66
Masters (n=150)	3.40	1.57
Other (n=69)	3.78	1.49
Subject taught		
Mathematics (n=205)	3.38	1.68
Chemistry (n=128)	3.48	1.53
Biology (n=100)	3.58	1.48
Physics (n=110)	3.45	1.51

In the above table, results demonstrated the descriptive statistics on the rate of the implementation of the new mathematics and science curriculum in regards to the five selected demographic variables. In table (15), the mean scores were derived for descriptive purposes and for testing on differences. In regards to gender, both male and female groups closely rated the implementation of the new mathematics and science curriculum to encourage students to use in their courses as moderate emphasis. The mean scores for the male group was (M=3.41) and for the female group it was (M=3.29). In respect to years of teaching experience, participants with teaching experience greater than 16 years were closely to heavy emphasis with a mean value of M=3.76. While teachers with less than 16 years of teaching experience were closely to moderate emphasis with a mean value of M=3.39. In regards to participants' nationality, all teachers despite their different nationalities were closed to minimal emphasis with mean values ranging between 2.28 and 2.87. The implementation of the new science and mathematics curriculum was closely associated to the heavy emphasis perception with respect to educational qualifications. Teachers with other degrees have shown higher mean score (M=3.78) as compared to the teachers holding master's degree (M=3.40). On the contrary, teachers holding bachelor's degree showed least mean score (M=3.39). Moreover, mean scores for the subject taught for chemistry, physics and mathematics were closely associated to moderate emphasis with mean scores ranging between (M=3.13) and (M=3.48). On the contrary, higher mean scores were shown for the teachers holding experience in biology group (M=3.58) since there is a close association to the heavy emphasis.

Table (16) T-test Table for the Group Difference on participant's gender and years of teaching experience

Variable	Df	T	P	Mean Diff	SD Diff
Teachers' perception /gender	543	1.652	.273	.053	.058
Teachers' perception / Years of teaching experience	542	1.529	0.039	.049	.062

The differences for teachers perception was indicated in table 18 with respect to gender and years of teaching experience. Findings have shown that there was no statistical difference between the two groups ($t = 1.652$, $p > .05$). The small variance between the two groups further revealed the insignificant statistical difference. By considering years of teaching experiences between participants, results of t-test have indicated significant difference between the two groups ($t = 1.529$, $p < .05$). In respect to participants with teaching experience greater that 16 years, the results were shown for heavy emphasis, to assist teachers to apply new instructional practices required for teaching the new mathematics and science curriculum. Moderate emphasis has been shown among teachers with less than 16 years of teaching experience, on encouraging students to use new teaching practices required for the newly implemented science and mathematics curricula. This was also concluded from the small variance between the mean values.

Table (17) t-test Table for the Group Difference on participants Nationalities

Variable	Df	T	P	Mean Diff	SD Diff
Teachers' perception / Nationality	543	1.68	1.49	.363	.35

The group difference between participant's nationalities was indicated from table 17. The results have shown that there was no statistical significant difference between nationalities of teachers ($t= 1.68$, $p>.05$). Teachers of different nationalities shared similar perceptions in respect to the newly implemented mathematics and science curriculum and its required teaching practices.

Table (18) ANOVA & Tukey Test for the Group difference on teachers' educational qualification

Variable	SS	Df	MS	F	P	η2
Between groups	14.89	5	2.97	2.890	.02	0.377
Within groups	1285.23	537	59.83			
Total	1300.12	542				

Multiple Comparisons

					95% Confidence Interval	
					Lower Bound	Upper Bound
	Minimal emphasis	.031	.072	.030	-.16	.22
	Moderate emphasis	-.039	.068	.073	-.21	.14
	Heavy emphasis	.063	.070	.020	-.12	.24
	None	-.031	.072	.038	-.22	.16
	Moderate emphasis	-.070	.056	.027	-.21	.07
	Heavy emphasis	.032	.059	.046	-.12	.18
	None	.039	.068	.075	-.14	.21
	Minimal emphasis	.070	.056	.003	-.07	.21
	Heavy emphasis	.102	.053	.021	-.03	.24
	None	-.063	.070	.080	-.24	.12
	Minimal emphasis	-.032	.059	.046	-.18	.12
	Moderate emphasis	-.102	.053	.021	-.24	.03

Results have showed that teachers possessing a master’s degree with other higher educational degrees were closely associated around the heavy emphasis with respect to educational qualification variable. Higher mean was notified among teachers with other degree (M=3.78) as compared to the teachers holding master’s degree (M=3.40). However, the mean score for teachers holding bachelor’s degree was the lowest (M=3.39). Table 18 has shown the statistical differences between educational qualification awareness on the implementation of the new mathematics and science curricula. Results have shown statistical significant difference between the mean scores of educational qualification awareness and the newly implemented curricula and it instructional practices (*F= 2.890*, $p < .05$).

The significant differences illustrated from the ANOVA tests were identified from Tukey test for teacher's perception and implementations of the new mathematics and science curricula. The results of multiple comparisons have shown that there was statistically significant difference between teacher's perception and minimal emphasis (p=0.046) as compared to moderate emphasis (p=0.021). On the contrary, the results from multiple comparisons have shown statistical difference between minimal and moderate emphasis (p=0.027).

Table (19) ANOVA Table for the Group Difference on participants' subject taught

Variable	SS	Df	MS	F	P	$\eta2$
Between groups	8.06	3	2.68	2.191	.263	.405
Within groups	1292.06	539	2.39			
Total	1300.12	542	5.07			

In regards to the participant's subject taught, results of the mean scores were between 3.02 and 3.58. In addition, the ANOVA test indicated there were no differences among the four subjects' mean scores (chemistry, biology, physics and mathematics) on participant's awareness on the implementation of the new mathematics and science curricula and its required instructional practices when teaching: $F= 2.191$, $p > .05$.

3- Rate of the newly adapted mathematics and science curricula's delivery in the classrooms

Table 20 demonstrated the mean scores and standard deviations of teaching the new mathematics and science curricula in the classroom. By providing the participants with four options to report their perceptions regarding classroom practices, the adaption rate of the new mathematics and science curriculums employed was identified. The included options were: 1= no opinion, 2= disagree, 3= somewhat agree, 4= strongly agree.

Table (20) Rate of adapted mathematics and science curriculum delivery in the classrooms (N = 543)

Teaching the New Math and Science Subjects in a Classroom	Adapted	
	M	SD
29) Teachers are well prepared and equipped to teach the new math/science curriculum	2.40	1.03
30) Teachers on your school regularly observe each other's classes as a part of sharing and improving instructional strategies	2.87	0.91
31) The new Math and science curriculum is contributed to STEM education	2.80	0.93
32) Teachers' development programs and workshops were offered before new curriculum implementation	1.63	1.05
33) The new curriculum offers students better learning opportunities	2.74	0.99
34) The new curriculum is more relevant to students lives and 21century demands	3.02	0.89
35) The new curriculum is considered as an improvement in Saudi Arabia's education	2.99	0.94
36) The new curriculum challenges students by offering complex problems related to real-world scenarios	2.92	0.94
37) STEM education has been integrated as something other than adding additional science and mathematics instruction/courses into your school	2.82	0.95

The above table revealed teachers' perceptions on teaching the new mathematics and science curricula in the classroom. The above table concluded that all participants placed their opinions, as none chose the 'no opinion' option. Teachers somewhat agree on the fact that STEM education has been integrated as something other than adding additional science and mathematics instructional courses in schools (M=2.82). Teachers regularly observed each other's classes as a part of sharing and improving instructional strategies (M=2.87). The fact that the new mathematics and science curriculum is contributed to STEM education (M=2.80). From results, the highest mean scores were achieved in the following points, where participant teachers strongly agreed on the fact that the new curriculum is more relevant to students' lives and 21st century demands (M=3.02), The new curriculum is considered as an improvement in Saudi Arabia's education (M=2.99) and that the new curriculum challenges students by offering complex problems related to real-world scenarios (M=2.92). The lowest mean scores on the other hand, revealed that teachers did not fully agree on the fact that teacher' development programs and workshops were offered as a requisite before the new mathematics and science curriculum was implemented (M= 1.63). Moreover, on the fact that teachers are well prepared and equipped to teach the new mathematics and science curriculum (M=2.40) and that the new curriculum offers students better learning opportunities (M= 2.74).

Table (21) Rate of the newly adapted mathematics and science curriculum delivery in the classrooms used by Demographic Variables (N = 543)

Teaching the New Mathematics and Science Subjects in a Classroom	**Adapted**	
	M	**SD**
Gender		
Male (n=168)	2.89	1.23
Female (n=375)	2.69	1.25
Years of teaching experience		
1 – 16 (n=356)	2.59	.56
> 16 (n=187)	3.97	.69
Nationality		
Saudi (n=400)	1.95	.54
Egyptian (n=70)	1.65	.76
Jordanian (n=30)	1.83	.54
Other (n=43)	1.88	.66
Qualification		
Bachelors degree (n= 324)	2.41	.61
Masters (n=150)	3.54	.67
Other (n=69)	3.86	.53
Subject taught		
Mathematics (n=205)	3.97	.56

Chemistry (n=128)	3.21	.52
Biology (n=100)	2.45	.51
Physics (n=110)	1.90	.73

In the above table 21, results demonstrated the descriptive statistics on the delivery rate of the newly adapted mathematics and science curricula in the classrooms, in regards to the five demographic variables. In table 21, the mean scores were derived for descriptive purposes and for testing on differences. With respect to gender, both male and female groups closely rated their adapted level of using new teaching practices required for the delivery of the new mathematics and science curricula to their students in the classrooms. The mean score for male teachers was 2.89 and 2.69 for females. In respect to participants' years of teaching experience, teachers with experience greater than 16 years shared positive feedback on the implementation of new teaching practices required for the implementation of the new mathematics and science curricula, as a step toward STEM education (M=3.97) when compared with teachers with less years of teaching experience (M=2.49). In respect to participants' nationality, all teachers despite their different origins shared similar feedback on the implementation of new classroom instructional practices, with mean scores ranged between 1.65 and 1.95. In regards to participants educational qualifications, teachers holding a master's degree (M=3.54) and other higher certificates (M=3.86) shared similar perceptions in adapting required teaching methods for the implementation of the new mathematics and science curricula in different STEM subjects when teaching, when compared with participants holding a bachelor's degree (M=2.41). Finally, in respect to participant's subject taught, results of the mean scores were between 1.90 and 3.97. The largest two mean scores across the subjects taught were obtained representing the teacher's results for teaching mathematics, chemistry and biology. However, the mean scores for teachers teaching physics showed the least group.

Table (22) t-test table for the group difference on participant's gender and years of teaching experience

Variable	Df	T	P	Mean Diff	SD Diff
Rate of adapted math and science curriculum delivery in the classrooms used/gender	543	1.675	.265	.067	.058
Rate of adapted math and science curriculum delivery in the classrooms used /Years of	543	1.78	0.04	3.50	1.67

teaching experience

The group difference among participant's gender and years of teaching experience was demonstrated using t-test (Table 22). The results have indicated statistically insignificant difference between the groups (t = 1.675, p > .05). The difference was shown for the newly implemented science and mathematics curriculum in the classroom. Small variance between the mean values further indicated insignificant difference between both groups. The findings of the t-test have shown that there was statistically significant difference between two groups with respect to years of teaching experience (t = 1.78, *p* < .05). Positive feedback was shared by teachers holding greater than 16 years' experience and thus, revealed more qualified to implement new teaching instructions required for teaching the new mathematics and science curricula. This was also concluded from the small variance between the mean values.

Table (23) ANOVA Table for the Group Difference on participants' nationality

Variable	SS	Df	MS	F	P	η2
Between groups	9.952	3	3.311	2.421	.233	.078
Within groups	834.403	539	1.511			
Total	814.465	542				

The group difference between participant's nationalities was indicated from table 23. The results have shown that there were no statistical significant difference between nationalities of teachers (F= 2.421, p > .05).

Table (24) ANOVA & Tukey Test for the Group Difference on participants educational Qualification

Variable	SS	Df	MS	F	P	η2
Between groups	54.150	3	18.285	2.659	0.04	0.49
Within groups	2795.199	539	8.005			
Total	2849.349	542				

Multiple Comparisons

					95% Confidence Interval	
					Lower Bound	Upper Bound
	masters	.032	.081	.033	-.18	.24
	other	.082	.177	.023	-.37	.54
	bachelors	-.032	.081	.033	-.24	.18
	other	.050	.192	.040	-.44	.54
	bachelors	-.082	.177	.023	-.54	.37
	masters	-.050	.192	.040	-.54	.44

Table 24 has shown the mean scores between educational qualification and subject taught. The results have shown mean scores ranged between (M=2.41) and (M=4.54). Higher mean scores have been shown among teachers holding masters and other educational degrees with respect to qualification factor. On the contrary, the results have shown least mean scores for teachers holding bachelor's degree. Table 24 has further shown statistical differences between the qualification awareness. The results have shown that there were significant statistical difference between qualification awareness mean scores $F= 2.659$, $p < .05$. The findings of Tukey test have shown significant difference between bachelors and masters with respect to educational qualifications. Further, the results have shown a statistical significant difference between masters and others (p=0.040), masters and bachelors (p=0.33) and bachelors and others (p=0.023).

Table (25) ANOVA & Tukey Test for the Group Difference on participants' subject taught

Variable	SS	Df	MS	F	P	ɳ2
Between groups	57.136	3	19.045	2.719	0.03	0.44
Within groups	3775.199	539	7.004			
Total	3832.335	542				

Multiple Comparisons

					95% Confidence Interval	
					Lower Bound	Upper Bound
	Disagree	.028	.081	.986	-.18	.24
	Somewhat Agree	.150	.068	.126	-.03	.33
	Strongly Agree	.284*	.074	.001	.09	.48
	No opinion	-.028	.081	.986	-.24	.18
	Somewhat Agree	.122	.060	.179	-.03	.28
	Strongly Agree	.256*	.067	.001	.08	.43
	No opinion	-.150	.068	.126	-.33	.03
	Disagree	-.122	.060	.179	-.28	.03
	Strongly Agree	.134*	.051	.044	.00	.26
	No opinion	-.284*	.074	.001	-.48	-.09
	Disagree	-.256*	.067	.001	-.43	-.08
	Somewhat Agree	-.134*	.051	.044	-.26	.00

Mean scores were ranged between (M=1.25) and (M=3.97) with respect to STEM subject taught. Higher mean scores were identified among teachers teaching chemistry, biology and mathematics subject as compared to the least mean scores notified for the physics subject. Table 25 has shown the indication of statistical differences between implementing new mathematics and science subjects and subject taught awareness. The results have shown statistical significant difference between mean scores of implementing new mathematics and science curricula and subject taught awareness (F= 2.719, $p < .05$).

The significant differences illustrated from the ANOVA tests were identified from Tukey test for subjects and implementation of the new subject. The results of multiple comparisons have shown that there was a statistically significant difference between disagree and strongly agree perception ($p=0.001$) as compared to strongly agree and somewhat agree ($p=0.044$).

CHAPTER 5: DISCUSSION AND CONCLUSION

The previous chapter presented and reported the findings of this research study in a descriptive manner, however, this chapter analyses and elaborates these findings with relevance to the proposed framework, research questions and previous research conducted within the area of study. The chapter is organized into four sections: the first section discusses the findings of the research study, the second section offers recommendations and suggests area for future research, the third section outlines the limitations of the research study, and the final section presents the conclusion.

5.1 Introduction

Out of all the components of research, the discussion chapter is considered one of the most valuable parts when conducting research (Tuckman & Harper, 2012). The purpose of this chapter is to interpret the significance of the research findings in relevance to conclusions previously reached regarding STEM education. Furthermore, the discussion highlights STEM implementation practices in order to clarify the understandings of STEM implementation in comparison with new teaching practices required from the Ministry of Education, in order to successfully implement new mathematics and science curricula in Saudi Arabia. Additionally, the research intends to justify findings obtained from the qualitative and quantitative measurements applied, including teachers' interviews, class observational methods, and the cross-sectional questionnaire. Related research findings with relevance to the research questions have been also presented.

In this chapter, the qualitative and quantitative results were analyzed to investigate teachers' perceptions and instructional practices of the new mathematics and science curricula as a step towards STEM reform in the kingdom of Saudi Arabia. The objective was to gain an insight on how teachers perceive, acknowledge and implement new teaching practices required for teaching the new curricula, and its relevance with instructional practices required for STEM implementation. Findings were presented with an aim to improve the standards of Saudi Arabia's educational system in general and the abilities of students in the fields of mathematics and science in specific. Moreover, this research hopes to provide the Ministry of Education (MOE) with new information related to considerable issues that address future educational research, reform, policies as well as recommendations. It can be achieved by addressing the following research questions:

1. What are the major aspects of the new mathematics and science curricula as a form of

STEM education implementation in Saudi Arabia?

2. What are teachers' perceptions of the implementation of the newly adapted science and mathematics curricula?
3. How is the newly adapted mathematics and science curricula delivered in the classrooms as a form of STEM education?

This study employs a parallel mixed method design as described by Johnson and Onwuegbuzie (2004); firstly, this chapter discusses the results, achieved from the qualitative instruments applied. It includes teachers' semi-structured open-ended interviews, class observational methods, and the five open-ended questions included at the end of the distributed questionnaire. The priority is placed on qualitative data, to gain a better understanding of teachers' perceptions on new teaching practices required for teaching the new mathematics and science curricula. Later on, the results achieved from the statistical means of the quantitative phase are discussed. Finally, a critical discussion of the similarities and differences between both the qualitative and quantitative results is presented in order to gain an understanding of the broad spectrum of teachers' perceptions. Therefore, this discussion can enhance the understanding and analysis of significant findings in educational evaluations regarding the newly adapted mathematics and science curricula in Saudi Arabia. The purposes of this study were consistent with the reasons behind using a mixed methods design as a mean of gathering data for this research, as was state previously in the methodology chapter.

5.2 Discussion of the Qualitative Results

In this section, qualitative results obtained from teachers' interviews, class observations, and the five open-ended questions included at the end of the distributed questionnaire were discussed and compared to previous research studies conducted in the same area of research. These results provide a better understanding of the major aspects of the new mathematics and science curricula from a teacher's point of view, in terms of its new required instructional practices and its relevance to STEM education implementation.

5.2.1 Discussion of Teachers' responses to the semi-structured open-ended Interviews

In this section, previously conducted interviews consisting of eight open-ended questions are fully discussed and analyzed in relevance with previous research conducted within the same area of study.

In the first question, teachers were asked, *"Are you familiar with the concept "STEM education?"*

Results from teachers' interviews indicated that the concept STEM is new and is not common among most participating mathematics and science teachers in Saudi Arabia. This is similar to El-Deghaidy and Mansour's (2015) attempt to identify science teachers' perceptions of STEM Education, its possibilities, and challenges in Riyadh, Saudi Arabia. One of the important findings revealed that teachers reported concerns in their actual knowledge of STEM education. Moreover, teachers expressed concerns of their preparation to use STEM applications with their students in the classroom. Interview results revealed that the physics teacher was the only participant familiar with STEM education and its implementation strategies. It was concluded that her knowledge was gained from her own personal experience, outside of the school's curricula. Therefore, it can be concluded that the term STEM education was not introduced as a clear term or definition within the new mathematics and science curricula. Moreover, it was not introduced as a requisite from the Ministry of Education in Saudi Arabia. A quantitative study by Brown et al. (2011) investigated teachers and administrators' perceptions of STEM education through a one-time survey. Results indicated a misunderstanding of the actual meaning of STEM, lack of clarity among participants on the actual vision of STEM, and lack of collaboration between STEM teachers. This questioned the fact that STEM education and its teaching strategies were actually implemented within the desired school in the research study. In another survey by Rodger (2010) regarding STEM education, results indicated that teachers lacked the actual understanding of STEM and its implementation processes. It was, then, suggested that the first step to advance STEM education, is to create effective educational policies, programs, and practices to clarify STEM's specification and unify its definition.

In the interviews, after the researcher gave a brief description of the meaning and definition of STEM, it was apparent that participating teachers were all familiar with integrating mathematics and other science subjects. Teachers' responses to the definition of STEM education indicated similar descriptions of the term, which ultimately highlighted the importance of the term itself when teaching the new mathematics and science curricula. It was similar to Kelley and Knowles (2016), who characterized STEM education as an approach to teach STEM content of two or more of

STEM subjects, using STEM teaching strategies that tend to connect these subjects together to enhance students' overall learning experience. Moreover, Sanders (2009) defined STEM education as an approach that investigates teaching and learning with relation between two or more of the four STEM subjects. It was found to be associated with Herschbach's (2011) correlated curriculum pattern approach, where each STEM subject retains its separate identity, with the addition of correlation and organization among topics within individual STEM subjects.

Despite participants' agreement on the importance of subject integration when teaching the new mathematics and science curricula, it was understood from participants' answers that they shared different perspectives on STEM implementation in their classrooms. English (2016) described STEM education to be perceived and defined differently among different educational programs in different departments despite being within the same institution. Also, Hughes (2009) described educators' mixed views on STEM: some view it as a new way of teaching STEM subjects, while others view it as a new curricula or program. Likewise, Bybee (2013) described STEM education as one of the newest movements in educational reform, introduced without a clear description of its definition, purpose or framework of application.

When comparing teachers' interview answers with previous conducted research on teachers' perceptions on the actual meaning of STEM education, it is within expectation that mathematics and science teachers in Saudi Arabia shared mixed views. The new curricula does not highlight STEM as a form of its educational instruction. As described by the chemistry teacher, "The new curricula focuses more on relating assigned topics with students, making it relevant to their daily lives more than the actual integration process between different STEM subjects" (Obikan, for Research and Development, 2010; Mullis et al., 2016). The fact that new mathematics and science curricula do not include STEM as a curriculum requisite does not erase the fact of its existence. The importance of STEM subject integration can be obtained from the mathematics teacher's responses as she highlighted, saying "We cannot separate mathematics from other STEM subjects especially physics and engineering, all subjects are related to one another like a chain reaction, if you cut one part out you lose the reaction." Moreover, part of the new curricula's objectives when teaching mathematics and science subjects includes using student-centered teaching techniques, which in turn are equivalent to the STEM educational way of teaching and learning. This was implied in the biology teacher's response, who stated that teachers have annual visits from the Ministry of Education to ensure that teachers are interpreting new student-centered teaching techniques. Currently, Ministry of Education aims to place students in the center of its educational process through the development of new quality control systems and organizing supervisions to aid in directing the learning process and meet the curricula's learning outcomes (Mullis et al., 2016).

In conclusion, the fact that STEM education is not a familiar term among most individual participants of this research study corroborates with the fact that there is a universal haziness on the actual term and meaning of STEM education. Moreover, its implementation process differs among different educational individuals, even in countries and schools that actually apply STEM as a curricular concept (Tofel-Grehl & Callahan, 2016). Thus, a successful integration of mathematics and science subjects depends heavily on teacher competency of content knowledge and integration processes. There are many challenges to STEM education implementation; one of the main challenges is the vital need for a clear definition of the acronym meaning of STEM education (Brown et al., 2011). Moreover, many teachers face some difficulties in teaching their own subjects, asking them to integrate other subjects that can be challenging and may lead to miscommunication. Therefore, this confusion affects the transmitted information students receive (Stinson, et al., 2009). Notwithstanding the many possible benefits STEM education provides, it is vital to concentrate on teachers' understandings, practices, efficacy and strategies required for a successful implementation of integrated STEM education (Stohlmann et al., 2012).

The second question of teachers open-ended interview is *"Do you believe that the new mathematics and science curricula is a form of STEM education? How?"*

In respect to the Ministry of Education's requirements when teaching the new mathematics and science curricula in Saudi Arabia, results revealed the following points, shared by participants, followed by their discussion:

1. Teaching the new mathematics and science curricula immerses students in hands-on inquiry and open-ended exploration
2. The new curricula involves students in productive teamwork
3. One of the new curricula's major specification is that it focuses on linking taught subjects to students' lives and daily issues
4. New teaching methods allow for multiple right answers and reframe failure as a necessary part of learning and progression
5. Students are involved in their own learning, where the teacher has become the facilitator and no longer viewed as the master source of information.

6. In some chapters, teachers found it mandatory to make a connection between different STEM subjects, in order to facilitate and enhance the overall learning experience for their students.

These new applied teaching practices required from the Ministry of Education to teach the new mathematics and science curricula were found to be equivalent to Zeidler et al.'s (2005) ten best teaching practices necessary for a successful mathematics and science integration process. The authors described that teachers should act more as facilitators rather than the main source of information. Also, teachers should encourage students' hands-on learning, concentrating on the use of cooperative-learning, critical-thinking, and problem-solving techniques. Moreover, during class, teachers should depend heavily on questioning, assumptions, and discussions. Furthermore, mathematics and science classes should be inquiry-based using student-centered teaching approaches. Additionally, more attention should be focused on the integration of technology (Zemelman et al., 2005). Therefore, it can be concluded that the actual meaning of STEM – which is subject integration between different STEM disciplines including mathematics, science, engineering and technology – is somewhat introduced within the new curricula through the application of new instructional practices, which in turn, are corresponding to teaching practices required for STEM implementation.

It was evident from participants' responses that despite the challenges of implementing an integrated way of teaching and learning, teachers believed that it is impossible to solve any social issue without the integration of other STEM disciplines in today's science. STEM has many definitions depending on the way subject integration is achieved. Any intervention or modification of the subjects related to science, mathematics, engineering and technology is considered as STEM implementation (Wang et al., 2011). Within 21st century educational reform, traditional STEM stand-alone subjects such as chemistry, biology, physics and mathematics are being improved using the integration of knowledge from other stand-alone STEM subjects. The connections are made to enhance students' investigation strategies and understandings of the subject matter from different angles (Herschbach, 2011). It aligns with the educational reform done within Saudi Arabia's school curricula in 2009, which was achieved through the introduction of a new mathematics and science curricula in a joint effort with al Obeikan Research Development Company. STEM education in the center of this study focuses on the implementation of new teaching strategies that use inquiry, student-centered and problem-based learning as a way to display disciplinary connections (Mullis, 2016).

From participants' responses, it was concluded that students' involvement in their own learning was facilitated through students' hands-on inquiry, open-ended exploration, productive teamwork, and linking taught subjects to their lives along with daily issues. These conclusions were found to be consistent with the New Generation Science Standards as proposed in the research study's framework (NGSS, 2012). The National Research Council released NGSS framework to increase students' interests in pursuing STEM fields within their educational path. It can be achieved by guiding students to build upon their existing knowledge when learning as a developing process, and to gain logical scientific views of learning and understanding STEM subjects. Secondly, by focusing on the reduction of the number of topics within each of the STEM disciplines, it provides students with more time to concentrate on each topic in depth and be able to relate topics to real life scenarios. Also, it facilitate the creation of connections between topics from other STEM disciplines. Moreover, it increases students' scientific engagement and investigation abilities, therefore enhancing students' understandings of core ideas. Thirdly, the framework concentrates on the idea of collaboration between knowledge and practice when designing scientific learning experiences (NAE & NRC, 2014; NGSS, 2012). The New Generation Science Standards (NGSS) proposed have the potential to influence new teaching methods that are required for teaching mathematics and science subjects. As it is the case with Saudi Arabia's new applied mathematics and science curricula, STEM education can be influenced by the NGSS through encouraging students' engagement in their own learning, especially in mathematics and science subjects, where most of the topics require the integration of different STEM disciplines. Furthermore, NGSS supports the progress and implementation of conceptual knowledge and reasoning while teaching STEM subjects. Despite all of this, one of the main challenges that faces the implementation of NGSS is to warrant the improvement of discipline-specific knowledge; while at the same time, it also supports the integration process to develop a connection between different STEM subjects (Honey et al., 2014).

Participants' responses indicated that a majority of teachers did not integrate technology or engineering as much when implementing the new mathematics and science curricula, despite the fact that technology (T) and engineering (E) are considered core elements for the integration of STEM. It was revealed that participating teachers did not have satisfactory understanding of the T or E in STEM education implementation process. STEM is generally comprehended as reinforcing mathematics and science instruction (National Commission on Mathematics and Science, 2000). In a recent national report, it was observed that despite all of the concerns regarding the quality of K-

12 STEM education among policymakers and educators, the role of technology and engineering education have barely been revealed. The STEM acronym has turned into a shorthand term for science and mathematics education only, where technology and engineering are assumed to automatically fall under mathematics and science subjects (National Academy of Engineering and National Research Council, 2009). A study investigated the importance of teachers' integration of technology into science teaching in intermediate schools in Jeddah, Saudi Arabia; results revealed that during the researcher's visits to schools in Jeddah and regional areas of the Kingdom, they observed little evidence of technology-based teaching being practiced in intermediate school (Al-Sulaimani, 2010). A study investigated the current level of information technology integration in science education and the barriers between its uses in the Yanbu school district in Saudi Arabia. Barriers in the study included infrastructure and resources, policy and support, science teachers' personal beliefs, and staff development. Results revealed that all factors were significant barriers for the integration of technology, as there is a pressing need to assess the technological capacity of all schools in Saudi Arabia. Appraisal of in-administration staff improvement systems was similarly done, including more instructor preparing, more opportunity for educators to figure out how to utilize innovation, and the addition of technical support staff (Al-Alwani, 2005). Such results were found to be related to El-Deghaidy and Mansour's (2015) study, where the authors revealed that science teachers might not have an adequate understanding of the nature of science and technology. In this research study, it can be concluded that even though teachers tend to apply new instructional strategies required for the implementation of the new mathematics and science curricula—which in turn are equivalent to those practices required for the implementation of STEM— more focus is required for the integration of technology and engineering to properly implement STEM education in Saudi Arabia's schools.

In the third question of the teachers' open-ended interview, participants were asked, *"Do you have experience in teaching the old mathematics and science curricula? If your answer is yes, did you experience differences in your coursework and instructional approaches required for the implementation of the new curricula compared to the old one?*

Here, participants shared similar responses in regards to the implementation of new instructional strategies required for teaching the new mathematics and science curricula. From their experiences, participants indicated that the new curricula differs from the old curricula as it holds the line on high expectations from two sides, the students' and the teachers'. Teachers are now challenged with the application of new teaching strategies that were not required when teaching the old curricula. Since students are required to be involved in their own learning, more focus, research, and work is required from their side. Research has demonstrated that students' learning can be enhanced when educators move from old customary, transmission- style of direction to a more student- centered, intuitive method of instructing and learning (Gao & Schwartz, 2015; Froyd, 2008). Deslauriers et al. (2011) compared students' learning achievements using two different instructional approaches under controlled conditions, using a traditional lecture and an instructional lecture-based on research in cognitive psychology and physics education. Results revealed an increase in students' attendance, higher engagement, and more than twice the learning in the section taught using research-based instruction. Therefore, educational reformers and policy developers have employed many efforts and resources in research to overcome these restrictions, and determine the limitations of traditional, lecture-based instructional methods of teaching and learning. The aim is to develop and reform instructional strategies that improve the success of STEM implementation (Henderson & Dancy, 2011). Another point shared among participants' responses was that the content of the new mathematics and science curricula focuses more on relating each topic in relevance to students' lives and focuses more on achievement gaps. As the aim was to motivate students and improve their preparation for college, higher education and future work experience are needed (Mullis et al., 2016).

Hofstein et al. (2011) discussed that one of the main concerns in regards to the contents of school science curricula is related to the irrelevance found between its pedagogical approaches, interests, and needs shared by the majority of students, including their daily life circumstances, environments and the role they play as citizens. Tytler (2007) argued that one of the major crises in science education causing the drop of students' proportional numbers in science courses enrollment, including physical science and advanced mathematics subjects, is the traditional way of teaching. Students fail to engage in meaningful learning due to the irrelevance found between science subjects and their daily life issues and future needs. Furthermore, participants implied that the new curricula foster more engaging science instructions, including student hands-on activities. Research has proven the importance of experimental, hands-on educational practices in improving students' educational motivation levels, especially for learning STEM disciplines. Thus, by providing real-world meaning to abstract knowledge based information, increased attention has been paid to develop innovative tools for improved teaching of STEM (Mataric, et al., 2007). This aligned with the objective of the new mathematics and science curricula, which aim to increase Saudi Arabia's students' educational standards, especially in STEM disciplines through the adaptation of a constructivist theory of teaching and learning that focuses on critical thinking and problem-solving techniques (Almannie, 2015; Rwathi et al., 2014).

The fourth question of teachers open-ended interview, participants were asked *"In your opinion, in the new curricula does the Ministry of Education, aside from connecting mathematics and science subjects to real life scenarios, focus on STEM implementation (STEM subjects integration) in their annual visits?"*

It was concluded from participants' responses that the new curricula focuses more on the improvement of mathematics and science subjects including biology, chemistry and physics as standalone subjects, with more focus on improving the content of each subject, its instructional practices and its relevance with students' lives (Almannie, 2015; Rwathi et al., 2014). This was found to be relevant to the fact that throughout the last decade, STEM instruction was centered around enhancing science and mathematics as segregated disciplines (Sanders 2009; Wang et al. 2011) with little integration and attention given to technology or engineering (Bybee 2013). Most mathematics and science teachers indicated in their answers that the new curricula focus more on students' engagements, placing more weight on subjects' relevance to students' daily lives. However, STEM implementation and the integration of its subjects are approached within that process. For example, the biology teacher described that part of their teaching requirements from the Ministry of Education is finding relevance with students' lives, while encouraging their engagements and inputs. Adding to her answer, she mentioned that "relevance to real life" was not included in the old curricular textbooks, nor was it a part of the Ministry of Education inspections.

Today, the Saudi Ministry of Education focuses more on the application of new instructional practices including active learning, hence, enhancing students' engagement in their own learning (Mullis et al., 2016). Therefore, it can be said that STEM education is introduced within the new mathematics and science curricula, although not in terms of a requisition of its name or definition. Rather, it is present through the introduction of the new teaching and learning strategies required for its implementation, which are found to be relevant to those required for the implementation of STEM education. Asunda (2011) and Herschbach (2011) described that in order to implement STEM education in schools, more efforts are required to enhance hands-on curriculum techniques by constructing classes to be more student-oriented. This was done through encouraging students to be more active and engaged in their own learning. This aligns with the chemistry teacher's answer, as he described that even though he prefers the new teaching methods, he still finds the new curricula challenging to teach; he stated “While STEM implementation is not a part of the Ministry’s direct requirements, integration among different STEM disciplines when teaching chemistry is required to achieve the new curriculum’s educational goals and objectives.” He further explained, “Not all of us teachers are familiar with the title STEM, still we are all aware of its meaning, I often ask my fellow teachers for support in some of the information related to their subjects, as in the battery section, I relied on the physics teacher to assess me with information regarding electron transportation so I can be well-prepared and able to answer all questions addressed to me by the students.” When students observe coherence between different subjects, these subjects will have more meaning to them, and vice versa, because understanding the meaning helps them identify the coherence (Dierdorp, et al. 2014).

For mathematics, the teacher argued that not all teachers and students are aware of STEM integration concept. “Teachers are not all prepared or knowledgeable enough in this part and students are just following their teacher’s path, if the teacher is not knowledgeable of the term, how can the students be? In education the teacher holds the key to curriculum reformation success, without them educational improvements cannot be successful.” This is very similar to El-Deghaidy and Mansour (2015) study’s results, which described several aspects that should be considered from the teachers’ side in order to introduce STEM education in Saudi Arabia’s schools. These aspects included science teachers’ deep content of knowledge, not only of the subject taught, but also in other related STEM disciplines. Science teachers should be qualified in using innovative teaching strategies required for the implementation of STEM, including interdisciplinary learning to be able to make the connection between different STEM disciplines, and improve students’ critical thinking and problem solving techniques.

In the fifth question of the teachers’ open-ended interview, participants were *asked, “Do you believe teachers are qualified to teach the new mathematics and science curricula? Explain the challenges that faced you as an instructor.”*

In this question, results indicated that teachers’ shared mixed views in regards to their level of qualification in teaching the new mathematics and science curricula in Saudi Arabia. A majority of participating teachers responded by stating that mathematics and science teachers are not fully qualified and confident about knowledge and practice to implement new teaching strategies of the new mathematics and science curricula in Saudi Arabia. For example, the chemistry teacher explained in the interview, “Most teachers are not capable or qualified enough to teach the new curriculum. It requires more effort from the teacher’s side in terms of using new teaching strategies and requires more knowledge to verify hidden information to the students that is related to the topic or chapter, hence, relating topics with other relevant STEM subjects.” This statement is supported by Stinson et al. (2009) and Bell (2016) as the authors described how teachers’ understandings, content knowledge and perceptions of the integration process heavily affect the success of STEM implementation. Additionally, many teachers faced some difficulties in teaching their own subjects, and asking them to integrate other subjects can be challenging in a way that may lead to some degree of miscommunication, which can affect transmitted information to the students. The mathematics teachers shared similar perceptions, explaining that “Engaging students and focusing on student-centered techniques requires time, knowledge, and experience that are not common among all teachers. It is very difficult to teach the new curricula, find relevance with other STEM subjects, plus to engage students in every step of the way. It requires time, as the curricula are long. The Ministry of Education specified seven classes per week for mathematics, in our school I requested two more classes in order for me to be able to achieve the curricular requirements and objectives.”

Different studies concluded that mathematics and science teachers lack sufficient educational background in STEM disciplines. Moreover, they share a shortage of in-field training in regards to the application of hands-on experience in teaching STEM disciplines (El-Deghaidy & Mansour, 2015). Suchman (2014) clarified that enhancing undergrad science, technology, engineering and mathematics (STEM) training obliges personnel with the required abilities, assets, and time to make dynamic learning conditions that encourage students' engagement. Be that as it may, current workforce enlisting, advancement, and residency rehearsals don't quantify, compensate, nor energize personnel to quest for these abilities, highlighting the importance of cultural change in order to foster desired improvements. In the above statements, teachers have shared similar perspectives with Nadelson (2009) who described inquiry based teaching instructions as complex, as it requires teachers’ knowledge, skills and creativity. But, it is difficult to incorporate within teaching practices without the sufficient support, feedback, and adequate time for reflection. Furthermore, the results closely mirrored that of a study by Hall et al. (2011), where it was found that students' absence of enthusiasm for scientific careers may mirror the lack of qualified educators and poor offices found in many schools. The creators expressed that students must be seriously occupied with STEM controls to contend to lead in the 21st century. The barrier was that majority of the teachers are not adequately prepared and qualified to teach STEM subjects. Moreover, the use of ineffective teaching methods and techniques inhibits student interest. Slavit et al. (2016) portrayed instructors' part as an intricate blend of learner, daring person, inquirer, educational programs creator, mediator, colleague, and educator. Instructional and curricular support requires considerable time to synthesize and endorse visioning, collaborating, and planning of the curriculum and its instructional practices in order for teachers to be fully engaged and prepared.

In light of these results and in order to achieve effective instructional change, Fairweather (2008) described two important points that should be taken into consideration. The first aspect is related to teachers and where they are being requested to change and modify their instructional strategies by shifting away from old teaching methods into a more active way of teaching and learning. Secondly, the change agents including curricular developers and professional development providers provided new instructional practices, encouragements, and materials to help instructors for achieving a successful instructional implementation. Furthermore, Froyd (2008) described that educational reform can only be successful if it involves faculty members as meaningful participants in the process. Schools have been structured to work well with traditional instructions, as there are many barriers to instructional innovations. Some of the common barriers include curricular time constraint; teachers are challenged to cover curricular content in an expected period of time, where research based methods that require deep understanding of subjects may not be applicable. Also, lack of instructor time: teachers are usually overwhelmed with teaching loads and do not have enough time or focus to learn about new integration practices. Further, teachers find it challenging to follow new teaching approaches when the norm around them supports traditional teaching methods, with no local role models around to follow or offer support. Moreover, students' resistance to research-based instructional practices can also be considered as a barrier. Additionally, class size and room layout can be a barrier to the implementation of research-based methods. And finally, time structure, as school semesters usually have fixed hours and do not allow individual differences in learning needs. Froyd's (2008) descriptions of the barriers facing instructional changes were very similar to the challenges participants referred to when teaching the new mathematics and science curricula. It was concluded from teachers' responses that mathematics and science teachers suffer from curricular time constraints and work overload. Most schools tend to encourage old teaching methods, lack of STEM role modules, students' resistance to change, and their lack of motivation to be involved in their own learning. Finally, school semester fixed hours, including frequent public holidays during the school year is a major barrier. Therefore, recent efforts to introduce the benefits of applying research-based instructional techniques when teaching undergraduate STEM courses have faced some victories and numerous disappointments.

In the sixth question of teachers' open-ended interview, participants were asked*, "As a teacher were you offered any sort of teachers' development programs or workshops for preparation to teach and implement the new mathematics and science curricula? How important do you think is it for teachers?*

Professional development programs are considered one of the most significant means for maintaining high standards in teaching science (Mansour & Al-Shamrani, 2015). It was concluded from participants' answers that the Ministry of Education does offer continuous workshops and different teachers' development programs, for a successful implementation of the new teaching strategies required for teaching the new mathematics and science curricula. Despite that, it was concluded that most participating teachers were not required nor obligated to enroll in workshops or teachers' developing programs before teaching the new mathematics and science curricula in their schools. It can be due to the fact that only recently, teachers' professional development programs have been considered as a national need and a primary research need in the field of science training in Saudi Arabia (Almazroa & Al-Shamrani, 2015). In participants' responses, it was revealed that teachers' professional development programs should be carefully organized and designed based on the actual curricula and teachers' requirements. Most offered professional development programs in Saudi Arabia have been unsuccessful in meeting the demands of the new mathematics and science curricula. This was due to the mismatch that was found between the perceptions of science teachers and the demand they require from attending these professional programs and workshops. The analysis of the listed professional development programs and guidebooks for training programs in some educational districts in Saudi Arabia indicated that there is a lack of guiding goals for these programs (Almazroa & Al-Shamrani, 2015). When designing the programs, the Ministry of Education may have had different priorities and needs than what science teachers actually require. In order to design proper programs, teachers' needs and requirements should be taken into consideration, as teachers must participate in articulating the goals they acquire from attending these programs to achieve its expected outcomes. Additionally, a one size fits all program cannot accommodate the requirements and needs of all teachers and circumstances, as teachers knowledge, needs, subject taught and school contexts should all be taken into consideration (Almazroa & Al-Shamrani, 2015).

All teachers agreed on the significance of teachers' professional development programs, but shared mixed views in regards to their impact on applied classroom practices. Froyd (2008) described that most faculties seem to appreciate these alternative instructional approaches and seem to value them. On the other hand, the level of depending on these strategies remains low; furthermore, faculty members who utilize these new teaching strategies tend to modify them to be more similar to old traditional instructional practices. The mathematics and physics teachers described the workshops they attended as lecture-based workshops. Further, the mathematics teacher described it as poorly organized implicational practices. Penuel et al. (2007) described that successful teachers' development programs require an extended period of time. Programs should consist of multiple cycles and stages of presentation in order to provide participating teachers with several opportunities to embrace new knowledge and teaching practices. Thus, programs have the opportunity to reflect and give feedback on their own implementation techniques. Professional development has more effectively served as a medium for broadcasting information on reformed teaching strategies than instructing teachers on how to apply them in their practice (Ebert-May et al. 2011; Henderson & Dancy 2007). Effective teachers' professional development programs are characterized by some factors. Firstly, their success relies on time, where a single or a limited number of workshops are not enough. Secondly, they should provide participating teachers with guidance and feedback on the actual design and instructional strategies required in the reformed lessons. Thirdly, it should place more emphasis on the collaboration between STEM disciplines. Finally, it should embrace the challenges and authentic experiences required in changing adulthood teaching beliefs, where change requires a prolonged period of time (Henderson & Dancy 2007; Pelch & McConnell, 2016; Penuel et al., 2007).

It can be concluded from participants' responses that there is a need for restructuring and re-organization of available workshops in terms of their content and implementation practices. Moreover, it is necessary to highlight the importance of teachers' enrollment in these workshops, and categorizing it as a requirement from the Ministry of Education to teach mathematics and science subjects in schools. More attention is required in this area for the success of the implementation of the new mathematics and science curricula. Alshamrani et al. (2012) distinguished a portion of the impediments Saudi science instructors confront when taking an interest in teachers' development programs and workshops. These obstacles included educators' overpowering workload, poor planning of the expert improvement programs, nonattendance of publicizing, the set number of available expert advancement programs, and the constrained motivational experiences to support instructor's interest.

Stohlmann et al. (2012) believed STEM education is associated with many possible benefits. Hughes (2009) explained that the shortage to successful STEM implementation does not rely solely on the number of students and teachers. It is essential to concentrate on the quality of teachers, as most primary and secondary STEM teachers are not one hundred percent confident in what they are teaching, since they do not acquire enough knowledge or practice on STEM subjects or the way they should be taught. Corlu et al. (2014) described STEM education as a key to achieve a successful education in Turkey, and how the country moved its schools from a traditional way of teaching to an integrated model. This model promotes an innovational way of teaching and learning to focus on integrated teachers' knowledge which relates to the case in Saudi Arabia, as educational improvement takes place through the implementation of new teaching methods required for the success of the new mathematics and science curricula, and the overall level of learning and teaching (Mullis, et al., 2016). Where students accomplishment is specifically connected to the underlying skills of educators and their continuous professional development (Forawi, 2015).

In the seventh question of teachers open-ended interview, participants were asked, "*What do you think are the major aspects of the new mathematics and science curricula that are considered as a step towards implementing STEM education?"*

In this part, participating teachers shared similar perspectives in terms of the new mathematics and science curricula and its relevance to STEM implementation. Firstly, was the relevance of mathematics and science subjects connected to real life examples and circumstances? Willms et al. (2009) emphasized the importance of meaningful learning as they believed that students need to address real life issues by connecting their life experiences with the topics covered in the classroom. Secondly, was the minor connection required between different STEM subjects when teaching? STEM implementation or curricular integration concentrates mainly on developing students' understanding of science discipline as a unity, rather than viewing STEM subjects as different individual isolated disciplines. Moreover, instructional practices that focus on developing students' problem solving abilities helps students perceive STEM disciplines as a unit that can address real world problems (Wang et al., 2011).

Thirdly, the new curricula's textbooks focus on inclusion of images, visuals, and illustrations, which facilitates the learning experience for students. Evagorou, et al., (2015) focused on visual representations or visualization in science subjects describing them as epistemic objects. The researchers explained how visual representations including photographs, diagrams and models have been used as a vital part of science learning, and its role in facilitating the representation of complex phenomena that are not observable in other ways. Moreover, visualization was defined as a process for knowledge production and growth in science subjects, as the researchers highlighted the importance of visualization when designing curricular materials and learning environments. Fourthly, it is related to the summary found at the end of each chapter containing key points, revision questions and multiple real life examples. These aspects, shared by mathematics and science teachers regarding the aspects of the new mathematics and science curricula in Saudi Arabia, were all equivalent to STEM education implementation. It can be concluded from teachers' responses that the new mathematics and science curricula could be a step in introducing STEM education to the Saudi educational organization including teachers, students and the society as whole. As all required new teaching strategies that have been proven, its effectiveness in the implementation of STEM education is equivalent to the new teaching strategies required from the Ministry of Education for a successful implementation of the new mathematics and science curricula in Saudi Arabia.

The eighth question of teachers' open-ended interview, participants were asked, *"What is your overall perception on the newly implemented science and mathematics curricula?*
Participants agreed that the new curricula is a step forward in Saudi Arabia's educational system, which was equivalent to AlGhamdi and Al-Salouli's (2012) study investigating elementary teachers' beliefs and perceptions regarding the new applied science curricula in Saudi Arabia. Findings revealed that the new curricula's interactive and group-oriented activities have increased enjoyment for teaching and learning science that led to higher achievement and understanding of scientific concepts among students. On the other hand, in regards to the new teaching methods required from teachers to meet the curricula's objectives, participants felt challenged, as there is a gap between teachers' performance and the actual curricula's requirements.

Lund and Stains (2015) highlighted the significance of improving comprehension of the distinctions in instructional practices and basic leadership forms over an assortment of STEM orders, inside an assortment of organizations, altogether for instructional changes to be powerful. Williams (2011) agreed with teachers' perceptions in regards to the challenges they face in implementing the new mathematics and science curricula as a step towards STEM education in Saudi schools. The study described the barriers that were faced during the implementation of STEM education, including inflexible school timetables and curricular structures, lacking mindfulness by instructors of other branches of knowledge, unbendable classroom outline, and evaluation. The study further added that STEM should be proceeded gradually with caution; more focus should be distributed towards teachers' preparation and intervention rather than focusing on STEM subject integration matter itself. Criticism on STEM disciplines to be irrelevant with real world context situations, the new mathematics and science curricula attempts to make meaningful connections with students' lives as a way to increase students' interest in STEM and enhance their educational outcomes. In a research study conducted in Abu Dhabi schools, Badri (2016) investigated students' interests in science subjects. It was concluded that there is a gap between science in schools and real life context of students, which resulted in students' views of science subjects as not useful. Results reviewed that students tend to prefer and do better in STEM subjects that are more relevant to their lives as biology and chemistry. Furthermore, the change in instructional practices has proven to increase students' interest and achievement levels in STEM subjects.

5.2.2 Discussion of Class Observation Results

Classroom observation results were achieved through the use of an observational checklist that was developed by the researcher. The checklist was developed with relevance to the scope of the research study, literature review, theoretical framework, and the nature of the research questions. In this section, the attained observational data was discussed thoroughly as compared to participants' interview responses. Moreover, to answer the following research question: How is the new mathematics and science curricula delivered in the classrooms? Further analyzing the new applied instructional practices required for implementation of new mathematics and science curricula in respect to its relevance with instructional practices required for STEM education implementation.

It was achieved through analyzing new applied instructional strategies required for teaching mathematics and science subjects (chemistry, biology and physics). It included lesson plan, quality of teaching, mode of instruction, relevance of taught subjects with students' lives, and the integration between different STEM subjects. Bybee (2013) described that instructional practices include individual elements such as the interaction between teacher and students, within students themselves, educational advancement accessibility and laboratory, and diverse applied teaching techniques. Classroom practices ought to be expectable with the new implemented educational policies to fulfill the objective of STEM training. Moreover, enhancing classroom practices is considered as the instructional center to STEM education implementation.

5.2.2.1 Teaching strategies

- **Lesson Opening**

Observing different mathematics and science classrooms, including chemistry, biology and physics, it was concluded that all mathematics and science subjects' classes started with a review on previous lessons. It included students' previous general knowledge from other STEM subjects to recap, connect, and build upon existing information. In most attended classes, teachers started their classes with a review on previous lessons, students' general knowledge and a fair introduction to the new topic by posing questions to the class as a whole and receiving individual student responses, consequently resulted in encouraging class discussions and argumentations among students and the instructor. Moreover, it increased students' interest before providing a fair introduction to new topic. Research has proven the importance of questioning while teaching as a way of improving the overall quality of students learning experience. Since 1970, Gall considered questioning as one of the basic instructional approaches that motivate students thinking and learning. Moreover, Zeidler et al. (2005) considered questioning as one of the ten best teaching practices for mathematics and science integration. Furthermore, the observed instructional practices in mathematics and science classrooms were found to be parallel to some of the undergraduate STEM teaching practices described by Williams, et al. (2015). For example, in chemistry class, before introducing the covalent and ionic bond chapter, the teacher asked the students about the specifications and differences between electrons, protons and neutrons. Here students had to use their previous knowledge from physics and previous chemistry classes to specify the differences. In mathematics, the teacher gave a full revision on the previous lesson "Pascal's triangle" before the introduction of the binomial theorem.

These experiences were consistent with the first category of the Next Generation Science Standards (NGSS) framework, *learning as a Developing Process*. It was described as guiding the students to build upon their existing knowledge when learning, to gain logical scientific views of learning and understanding STEM subjects (NRC Framework for K-12 Science Education, 2012). Moreover, the experiences were also parallel to the first three points described by Berlin and White's (1995) in their recommendations. The recommendations were related to different teaching approaches that can benefit the recent educational process of STEM education implementation or subject integration. The implementation strategy was based on their early work, Berlin-White Integrated Science, and Mathematics (BWISM) Models (1994). The first strategy is to focus on students' prior knowledge; secondly, to focus on organization and building upon existing knowledge to incorporate interrelationships of concepts and themes. Thirdly, the strategy is used to create understudy information to incorporate interrelationships of thoughts and strategies. Fourthly, it is used to comprehend that achieved knowledge is a circumstance or context specific. Fifthly, it can be also used to empower information to be progressed through discussions and relevance to real life scenarios. And finally, it is needed to comprehend that knowledge is socially developed after some time.

- **Quality of Teaching**

Research has proven that the implementation of STEM educational activities provide the teachers with the chance to focus more on concepts that are naturally connected between different STEM disciplines (Milner, 2015; Kelley &Knowles, 2016). It has been observed that the results of class observational checklist revealed that mathematics and science teachers applied unique practices of teaching, which were required in order to teach the new curricula. Moreover, observations concluded that teachers were starting to become more comfortable with the idea of students engagements in their classrooms. It was performed through the implementation of investigative strategy applications, hands on learning and activities, teamwork, overall class discussions, argumentations and debates. Research has proven that students' classroom engagement eventually increased their achievement levels, positive behaviors and their sense of belonging in the classroom (Parsons & Taylor, 2011). For example, in chemistry, the teacher was able to engage students and encourage their interactions through continuous debates and class discussions using open-ended questions. This was observed in the hybridization lesson, where the teacher asked if all electronic fields were equal in their shape and energy. Students were also asked to elaborate and discuss their answers. Willms, Friesen and Milton's (2009) described five effective teaching practices to enhance students' engagement in learning that were equivalent to most teaching practices observed in the attended classrooms of this research study. Some practices included the creation of thoughtful and purposeful designs for learning. The use of a unified assessment tool to help improve students' learning and guide teaching (Willms et al., 2009). Additionally, class observational methods indicated that most mathematics and science teachers' implemented students' hands on class activities, which entailed worksheets and building modules. For example, in physics, these activities are used to engage students and make it difficult for them to slack off. Students were divided into groups of two where the teacher distributed handouts to solve problems and different exercises in the kinetic energy section.

These results were found to be similar to Kelly and Knowles (2016) study, where they described the concept of learning as an activity that does not only influence the context of learning, but also the social aspect of it. Learning science in a relevant context while being able to transfer scientific knowledge to realistic situations is key to authentic understandings that enhances students' curiosity and openness to scientific contexts. Knezek et al. (2013) studied the effect of hands-on project activities on students' perceptions and content knowledge of STEM within six different middle schools in the United States of America. Findings revealed students' increased knowledge in STEM fields and an improvement in their creative tendencies and perceptions about STEM subjects and careers. Moreover, a comparison study at a junior high school in Taiwan was included to compare the effect of two teaching methods. Results favored the inquiry group, where students achieved higher test scores and better understandings along with subject matter attitudes (Chang & Mao, 1999).

New instructional practices required for teaching the new mathematics and science curricula, were also found to be equivalent to Berlin and White's (1995) recommendations of different teaching approaches. These approaches can benefit the process of STEM education or subject integration. Moreover, aligned with the three points required for the implementation of STEM in the NGSS, as proposed earlier in the research study's framework. Furthermore, new applied teaching practices were found to be corresponding with Zeidler et al. (2005) as the study stated the ten best teaching practices necessary for a successful mathematics and science implementation that were described earlier in this study. Williams et al. (2015) emphasized the importance of applying new instructional practices, as they described teachers, who accentuated on the idea of students' investigation strategies and inquiry-based learning. These were more significant as compared to teachers following traditional instructional practices through old-fashioned explanations and lectures. Further, Williams et al. (2015) described some of the teaching practices required for the implementation of STEM education among under graduate students; these practices were very similar to the practices observed in mathematics, physics, chemistry and biology classes. The practices included 1-Instructor relates content to scientific work and to real-world examples. 2-Course ideas are identified with each other and to outside assortments of learning. 3- Supporting classroom discussions and argumentations in regards to the context of the lesson. 4- Urge students to and apply information to new difficult circumstances or to other applicable settings, where they are required to break down or control information. 5-Students' are given chances to show their calculated comprehension and have the capacity to process aptitudes or practices. 6-Encouragement of group work in completing class assignments, assessment tests, problem solving tasks, classroom discussions and debates. 7- Encouragement of students' independent work and self-efficiency. 8- Encouraging students' engagements in different scientific inquiries, under different levels of assistance from the instructor. 9-Encourage students' exploration of essential writing that could possibly be given by the educator. 10-Applying proper methodologies that urge students to consider what they know and why they know it. 11-The educator shows a wonder or how to do an undertaking and students are left with choices on the best way to accomplish it. 12-Assessment intended to assess students' comprehension of course concepts or capacities for playing out a given task. 13-Apply practices that empowers, expand upon, or assess students' learning and thoughts before a summative evaluation. In an investigation study by Knezek et al. (2013) that took place within six different middle schools across different states in America, to study the effect of middle school hands-on genuine project activities on students' STEM content knowledge and perceptions. Findings revealed that students witnessed an improvement in their creative tendencies and perceptions about STEM subjects and careers.

- **Mode of Instruction**

Coffey et al., (2013) discussed that one of the main reasons that causes students' distractions away from gaining class involvement and productive inquiry, is the traditional distinct teaching methods used for teaching science subjects. It can be concluded that the implementation of new teaching strategies required for teaching the new mathematics and science curricula, including students' continuous involvement within own learning experience through the implementation of student centered teaching techniques, enhances students' educational achievement levels (Motschnig-Pitrik & Holzinger, 2002).

In the observed classes, teachers were implementing new instructional practices, where students' were involved in every step of the way. The only difference observed between mathematics and science classes is that in mathematics, there was not much space to implement different class activities, as most of the year curriculum's activity involves resolving mathematical equations and exercises. In mathematics observed classes were mostly problem based (PBL); where in science, most attended classes were based on inquiry-based learning technique (IBL).

Research has concluded that many STEM- focused schools, particularly in the United States, apply project-based learning (PBL) as an instructional practice when teaching STEM disciplines (Ashgar et al., 2012; Slavit et al., 2016). Savery (2015) defined problem-based learning (PBL) as an instructional approach, successfully implemented in multiple disciplines during the past thirty years. It has been portrayed as an instructional and curricular learning focus approach that motivates learners to explore, incorporate hypothesis and hone, and apply information and aptitudes to build up a significant answer for a specific issue. Problem based learning (PBL) instructional practices focus on the advancement of conceptual knowledge and application through amplified learning encounters around a center or subject. PBL direction networks with the STEM development is a characteristic stage to advance multi-disciplinary educational modules and inquiry- based educational instructive encounters that are regular in STEM-centered schools (Wallace & Webb, 2016; Slavit et al., 2016). In a study to investigate the effects of different types of curriculums including; problem-based, subject-based or hybrid based on students' perceptions of their academic environment. Findings revealed that the implementation of problem-based curriculum instructional practices carried desirable effects on the quality of learning when compared with other instructional approaches (Sadlo & Richardson, 2003). In a study to investigate the effect of PBL instructional strategy in STEM education on students development of the 21st century skills including cognitive skills, collaborative skills, and content knowledge. The study was conducted among teachers and 11th grade students selected from seven schools around UAE using mixed methods. Results revealed that STEM education is best taught using PBL learning approach to enhance students' cognitive, content, and collaborative skills. Science and engineering teachers demonstrated good evidence in integrating those skills in their practices. Further, students' perceptions towards the subjects show a great interest in the engineering and science subjects, which enhance careers in STEM fields (El Sayary, Forawi & Mansour, 2015).

Inquiry-based instructional learning (IBL) can be considered as signature pedagogy of science education, especially in integrated content areas, including (STEM) education (Crippen & Archambault, 2012). Research revealed that the implementation of an inquiry-based curriculum could positively influence students' achievement and interest in STEM education (Pelch and McConnell, 2016). The national research council (2012) defined some of the scientific practices included when applying Inquiry based-learning. These practices include asking questions, development and usage of models, students' engagement in argumentations and class discussions, constructing and communicating explanations. These instructional practices were relevant to the practices observed in the attended science classes. For example, when observing the biology class, the circulatory system chapter, the teacher started the class with an open-ended question that lead to class discussion and argumentation regarding its components, functions and different associated diseases. In chemistry, students were required to represent the methane structure with an angle of 109.5 using pens and balloons. Moreover, students used these modules to discuss the areas containing the electrons and demonstrate the hybridization process, while defining the different types of interventions that happened within the last field the hybridization process in class. Evagorou, et al. (2015) emphasized the importance of implementing inquiry-based scientific practices; hence, moving from teaching science subjects as knowledge, to teaching it as a way of understanding the process and the epistemic aspects of science. Moreover, stressed on the importance of students' engagements in scientific practices, in order for them to perceive science subjects as meaningful contexts that resembles the reality of the world they live in and be able to acknowledge the scientific discoveries surrounding them. In an article by Crippen and Archambault (2012), the authors discussed the nature of scaffold inquiry-based instruction and its implementation techniques in science classrooms. Results concluded that using inquiry-based learning not only helped students to learn the contexts of STEM, but also were able to answer critical socio-scientific questions that face the modern world they live in.

In the observed mathematics and science subjects' classes, teachers managed to encourage students' critical thinking and problem solving techniques by using different investigative strategies. Group-work class activities are one of the most vital characteristics to enhance students' investigative learning (Michael, 2006) it is a way of improving their involvements, encouraging class discussions, and investigations. Thus, it is helpful to enhance students' overall learning experience. Furthermore, it was noticed that teachers were applying competitive-learning techniques as a way to motivate and engage students. Competitive learning was introduced in most observed classes, but mostly in mathematics and physics. For example, in most attended mathematic classes, students were assigned in groups of two, each group was required to solve different set of problems that were distributed to them by the teacher through printed handouts. The first group to finish was praised with a bonus mark. In a comparative analysis study that was conducted to investigate the relationship between different learning styles and mathematics performance, results revealed that competitive learning was significantly and positively associated with students' mathematics performance. The significant results were observed across all countries examined within the research study (Ma & Ma, 2014).

In order to engage students in their learning, Claxton (2007) suggested that curricula and classroom activities should include three factors; first is relevancy, connecting topics with students' interest, and concerns. Second factor is responsibility, where students have some control in organizing their learning. And the third factor is reality, including students' involvement in problem solving activities. Therefore, it can be concluded from class observational results of mathematics and science subjects that the applied instructional strategies mainly included problem based learning and inquiry-based instructional strategies. These instructional strategies required for teaching the new mathematics and science curricula are parallel to the strategies required for the implementation of STEM education, as it was described in previous research studies.

- **Relate taught subjects with students' daily life**

Classroom observation methods of mathematics and science subjects indicated the relevance of the new mathematics and science curricula with students' real life circumstances. In an article to discuss the utility and beauty of STEM education and learning, Milner (2015) discussed the consistent system among STEM subjects and what it means in the context of a curriculum, based on the idea of educating students in an interdisciplinary and applied approach. It also discusses education through a cohesive learning paradigm based on real-world applications. Argumentation in socio-scientific contexts enhances students' understanding of the interdependence between science and society (Simonneaux, 2007). SSI movement focuses on empowering students to consider how science-based issues reflect, in part, moral principles and elements of virtue that encompass their own lives, as well as the physical and social world around them (Sadler et al., 2007). From participants' interview responses, it was concluded that in the new curricular textbooks, there is a section to explain the relevance of the given chapter to real life surroundings. When observing biology classes, topics observed were interesting and relevant to students, including the anatomy of birds, the human circulatory system, blood pressure and different blood types. In the class, the teacher kept referring back to medical conditions that are caused by the malfunction of blood circulation using real life diseases as heart attacks, strokes and blood pressure. Students were engaged in sharing different medical cases of their family members in relation to the topic. Furthermore, the teacher gave a brief introduction that relates to the inheritance of blood types, DNA tests and genetic series. It enhanced class discussions, as students could not wait to share stories about how some crimes were solved by DNA analyses, either from TV shows, movies or stories they read in the newspaper.

Additionally, each student was asked to write down their blood type along with their parents to see whom they inherited their blood type from to implement students' hands on activities. Another example was observed in chemistry, as the teacher linked the need for the elements to receive and make connections with other elements in the hybridization process. In mathematics; however, due to nature of the subject, fewer connections were made with real life circumstances when compared with science subjects. Here, most observed connections were made in the exercises given to the students, the objective was to teach students how to solve real life problems using mathematical equations and calculations. For example, the teacher asked the students if they were fans of a certain soccer team in the Binomial theorem lesson; she asked this question to engage students and gain their interest. Another example; when discussing matters applied to calculate the distance integration accounts, the teacher started the class with a problem that students can relate to from their life. For example, a land area which is located between two unparalleled streams.

Research suggests that science instruction must carry greater engagement and meaning to students in order for them to become scientifically literate citizens. Dede et al. (2004) portrayed scientific literacy as the ability to comprehend the interrelationships between the regular world, technology, and science. Furthermore, the author portrayed that science guideline must give students the chance to investigate the world, to apply logical standards, to test and dissect information, and to make associations among these investigations. This can be related to socio scientific issues (SSI) that were proposed in the research study's framework, as SSI provide situations where science teachers and students analyze complex issues associated with ethical, political, and social dilemmas (Zeidler & Sadler, 2010). One of the major requisites of the new mathematics and science curricula is its relevance to students' lives, this was found to be equivalent to the purpose of STEM education. STEM is a broad field, a unitary idea that offers a greater connection to the real world by providing authoritative purposes for learning and problem solving (Hall et al., 2011).

Implementing STEM education in educational programs is helpful to remove the traditional barriers between its four disciplines, aiding a teaching and learning experience that help students in making sense of their studies. It was done by linking it to their everyday lives and making the connections between their school, community, work and the global world their living in (Lantz, Jr., 2009). Teaching students in an interdisciplinary and connected approach and incorporating them into a strong learning worldview in light of true applications is the premise of STEM instruction (Pritchard, 2016). The STEM Task Force Report (2014) argued that STEM disciplines are not supposed to be taught in isolation to each other. Moreover, it approved the view that STEM education is more than a convenient integration among its four disciplines. But, it is a process that encompasses real world along with problem based learning that can be achieved through the application of consistent and active instructional approaches. Further, Roberta (2015) described the STEM way of learning as an ability to promote students' critical thinking on how STEM concepts, ideas, standards, and practices are associated with daily life experiences.

Scientific knowledge and technological products are expanding, science and social controversial are stimulated and need to incorporate into school science. Learning strategies need to prepare students to learn in the era of changing world. Science educators should engage students learn how to think as scientist and also social concerns (Zeidlrer & Sadler, 2010). Badri et al. (2016) investigated students' interest in science among Abu Dhabi high schools, it was found that one of the most common factors that contributes to students' resistance is the lack of relevance they sense between school science subjects' curricula and their everyday life. In their view, there is a significant mismatch between science subjects taught in school and science in society and daily life experience.

- **Making connections between different STEM subjects when teaching**

In the observed classes, teachers managed to make a connection between different STEM subjects to facilitate and connect different information to the students; for example, integration was made with biology when studying the meaning of multiple thresholds in the physics class. The teachers compared between the meanings of threshold in biology and in physics as an introduction to the class topic. Another example was observed in the biology class, where the teacher managed to connect with chemistry when describing the hybridization process; the teacher gave the students a brief revision on entire topic and how it relates to the hybridization process between domains in chemistry. Moreover, minor connections were also made between biology and physics; first connection was observed in measuring and calculating the diastolic and systolic pressure. The second was related to mercury's density and its specifications. In mathematics; however, due to the nature of the subject, most integration was done with physics and engineering. For example, the teacher gave a general description of the topic, highlighting how it is often used not only in mathematics in the resume limits chapter, but also in many physics and engineering problems. More integration with physics was observed in the exercises, given in the existence of the tangent curve and velocity chapter.

Results were consistent with Hartzler's (2000) who found fewer benefits to STEM integration when applied to mathematics and compared with other science subjects. Therefore, the study called for more research on different approaches to facilitate STEM integration in mathematics to enhance overall learning outcomes for STEM disciplines. Similarly, Honey et al. (2014) suggested that mathematics achievement is challenging to promote through STEM integration approach. Becker and Park (2011) examined the effects of integrative approach among STEM subjects on students' achievement levels; twenty-eight studies were analyzed. Results revealed a positive effect on the achievement levels of students when applying integrative approaches. However, mathematics achievement showed the smallest effect size, which indicated the inadequate research found on the effects of integrative approaches on mathematics learning. Previous studies justified the results, achieved from mathematics observational checklist when compared with other science subjects in regards to subject integration. In the achieved results, all observed subjects showed minimal integration, described as selective integration, where teachers have the ability to connect or integrate topics between different STEM based on their teaching qualification, experience, and knowledge. Recent studies indicated that students' motivational and performance levels in mathematics are enhanced when teachers apply integrated STEM educational approach. It is due to the fact that students want to know how they can relate to mathematics, and not just use it to complete mathematical tasks (Kelly & Knowles, 2016).

While most teachers made an attempt to infuse relevant concepts and skills from other STEM disciplines; the few integration examples observed were all dependent on the teacher, the subject, and the topic or chapter discussed. It can be due to the fact that no major connections between different STEM disciplines were mandatory, as very limited integration was given within the assigned school textbooks as a curricular requirement by the Ministry of Education. For example, when the biology teacher was referring back to anti antigens and chemical components of the blood; students were learning about the ionic bond in chemistry. It was also confirmed from the class observational checklist, as it revealed that connection between different STEM disciplines was only made when it was mandatory, depending to the topic area of each class and based on teachers' knowledge, qualifications and experiences. Moreover, no interaction between different STEM teachers was observed in any of the attended classes. This was found to be corresponding to El-Deghaidy and Mansour's (2015) which investigated Science Teachers' Perceptions of STEM education, its Possibilities and Challenges in Saudi Arabia, specifically in Riyadh schools. As results revealed that teachers often worked independently when teaching the new mathematics and science curricula, which highlighted a major barrier to STEM way of teaching or in other words STEM subjects' integration, as teachers were supposed to coordinate to connect different STEM disciplines. Moreover, lack of coordination among STEM teachers was exhibited, as each teacher was concentrating on their own subjects. Even though, it can be concluded from the chemistry teacher's response from interview, when he said that "he often refers back to other science teachers for support, depending on the topic at hand. Giving an example of referring back to the physics teacher for support in the battery chapter." However, in the observational method, no other STEM teachers attended any of the observed classes as extra support or to verify information from other subjects. From this perspective, it can be concluded that Ministry of Education did not conceptualize STEM implementation or subject integration as a direct approach to the implementation of their curricula. Mathematics and science teachers currently view STEM education or subject integration as one more thing that they were now expected to cover along with applying new instructional practices. In order to effectively communicate and advocate the utility and beauty of STEM Education and promote the future of STEM in the 21st century, educators, students, parents, practitioners, researchers, local stakeholders, and state and federal policymakers must all coordinate and work together (Milner, 2015).

5.2.2.2 Learning environment

- **Classroom Environments**

The amphitheater style and layout of the observed mathematics and science classes among the three different schools in Jeddah, Saudi Arabia were found to be suitable for the subjects taught. In most attended classes, the layout of the room gave teachers the center position, as all students were able to see and hear clearly. Moreover, all classes were well organized, clean, and spacious as it was easy for the teacher and students to maneuver freely. Further, laboratories were well organized, as everything was labeled and all safety precautions were taken into consideration.

Henderson and Dancy (2007) explained how instructors tend to blame situational factors as a reason for them to favor traditional instructions, class size, and room layout that were listed among the top factors. The research evidence has illustrated that students' engagements is also affected by class size and teachers motivational and students' satisfaction rate. Results revealed that there were no significant differences in average class size for STEM and non-STEM students (Pawson, 2012). Therefore, it can be concluded that the problem in Saudi Arabia does not rely on the available teaching facilities and resources or classroom size, the problem sets on the actual teaching process itself.

5.2.3 Discussion of the Five Open-ended Questions at the End of the Distributed Questionnaire

This section provides a detailed discussion, achieved from the five open-ended questions included at the end of the distributed questionnaire. The researcher developed the questions with relevance to the scope of the research study, literature review, framework, and the nature of the research questions. Participants' responses were discussed and compared to participants' interview responses and observational data. Moreover, a comparison was made by considering the objective of investigating teachers' perceptions of the new mathematics and science curricula and the implementation of STEM education in Saudi Arabia.

In the first open-ended question "*As a teacher are you familiar with the concept "STEM education"?*

In the attained results, most teachers responded with using the "yes" word as an answer, while some added couple of points to further define the meaning of STEM. Three different points were mentioned among participants, including: STEM lessons immerse students in hands-on inquiry and open-ended exploration. Also, STEM lessons relayed on subject integration. Additionally, STEM lessons focused on real-world issues and problems. These shared characteristics of STEM, were corresponding to participants' interview responses on the actual meaning of STEM. As when the chemistry teacher described that the new curricula focuses more on relating assigned topics with students' lives. Further, in regards to subjects integration the teacher added, "All subjects are related like a chain reaction, if you cut one part out you lose the reaction." While in terms of the new applied teaching practices, the biology teacher described that part of the new curriculum's objectives when teaching mathematics and science subjects is applying new student-centered teaching techniques. This was found to be equivalent to the STEM educational way of teaching and learning. Adding to that, when the teacher further described: "All of us teachers within different fields have annual visits from the ministry of education to make sure that we are following the new student-centered teaching techniques and are applying the new curricular goals and objectives."

Further, participants' responses were also found to be consistent with classroom observational results. Where teachers applied the new teaching practices through the application of investigative strategies, hands on activities, group-work, debates and class discussions to encourage students by getting involved in their own learning. Furthermore, shared characteristics were also equivalent to Wang et al. (2011) definition of STEM, as they described many definitions to STEM education, depending on the way subject integration is achieved. Any intervention or modification to subjects related to science, mathematics, engineering, and technology can be considered as STEM implementation. It can be applied to Saudi Arabia's old mathematics and science curriculums as they were reformed with relevance to the characteristics of STEM education.

In the second open-ended question "*Do you believe that the new mathematics and science curricula is a form of STEM education?*" Most teachers answered with a "yes", while several points were referred to different ways for achieving acquaintance with STEM education. It included subject integration among different STEM disciplines, the application of new teaching practices, relevance of the new curricula, and the encouragement of students' involvement. These points were related to teachers' interview responses to the application of new instructional practices as required from Ministry of Education. Moreover, they were relevant with the observational data achieved from observing different mathematics and science subjects' classes regarding applied teaching practices.

In addition, new applied teaching practices were corresponding to the teaching practices required for the implementation of STEM education as it was described in many previous research including Williams et al. (2015). In this research study, teaching practices required for the implementation of STEM education among under graduate students were correspondent to Berlin and White's (1995) recommendations of different teaching approaches that can benefit the process of STEM education or subject integration. Moreover, with Zeidler et al. (2005) ten best teaching practices necessary for successful mathematics and science integration process; hence, STEM education.

The physics teacher was the only participant referring to the integration of technology when teaching the new physics curriculum, as she stated; "The new curricula introduced the integration of technology, even though it is still considered as limited and at its early stages." Research has shown that instructors' supported convictions concerning the mix of classroom innovation hones don't adjust to their genuine convictions. In a review by Ertmer et al. (2012) endeavored to explore the question, "How do the academic convictions and classroom innovation practices of instructors, perceived for their innovation utilizes, adjust?" Results uncovered that educators' own particular convictions and states of mind about the pertinence of innovation to students' learning were seen as having the greatest effect on their prosperity, and in addition their present levels of information and aptitudes. Barns et al. (2007) discussed some technological methods that have proven to enhance students' engagement in their learning. In addition, it additionally showed how students' might incorporate technology into autonomous learning exercises while guaranteeing time is given to data proficiency and basic deduction abilities. The rundown included Web Quests, online journals, wikis, YouTube, video documentaries, and an assortment of other interactive media ventures.

In the third open-ended question "What *are the challenges facing teachers in teaching the new mathematics and science curricula as a form of STEM implementation/ subject integration into schools?*"

In this question, respondents described several points they considered as barriers, which challenged the implementation of new teaching strategies. These barriers included poor instructional design, insufficient teacher preparation programs and workshops, time constrain, students' resistance to change, lack of recognition, and lack of encouragements, in sufficient school resources, large class size, and lack of a unified assessment form. The barriers, described above, were associated with the barriers described by participants in their open-ended interviews particularly in the fifth question, when participants were asked, "Do you believe teachers are qualified to teach the new mathematics and science curricula? Explain the challenges that faced you as an instructor." Moreover, results were equivalent with barriers described by Honey, et al. (2014). Furthermore, with Froyd's (2008) depictions of the obstructions confronting instructional changes. Educators report that the most dominating hindrance to the appropriation of changed showing methodologies incorporate; deficient time to find out about required improved showing techniques, restricted preparing in the utilization of transformed showing procedures, absence of assets accessible, instability with the practice, and the nonattendance of institutional support (Henderson and Dancy 2007; Czajka, and McConnell, 2016; Pelch and McConnell, 2016). In the course of recent decades, there has been a developing enthusiasm for STEM training, especially on the powerful systems required to prepare students for cutting edge study in STEM-related fields. Kelly and Knoewles (2016) described several barriers to STEM education implementation that were consistence with the barriers as described by the participants in the open-ended questions. It included rigid school structures, isolated subjects and topics, departmental agendas, curricular requirements and contents, end of the year examinations as mood of assessment.

Asghar et al. (2012) described internal and external factors that challenge the implementation of STEM education. First factor is related with the internal barriers; these barriers were related to teachers' beliefs, capacity, knowledge, and requisite skills. Such skills enabled teachers to sense the connections among different STEM disciplines and the external links between science, mathematics, engineering and technology. Teachers' perceptions and understandings positively affect the implementations of STEM education on the level of students' content understanding and developing skills (Han et al., 2015). Second factor was related to the external factors that can be traced involving three external barriers. The structures of schools, the curricula, and the way education is organized and evaluated at the national level (Asghar et al., 2012). Moreover, the researcher accentuated on external factors that play a larger role in changing the resistance of participants, elaboration of the traditional school settings, and compartmentalization of scientific knowledge that formulates rigid boundaries (Asghar et al., 2012). Situational variables may vary, however it ordinarily incorporates class size and room format, students' imperviousness to change, desires of substance scope, and instructor's planning time (Henderson & Dancy, 2007). The reform is further complicated in STEM fields since different disciplines have their own set of standards and unique curricular requirements (Hora et al. 2013; Pelch & McConnell, 2016).

The fourth open-ended question in the distributed questionnaire was "*Do you believe that the new mathematics and science curricula improves the standards of education in Saudi Arabia? Please answer with yes or no and explain.*"

Here, most of the shared themes were concentrated around the idea that the new curricula is more suitable to the next generation standards including its material contents and applied teaching strategies. Moreover, it emphasized on the accomplishment of students and motivational levels towards mathematics and science education. Moreover, it stressed on the integration process between different STEM subjects and the real world. These characteristics were parallel to the characteristics shared by participants' responses in their interviews. The challenges remain under the fact that instructional strategies no matter how cautiously developed, cannot be equivalent to constrain of local reconstructions including regional schools, different classrooms and most importantly teachers' personal preferences, knowledge and educational skills. Instructors need to be properly trained to customize new instructional strategies that are suitable for the situation (Foyed, 2008).

In the fifth open-ended question "*From an educational point of view, which do you think is more beneficial to students the old or new mathematics and science curricula?*"

Analysis of teachers' responses revealed that most respondents favored the new mathematics and science curricula, due to the following factors; its relevance to real life situations, concentration on the development of students' self-efficiency, confidence, motivational levels and educational outcomes were achieved through the implementation of new teaching methods, which have proven its success throughout many previous research studies. Stanford et al., (2016) described that there is a growing evidence that integrative programs consistently outperformed students in traditional integrated curricular programs. Recent studies have revealed that traditional approaches in teaching mathematics and science subjects are associated with students negative attitudes towards STEM (Czajka & McConnell, 2016; Badri et al., 2016; Knezek et al., 2013). The purpose of the newly adjusted mathematics and science curricula in Saudi Arabia is to create meaningful connections between students' lives and their educational experiences by setting more weight on students' centered learning and understanding the concepts instead of relying on memorizing texts. Furthermore, the implementation of new curricula adopts a constructivist theory of learning that focuses on critical thinking and problem-solving techniques (Obaikan for Research and Development, 2010; Mullis et al., 2016).

5.3 Discussion of Quantitative Results

Educational reformation was completed in Saudi Arabia's school curricula in 2009, with a joint effort with al Obeikan Research Development Company as a form of STEM education and as an adapted series of science and mathematics textbooks produced by the American publishing company McGraw Hill. STEM education, in the center of this research study, can be achieved through the implementation of new teaching practices that are inquiry as well as student-centered and problem-based learning. These are treated as a way to display interdisciplinary, important learning encounters that could incorporate two or more of the four primary controls distinguished in STEM training (Almannie, 2015; Rwathi et al., 2014).

The new mathematics and science curriculum is considered a positive move in the educational reformation of Saudi Arabia. Most of the shared opinions found in this study were concentrated around the idea that the new curriculum is more suitable to the next generation, including its material contents and applied teaching strategies. This is also confirmed by the chemistry teacher's interview response, as he stated: "The new required teaching techniques that focus on students' involvements in their own learning is considered as an evolutional change in education." Moreover, it focuses on students' achievements, attitudes, and motivational levels towards mathematics and science education and also stresses the integration process between different STEM subjects and the real world.

In this section, the discussion is particularly centered on the results achieved from the quantitative analysis portion of this research. The section is described in a comprehensive manner in order to give explicit meaning to these acquired results. These obtained results are also further discussed and compared with the results of studies in the past within the same area of study. Additionally, the results were compared to the tested hypothesis generated from the qualitative part of the research study to reflect how a better understanding of wider teacher perception can influence the implementation of STEM. This comparison was made to allow for a better comprehension of the convictions of large groups of science and mathematics teachers regarding the implementation of the new mathematics and science curricula in Saudi Arabia. The results were compared, analyzed, and interpreted to determine if the new mathematics and science curricula are considered as a positive step towards STEM education implementation in Saudi Arabia.

The subsequent discussion explores the results of a cross-sectional questionnaire which was prepared in the form of multiple-choice questions. Each dimension of questions included partial sets of variables. The first section covered in the discussion is teacher preparedness; this includes how teachers are prepared to teach the newly applied mathematics and science curricula as a step towards the implementation of STEM education in Saudi Arabia (extracted between questions 6 through 18). The second section includes the discussion of the results achieved from the teachers' perceptions on their current implementation of teaching the new mathematics and science curricula (determined from questions 19 through 28). The final section discusses the results on the actual process of teaching the new mathematics and science curricula in the classroom (determined from questions 29 through 37).

1- Rate of teachers' preparation to teach the new mathematics and science curricula

In respect to teachers' preparation to teach the new mathematics and science curriculum as a step towards the implementation of STEM education in Saudi Arabia, participants' views were investigated through questions 6 to 18 of table 8 in the cross-sectional questionnaire. These questions explored teachers' backgrounds and awareness of the new curriculum as well as their familiarity with ways to implement these into the classroom. Questions included gauging teachers' knowledge on how to successfully relate science and mathematics curriculum to other subjects and other elements of student life; their familiarity with how to facilitate critical thinking in the classroom; and previous knowledge on how to apply new teaching techniques that focus on the students. From the achieved results, it was concluded that the level of preparedness varied among different participants depending on their background. This conclusion was derived from cross-examining the five demographic variables that likely have had an effect on teachers' preparation levels: participants' gender, nationality, years of teaching experience, educational qualification, and the subject being taught.

Gender

According to the results, participants' gender did not carry a statistically significant effect on teacher preparation levels; mean scores of both genders closely rated the well prepared option (table 11). Moreover, findings from table 10 have shown that there was no statistical differences found between participants' gender and the rate of preparedness of newly implemented mathematics and science curricula ($t = 85.148$, $p > .05$). This was found to be consistent with Owolabi and Adebayo's (2012) study results on the investigation of the relationship between teachers' gender and their qualification on secondary students' performance levels in physics. Results revealed that teacher's gender had no effect on students' impact of knowledge; teachers' qualifications were considered as the major influential factor for students' academic performance across gender (Owolabi & Adebayo, 2012).

Educational Qualification

This was relevant with the research study's results in respect to the effect of participants' qualifications on the level of their preparedness to teach the new mathematics and science curricula. Results of table 12 revealed that teachers with Master's (M=2.15) and other degrees (M=2.16) showed the largest two mean scores across participants' qualifications, which was closest to the somewhat prepared option. The mean scores of teachers with Bachelor's degrees indicates they are the group (M=1.41) most likely to choose the not prepared option. In addition, the ANOVA test indicated statistical differences between the mean scores on participants' qualification awareness in teaching the new mathematics and science curricula ($F= 2.719$, $p < .05$). Adeyemi (2010) described teachers' experiences and educational qualifications as prime predictors of students' academic achievement.

Darling-Hammond (2000) examined the effects of teachers' qualifications on students' achievement levels. The results indicated that teacher preparation and educational certification shared the strongest correlates of student achievement in mathematics. Further, the author described that teachers who held higher educational degrees and had more experience with teaching preparations were more confident and successful in implementing different instructional practices (Darling-Hammond, 2000).

Teaching Experience

On the contrary, in regards to participant's years of teaching experience, the *t*-test indicated that there was statistical differences between the two groups: t = 1.46, $p < .05$. Results revealed that teachers with higher teaching experience (> 16) along with their abilities to implement new required teaching practices were more capable and qualified to teach the new mathematics and science curricula when compared to teachers with less experience.

Moreover, highly experienced teachers shared positive perceptions on the level of awareness in making connections between different STEM subjects and on the application of the new teaching practices required for the implementation of the new mathematics and science curricula as a step toward STEM education. Previous research has demonstrated that self-efficacy increases with teachers' years of teaching experience (Wolters & Daugherty, 2007). Moreover, it has been proposed that new instructors have a tendency to depend all the more vigorously on one area of learning, while experienced educators could coordinate the greater part of all areas in their practice (Rozenszajn & Yarden, 2014). These results were contradicted however with Marshall et al.'s 2009 study, where results indicated no correlation between years of teaching experience in K-12 science and mathematics teachers and their perceptions on their preparedness for STEM curriculum.

Nationality

In respect to nationality, ANOVA test (table 11) indicated that there were no statistical differences found between participants' nationalities and their preparation to teach the new mathematics and science curricula (F= 2.191, p > .05). A study investigating the influence of culture and education among American and Taiwanese teachers' efficiency beliefs, however, demonstrated teachers' national background can inform their instructional practices. Results suggested that their academic background and their cultural perspectives influenced their beliefs, their ability to increase student proficiency, and their overall teaching experience (Lin, 2002).

Similarly, another study revealed that diversity-related burnout is likely in relation to several variables, including teacher background, a school's cultural heterogeneity, and certain aspects of the school organizational culture related to multiculturalism (Tatar & Horenczyk, 2003). Al-Mohannadi and Capel (2007) investigated the level of stress facing physical education teachers in Qatar and determined there were different causes of stress for different groups of teachers, which could be a result of different cultural and social expectations or environmental factors they encounter. This could be interpreted to mean that a teacher's nationality could affect their level of preparedness to introduce STEM into the curriculum. Despite the relation between teachers' background and nationality on their teaching practices found in prior research, insignificant results achieved in this research study can be due to the fact that all participated teachers came from similar backgrounds. Almost all of the participants had nationalities that mostly consisted of Middle Eastern countries that carry similar social, cultural, and religious customs, beliefs, and practices.

Subject Taught

In respect to the subject taught, table 13 has illustrated that the mean scores for the subject taught, which was closely associated with the somewhat prepared option, ranges between 2.29 and 2.31. Moreover, the ANOVA test indicates statistical significance between mathematics, chemistry, and biology subjects for a teacher's rate of awareness on how to implement new curriculum, such as in STEM education. Teachers' capability to connect taught subjects with students' daily life, issues, and experiences sees the highest mean value on the questionnaire. Participant interviews based on class observational methods show that the new mathematics and science curricula aim to make taught subjects relevant in a real world context.

Teacher Self-Evaluation

Based on background demographics, participants' questionnaire responses in table 8 show mean scores ranging between 1.63 and 2.63, with teachers' responses mostly consisting of somewhat prepared and well prepared. None of the results indicated that teachers were not prepared to teach the new mathematics and science curricula, yet it was concluded that none felt very well prepared to do so. Most responses were in the middle, which indicated that teachers are starting to adapt to the new curriculum and to its new required instructional practices. This was found to be relevant with participants' interviews, when teachers' shared mixed views on teachers' qualifications to teach the new mathematics and science curricula and implement new instructional practices. Yet, more focus should be applied towards teachers' preparation programs and work shops in order to achieve the new mathematics and science curricula's goals and requirements and therefore create a strong base for STEM implementation in Saudi.

Results also revealed that teachers were somewhat prepared to: develop students' conceptual understanding depending on the subject taught (M=2.28); encourage students' interest in mathematics and science subjects (M=2.31); teach the new mathematics and science curriculum (M=2.4); encourage students' interest in mathematics and science subjects (M=2.31); lead a class of students using investigative strategies (M=2.48); and make a connection between science and mathematics with other subjects (M=2.44). The lowest mean scores recorded indicated that teachers were not entirely ready to use assigned textbooks as a source rather than a primary instructional tool (M=1.63). This was relevant to Windschitl's 2003 research, who described open inquiry as pedagogically complex for teachers to apply when compared with structured inquiry. Research confirms that teachers' limited training, insufficient time, and lack of instructional and peer support were barriers to instructional reform (Henderson & Dancy, 2007). These results mimic the participant's interview responses when they were asked, "*Do you believe teachers are qualified to teach the new mathematics and science curricula?"* Throughout the results, it has been concluded that responses from the participants showed that teachers were not highly qualified for applying new instructional practices.

However, these instructional practices were required from the Ministry of Education to teach new mathematics and science curricula. For example, the physics teacher highlighted that teachers had a lack of knowledge and practice required for the implementation of new instructional practices including the application of investigative strategies and critical thinking and problem solving techniques. Thus, teachers usually tend to refer back to their old teaching methods during their teaching practices. These findings are equivalent to Nadelson (2009), who described inquiry based teaching instructions as complex because it requires teachers' knowledge, skills, and creativity, which is difficult to incorporate within standardized teaching practices. It is complex to integrate due to lack of adequate support, feedback, and adequate time for reflection.

Results revealed that teachers felt well prepared in applying new student centered teaching techniques, with the highest mean value of all the variables (M=2.63). Teachers also felt prepared: managing a class of students engaged in hands on project based activities (M=2.60); connecting taught subjects with students daily life issues (M=2.53); making connections between different STEM subjects when teaching (M=2.50); teaching lessons that appropriately combine STEM subjects (M=2.56); and providing a deeper coverage of fewer mathematics and science concepts (M= 2.59).

Benefits of Being Prepared for STEM

Conceptualizing the benefits of a STEM education can underscore the importance of teacher preparedness. Research has proven that one of the characteristics of effective science teaching is a deep understanding of science perceptions, which entails teachers to explain, identify, and apply scientific concepts. Moreover, it is critical in planning, delivering, and assessing scientific instructions in the classrooms (McConnell et al., 2013). One research study, in support for "Vision and Change in Undergraduate Biology Education: A Call to Action," determined that to improve undergraduate biology education, a more in-depth study of fewer topics, the use of evidence based teaching methods, and improving STEM education is crucial (Mulnix & Vandegrift, 2014).

In a review of research on undergraduate performance in introductory science courses, results uncovered that students covering no less than one noteworthy logical point in depth, for a month or more, in secondary school were found to get higher evaluations in school science subjects. These were compared with students who announced covering all major logical themes with no top to bottom scope. It was concluded from the review's outcomes that educators ought to utilize their judgment to annihilate the scope in secondary school science courses by extending at least one topic in a broadened time frame, keeping in mind the end goal to propel students' scientific education (Schwartz, et al., 2009).

From the study's results, it can be concluded that teachers started to apply new instructional practices and are gradually becoming more confident and familiar with their application. Further, STEM education helped teacher's feel more confident with the new mathematics and science curricula's requisites. Results show teachers' have a positively perceived ability to manage a class of students engaged in hands on project-based activities. In chemistry class, the teacher engaged 11th and 12th grade students in hands on class activities in multiple classes. In the attended class, students were asked to assemble a hybridization module using cardboards and colors and illustrate outside examples. In another class, students were required to represent the methane structure with an angle of 109.5 using pens and balloons. Moreover, in 12th grade, students were divided into four groups of five to manufacture a battery model using cardboards and aluminum foil; the first team to finish was praised with a bonus mark. From the results, it can be concluded that teachers were well prepared to implement new instructional practices which were found to be related to STEM instructional practices. Roberta (2015) described the STEM way of learning as an ability to promote students' critical thinking on how STEM concepts, ideas, standards, and practices are associated with daily life experiences.

2- The rate of the implementation of the New Science and Mathematics Curricula

This section of the discussion covers the portion of the questionnaire in which participants were asked to rate the emphasis on their classroom implementation practices of the new mathematics and science curricula as a step towards STEM implementation in Saudi Arabia, as seen in items 19 through 28 (table 14). This was achieved with relevance to participants' five demographic variables that might have carried an impact on their implementation, including gender, years of teaching experience, qualifications, nationality, and the subject taught.

In a study to investigate K-12 science and mathematics teachers' beliefs regarding the use of inquiry in the classroom, results revealed that "no correlations were found between typical and ideal percentage of time devoted to inquiry, the subject matter, content, knowledge, training, gender, years of teaching experience, or maximum degree earned" (Marshall et al., 2009).

Gender

In respect to gender, mean scores of both genders revealed moderate emphasis on their perception of new implementation practices (table 15). However, no statistical difference was shown between the two groups (t = 1.652, p > .05) (table 16). In a study to assess the relationship between teachers' gender and qualification on students' performance in industrial safety, it was concluded that teachers' gender and qualification do not have significant effects on students' academic performance. This implies that the rate of students' performance is the same when taught by male or female lecturers (Igberadja, 2016).

Teaching Experience

In respect to participants years of teaching experience, it was revealed that teachers with more than 16 years of teaching were rated as perceiving the need for a heavy emphasis on implementing new instructional practices required from the Ministry of Education to teach the new mathematics and science curricula. On the contrary, teachers with less than 16 years of experience rated moderate emphasis (table 17). Further, results of a t-test have indicated significant difference between the two groups ($t = 1.529$, $p < .05$) (table 16).

Educational Qualification

In regards to teachers' educational qualifications, it was concluded from the mean scores achieved that teachers with Bachelor's and Master's degrees were placed in the moderate emphasis category, while teachers' holding other educational certificates rated a heavy emphasis (table 15). Additionally, ANOVA test scores (table 18) have shown a statistically significant difference between participants' educational qualification and applied instructional practices of the newly implemented curricula ($F= 2.890$, $p < .05$). Ugbe (2000) investigated the influence of teachers' qualifications and experience on students' academic performance in a senior secondary school chemistry in Cross River State. Results revealed a significant difference between the performances of students taught by qualified teachers in contrast with students taught by unqualified teachers in chemistry. Consequently, Kilaha (2010) investigated the effect of chemistry teachers' effect on students' performance in Bungoma North District; results revealed that teachers' educational qualifications, teaching experience, and teaching approaches carried more influence on students' performance levels than with other demographics.

Nationality

In terms of participants' nationalities, all participants rated their perception of the need for implementation as minimal emphasis; moreover, a t-test indicated no statistical significance between different nationalities (table 17).

Subject Taught

In regards to subjects taught, mathematics, chemistry, and physics teachers rated their perception levels for the need to implement STEM practices with a moderate emphasis, while biology teachers rated a close to heavy emphasis. Further, an ANOVA test indicated there was no significance on perceptions of applying new instructional practices with subjects taught.

Perceptions on Process Success

Analyzing table 14, which shows responses to questions 19 through 28, the mean scores of participants' responses was between 2.26 and 2.78 which means ranging between minimal emphasis and moderate emphasis. It can be concluded that all participants agreed to the fact that they perceived some degree of emphasis on the learning and teaching process when implementing the new mathematics and science curricula; none of the participants chose the no emphasis option. This indicated that the new mathematics and science curricula have affected the process of teaching through the implementation of new instructional practices but still, it hasn't taken over old teaching methods.

Furthermore, teachers' responses to the interview question "Do you believe that the new curricula is a step forward in Saudi Arabia's educational reform and a step towards STEM implementation?" saw most participants share positive views regarding the educational reform movement. The chemistry teacher mentioned that the new curricula is a positive step in Saudi Arabia's educational reform that was long awaited. The physics teacher explained, "The new curricula is more advanced in terms of the information included and the level of coordination among subjects, including the sequence of its topics." Furthermore, the biology teacher described the new mathematics and science curricula as being a more pertinent and constructive approach in the 21st century.

The implementation was rated by the participants with minimal emphasis for preparing students for standardized tests, reporting at the lowest mean score (M=2.26). Almannie (2015) argued that despite Saudi Arabia's continuous investments in education and development of the new mathematics and science curricula, educational outputs do not reflect this investment. This result was translated in the low performance of Saudi students in TIMMS (2011).

Despite this fact, in the interview responses most teachers praised the additional presence of a large variety of revision questions found at the end of each chapter of the assigned textbooks, which varied in strength and style. This result was relevant to the mathematics teacher's response, as she highlighted the importance of exposing students to different styles of questioning rather than depending on the style and pattern of the teachers' exclusively. Further, minimal emphasis was also achieved in regards to the fact that the new curriculum and its implementation practices prepare students for future study in STEM fields (M=2.28).

Participants rated the implementation of the new mathematics and science curricula with moderate emphasis on the following aspects: learning how to communicate ideas in mathematics and science subjects effectively to students (M=2.67); receiving aid in learning important terms and facts of knowledge (M=2.68); learning about the relation between different STEM subjects (M=2.61); helping in making a connection between STEM subjects in problem solving (M=2.73);

aiding in learning basic concepts in mathematics and science subjects (M=2.53); effect on students interests in mathematics and science subjects (M=2.75); and on its emphasis on students' critical thinking and problem solving techniques (M=2.39). This helps point research in the direction of what works based off teachers' perceptions. Implementation tactics should follow a blueprint that incorporates these concepts.

Real World Emphasis

The highest levels of emphasis; however, is seen in teachers' ability to connect mathematics and science subjects to students' daily life issues (M=2.78). Class observational methods used in this study of mathematics and science subjects confirmed participants' interview responses in terms of the new mathematics and science curriculum, including chemistry, biology, and physics to students' real life scenarios and circumstances. This was found to be relevant with the new curricula's requisites from the Ministry of Education, which relates to the topics of students' lives (Mullis, 2016; MOE, 2015). Further, these results correspond to the teachers' interview responses, where most mathematics and science teachers indicated that the new curricula puts more weight on the relevance of mathematics and science subjects to real world context.

In one of the responses acquired from the biology teachers, it was found that part of the Ministry of Education's assigned requirements and inspections is relevance of taught subjects to students. Likewise, Badri (2016) argued that students tend to do better in STEM subjects when topics are relevant to real world context. Wang et al. (2011) described that in order to achieve a successful implementation of STEM education, teachers are required to organize the curriculum surrounding their real life in order to develop the real world problem solving.

This study's results show that there has been a moderate rate of emphasis on the implementation of new instructional practices required for teaching the new mathematics and science curricula perceived by teachers. Student's educational outcomes saw positive consequences increased by STEM subjects. Prince and Felder (2006) argued that the genuine capability of STEM education reform lays in the chance to influence change in instructor practice. Further, research study's results were found to be parallel to Berlin and White's (1995) recommendations of different teaching approaches to benefit the recent educational process of STEM education implementation. Additionally, with Zeidler et al. (2005) ten best teaching practices that is necessary for successful mathematics and science integration process, which include STEM benefitting students through instructor practices.

Teachers somewhat agree on that the new curriculum is more relevant to students' lives and 21st century demands, showing the highest mean value (M=3.02). Aikenhead (2006) argued that one way to increase students' interest in school science is to bring in a humanistic perspective. The SSI approach places science in a larger social, cultural, and political context, focusing on contemporary social issues that require scientific knowledge for informed decision making. Claxton (2007) explained that the most common requirement for increasing the level of indulgence of students during their learning phase is relevancy. The study described that students are more engaged and motivated in their learning if given topics were applicable to real-life scenarios and compared with theoretical and text-based learning.

Most mathematics and science teachers indicated that the new curricula focuses more on students 'engagements and placing more weight on subjects,' or relevance to students' daily lives. STEM implementation and the integration of subjects is approached within that process. For example, in the interview, the biology teacher described that their teaching requirements are to teach subjects relevant to student's lives while encouraging their engagements and inputs. Adding to her answer as assigned in the books at the beginning of each chapter there is a sub title under the introduction titled "Relevance to Real Life," which gives information and examples as obtained from real life scenarios. This was not included in the old books, nor was it a part of the Ministry of Education inspections. Observational methods were consistent with teacher's interview responses, as teachers were found to be creative in engaging their students through different classroom exercises and tasks.

3- Rate of teachers' Satisfaction with STEM Education and its delivery in the classroom

In this section of the questionnaire, participants were asked to state their opinion on the new mathematics and science curriculum as a step towards STEM implementation in Saudi Arabia, as seen in items 29 through 37 (table 20). This was filtered, as in part one and part two of the discussion, with participants' five demographic variables that might have carried an impact on their perceptions and implementation practices, including: gender, years of teaching experience, qualifications, nationality and the subject taught. It was concluded from teachers' responses to that all participants placed their opinions, as none chose the no opinion option.

Gender

In respect to gender, t-test results (table 22) have indicated a statistically insignificant difference between the two groups (t = 1.675, p > .05).

Teaching Experience

In regards to participants' years of teaching experience, it was revealed that teachers with more that 16 years of experience shared positive opinions on the new mathematics and science curricula, rating it closely to the strongly agree category. On the contrary, teachers with less than 16 years of experience closely rated their opinions to somewhat agree (Table 21). Further, results of a t-test (Table 22) have indicated a significant difference between the two groups (t = 1.78, $p < .05$).

Educational Qualifications

In regards to teachers' educational qualifications, ANOVA test scores (table 24) have shown a statistically significant difference between participants' educational qualification and their opinions on the newly implemented curricula (scores $F= 2.659$, $p < .05$).

Nationality

In terms of participants' nationalities, ANOVA test results have shown that there were no statistically significant differences found between nationalities (F= 2.421, p > .05)

Subject Taught

In regards to subjects taught, mathematics, chemistry and physics rated their awareness levels as moderate emphasis while in biology it was close to heavy emphasis. Further, ANOVA test shows a statistically significant difference between mean scores of implementing new mathematics and science curricula and subject taught (F= 2.719, p < .05).

Teacher Development Programs

Furthermore, results achieved revealed the following: teachers disagreed on the fact that teacher development programs and workshops were offered before the implementation of the new curriculum, showing the lowest mean value (M=1.63). These results support the qualitative results of this study, including participant responses to the interview question, *"As a teacher were you offered any sort of Teachers' development programs or workshops as a preparation to teach and implement the new mathematics and science curricula? How important do you think is it for teachers?"* It was concluded from different responses of mathematics and science teachers that there is a need for providing and restructuring available workshops and development programs for achieving a successful implementation of new teaching practices. These were required for teaching the new mathematics and science curricula. Moreover, it was consistent with the biology teachers' response, "I have been teaching high-school biology for a couple of years now, and so far I wasn't obliged to take any courses or workshops."

Previous research has confirmed the importance of teacher development programs for the success of an educational reform. Hence, STEM education implementation (Badri, 2016; Stanford et al., 2016; English, 2016) also focused on increasing students' achievement levels in mathematics and science subjects through ongoing development (Wenglinsky, 2002). Despite the importance of teacher development programs and workshops on teachers' performances, the level of teachers' dependence on the available workshop is considered relatively low. This could be because of the way that expert improvement projects may not furnish educators with the apparatuses needed to overcome situational boundaries (Ebert-May et al. 2011; Henderson et al., 2012; Froyd, 2008). In a study evaluating the effects of teachers' professional development programs, results revealed that 75% of teachers still rely on traditional or instructor-centered practices while teaching STEM subjects (Ebert-May et al., 2011). These findings argued strongly for the redesign of teacher preparation programs and workshops that provide teachers with the necessary pedagogical content knowledge. This is necessary for designing, developing, and implementing integrative STEM educational practices and instructions.

Failures

Participants disagreed on the fact that teachers are well prepared and equipped to teach the new mathematics and science curricula (M=2.40). This was corresponding to participant's interview responses, as most of the participants described teachers as unqualified to apply new instructional practices required for a successful implementation of the new mathematics and science curriculum. The mathematics teacher explained that teachers tend to go back to their old teaching methods when required. In a report to invest in the quality of teaching, Darling-Hammond (1997) concluded that most schools and teachers did not achieve new educational goals because they lacked the knowledge and implementation practices required. Furthermore, they did not receive support to do so.

Successes

Results further revealed that teachers somewhat agreed on the following: the new curricula offered students better learning opportunities (M=2.74); the new curriculum is considered as an improvement in Saudi Arabia's education (M=2.99); the new curriculum challenges students by offering complex problems related to real-world scenarios (M=2.92); STEM education has been integrated as something other than adding additional science and mathematics instruction/courses into your school (M=2.82); teachers at your school regularly observe each other's classes as a part of sharing and improving instructional strategies (M=2.87); and the new mathematics and science curriculum is contributed to STEM education (M=2.80). These obtained quantitative results correspond to participants' interview results when teachers were asked about the major aspects of the new mathematics and science curricula. Responses included: relevance of the new curricula to real life situations, minor integration between different STEM subjects, and new student-centered and problem based instructional practices. Most of the results were equivalent to those obtained from the qualitative method portion of the research, including teacher's interviews, class observational methods, and the open-ended questions included at the end of the distributed questionnaire. Moreover, these results were consistent with previous conducted research within this area of study.

Further, more images and illustrations were included in the textbooks along with a summary and key points at the end of each chapter to help students focus on the important themes and be able to build upon and connect information with other chapters. In the qualitative part of the discussion, results revealed that teaching practices required for the implementation of new mathematics and science curricula were equivalent to those required for the implementation of STEM education (Williams et al.; 2015; Berlin & White, 1995; NGSS, 2012; Zeidler et al. 2005). Class observational methods also confirmed teacher awareness and application of these new teaching strategies in their classrooms. Moreover, in the open-ended questions included at the end of the distributed questionnaire, most of the teachers' believed that the new mathematics and science curricula is a form of STEM education.

Mixed Views

In respect to respondents' answer to the fact that teachers are well prepared and equipped to teach the new mathematics and science curricula, there were mixed views. In teachers' open-ended interviews, results indicated that teachers shared mixed views regarding their level of qualification in teaching the new mathematics and science curricula in Saudi Arabia. Moreover, data confirmed the fact that teachers were moving away from following old traditional teaching methods to a more student centered and problem based way of learning in the class observational methods. In a study to investigate science teachers' beliefs in regards to teaching the new science curricula in Saudi Arabia, results revealed that interactive and group oriented learning have increased class enjoyment (Al-Ghamdi & Al-Salouli, 2013).

Regarding if teachers usually observe one another's teaching patterns regularly, it led to the response of mixed views. In participants' interview responses, most teachers agreed to the fact that teachers often rely on each other and attend each other's classes for support and knowledge. For example, the chemistry teacher explained: "I often go back to biology and physics teachers to assist me with questions and concerns in some chapters, which to me is an indication that there is a form of subject integration in terms of different topics." However, despite participants' responses, no observation of an attending class seeing mathematics and different science subjects was determined. El-Deghaidy and Mansour (2015) discussed the importance of the school culture while emphasizing the significance of consistent dialogues and experience sharing among teachers that teach STEM subjects.

It can be concluded that the new mathematics and science curricula can be contributed to STEM education. The new curriculum is more relevant to student's lives and 21st century demands (Mullis, 2016). It is considered as an improvement in Saudi Arabia's education and challenges students by offering complex problems related to real-world scenarios from which they can learn by practically implementing and comprehending. Results were parallel to those achieved from qualitative means and previous research conducted within this area. Herschbach (2011) described that in the 21st century's educational reformation, traditional STEM stand-alone subjects such as chemistry, biology, physics, and mathematics are being improved through the integration of knowledge of STEM.

5.4 Recommendations

The outcomes and results of the research study have important implications to enhance the STEM education practical implication in the schools of Saudi Arabia. The results acquired from the qualitative and quantitative methods have showed extensive and strong evidence that these results would assist in comprehending the major role that teachers play within the educational reform and its implementation. Achieved results provided a window to the applied teaching strategies and the weak spots that needs focus for future support and assistance. This section has effectively organized the future recommendations concerning the research study objective. Moreover, suggestions have been provided related to the practice of STEM education. Moreover, it also entailed the recommendations useful in future in profession of education and academics.

Recommendations related to research identified several areas of research to improve the impact and diffusion of STEM education innovations in Saudi Arabia. Due to the lack of supporting studies available in Saudi Arabia, more research is recommended to provide conclusive vision of the new mathematics and science curricular reform. Firstly, a call for more regional research is necessary to improve scientific educational systems to keep up with the rapid development pace needed as Saudi Arabia is considered far behind. This exploration study ought to be imitated to affirm its discoveries where additionally inquire about should be done in other geographic areas and crosswise over other STEM orders to recognize whether the techniques distinguished in this review are like those discovered somewhere else. Furthermore, it has been observed that there is very little research regarding the coherence between mathematics and science subjects in the attained curriculum, where more research is required to investigate how curricular coherence works for students. Moreover, work should be performed on how students perceive and observe these connections. Additionally, the introduction of *Reformed Education* approaches through professional development programs and workshops. Reformed education is about recruiting and adequately preparing teachers with both the content knowledge and the pedagogical content knowledge necessary to implement specific teaching strategies needed to effectively teach their content. Additionally, inadequate understanding about inquiry instruction, complexity of the approach, and educational significance to future educators and STEM professionals provide justification for offering and investigating inquiry-based STEM professional development. This development would be useful for faculty members teaching mathematics and science subjects in all school levels. The utilization of subjective research strategies in concentrate integrative practices ought to be expanded to permit specialists to investigate at more prominent profundity the marvels encompassing integrative techniques. In this manner, scientists are managed a wealthier record of occasions and more prominent understanding into an exceptionally complex instructional process.

In regards to practice, additional investments by the authorities in optimizing interactivity and collaboration among mathematics and science teachers are required. It could be in the form of an educational platform that brings together curricular developers, trainers, and teachers to provide resources and reference sources for best practice regarding STEM reform in the kingdom. Furthermore, research is required for redesigning and the restructuring of teachers' development programs and workshops with the addition of STEM training and implementation practices. Moreover, the enhancement of mathematics and science teachers' participation in workshops and professional development programs especially those that prepare teachers to design and implement integrative STEM and improving instructional practices. Furthermore, coordination among teachers, who are teaching different STEM disciplines in schools, should be enhanced and encouraged in order to achieve successful STEM implementation. Similarly, a platform for connecting students and allowing them to interact and collaborate with each other will deepen the interactive and collaborative capability of STEM implementation.

Recommendations related to the field of education, findings have recommended more effort to increase public awareness on STEM education and strategies needed for promoting its adoption and implementation. In order to legislate STEM education in Saudi Arabia, additional correlation and reorganization among topics within individual STEM subjects are required. Reorganization of the new mathematics and science curricula should be proceeded in a way where the topics between different STEM subjects are in sequence and consistent with each other. Thereby, facilitating the process of STEM subjects' integration. Additionally, designing an assessment form through identifying the best approaches that help assess the design of integrative instruction and the implementation of that instruction. Furthermore, the development of professional development programs and workshops need to be restructured to fit the educational needs, standards and be as beneficial as possible to match the objective and purpose of the new mathematics and science curricula. It can then be introduced as a form of STEM education implementation in Saudi Arabia, where more focus is required on the addition of STEM training. Also, in order to attain teachers' participation in faculty development and teaching related endeavors, educational institutions as the Ministry of Education and school heads should value such efforts. This can be achieved by motivating faculty members that additional time they spend on developing new instructional strategies will be accounted for annual reviews, raises, promotions and tenure. As well, there is a need to develop a unified documented tool to investigate instructional practices occurring in the classroom, as a form of assessment and quality control. At the same time, further research is required for developing the ways to aid or assist teachers to cater association among different STEM subjects. Most specifically when an appropriate curriculum frameworks and resources are inadequate.

5.5 Limitation of the Research

When conducting a research study, limitations affect the degree of trustworthiness of the research and generalization of its attained results (Creswell, 2013). The following are some of the limitations that need to be considered as they might have had an effect on the research study's findings.

Firstly, this research study is limited by the validity of measurement of the applied instruments, including teachers' semi structured open-ended interviews, class observational methods and the cross sectional questionnaire. Secondly, the qualitative part of the study was unique to Jeddah, consisting of only eight teachers. However, the rich description provided from qualitative measures applied including interviews, class observational methods and open-ended questions at the end of the distributed questionnaire aided in supporting the results. Thirdly, in the qualitative phase of the research study, participants' selection was limited to post-secondary mathematics and science teachers, with experience in teaching both the old and the newly adapted mathematics and science curricula in Saudi. Therefore, results may not be applicable to new teachers with any prior experience on teaching the old curricula or to teachers outside higher educational institutions. Fourthly, time considerations related to population, due to the school calendar including the frequent public holidays, where the researcher had to work around them. For example, the summer vacation in Saudi Arabia in 2016 lasted for four months (from the end of May until 11th of September). Fifthly, gaining access to schools and educational institutes. The researcher faced difficulties to gain access to some of the schools and teachers in the qualitative and the quantitative parts of the research study. Even though the researcher was granted with an official letter from the British University to allow access to schools (appendix 8). The university is still not accredited in Saudi Arabia; therefore, the researcher was denied access to several high school facilities. Moreover, in the research study, the researcher couldn't refer back to participated schools, as schools requested to be anonymous and not reveal their identity within the research. Sixthly, the proposed conceptual framework does not address all the problems concerning the new science and mathematics curricula and educational programs in Saudi high schools. Such as those imposed by law, by the politics of curriculum making, or by current science and mathematics teachers' professional development programs. Seventhly, due to the uniqueness of the research topic, currently there is no protocol purposefully designed to observe STEM integration classes or structured interviews for STEM implementation. Therefore, qualitative and quantitative instruments applied including teacher's interviews, class observational checklist and the cross-sectional questionnaire were developed by the researcher, with consideration of the scope of the research study, social and cultural concerns. Eighthly, classroom observational methods were concluded from females schools only, due to cultural and religious regulations in Saudi Arabia, schools are gender segregated where the researcher couldn't gain access to a male science or mathematics classrooms. Additionally, videotape recordings were not permitted. Ninthly, in the qualitative part of the research study, the researcher depended on note taking in gathering the results, as videotape recording and audio-recording of participants interviews and observational methods were not welcomed. Finally, much of the research study's literature review was based on research studies conducted in western countries, due to the fact that STEM implementation is considered as a new area in the educational system, where much research has lacked especially in the Middle East.

5.6 Conclusion

In respect to the outcomes, design and implementation practices of integrated STEM education, Saudi Arabia is still far behind, as there is still much more to be learned. Yet, the research agenda, findings and recommendations of this research study strongly suggest the potential of some forms of integrated STEM education to make a positive difference in learning. The level of evidence gathered from teachers' perceptions from the open-ended interviews, class observational methods and the cross-sectional questionnaire were not sufficient to suggest that integrated STEM education is being fully implemented. Nor was it sufficient to decide if it should replace the new mathematics and science curricula, which focus on individual STEM subjects. However, it was perceived that parts of the educational landscape in Saudi are already moving toward integration and STEM implementation practices when teaching. Therefore, the study ends with recommendations to direct and generate more research and evidence-based work to explore the benefits and limitations of integrated STEM education implementation. Given the inherent complexities, it will not be a surprise that designing and documenting effective initiatives will be time-consuming and expensive. Efforts and resources allocated in the development and adaptation of new curricula and models that in theory have proven its effectiveness does not mean its successful implementation in real life. Educators are required to understand the gap in the current educational system in order to develop effective strategies that can be applied practically.

The confusion in the literature about the coordinated educational module and the nonappearance of a reasonable hypothetical system are dangerous in building up a predictable hypothetical and pragmatic comprehension of curricular integration. It makes the shift from the traditional individual subjects a threatening challenge. Despite the international focus and recent research considering

STEM implementation, results revealed that there is still a lack of clarity on what STEM should look like. STEM educational pathway stands for a better understanding of the world everyone lives in, including social standings, economic wealth, and a healthy lifestyle (Hall et al., 2011). In Saudi Arabia, STEM disciplines are educated as isolated subjects inside partitioned classrooms, where the real way of work of most STEM experts obscures the lines between controls. Today, consideration of new educational reformation is crucial, responsible organizations and educators in Saudi Arabia need to consider new ways to think about the re-organization of curriculums and the presentation of its instructions. Curriculums need to be reorganized with coherence and relevance to each other especially between different STEM subjects. The Next Generation Science Standards (2015) declares that "K-12 science guidelines have been produced that are rich in substance and organized in a reasonable way crosswise over orders and grades to give all students a globally benchmarked science instruction" (Pritchard, 2016).

This research study further informed the developing literature on STEM education by helping scholars understand the factors that facilitate and hinder teachers from implementing integrated mathematics and science curricular materials. It also discussed how teachers' understanding of interdisciplinary teaching could evolve through targeted professional development activities. Equally important, findings showed that the biggest barrier of implementing STEM education in Saudi Arabia does not lay under the lack of knowledge about effective teaching practices. Instead, it is a result of inadequate knowledge on how to effectively spread and apply the use of currently available and tested research-based instructional strategies. This research study calls for the restructuring of teacher's development programs and workshops, making them as mandatory requisites to teach mathematics and science subjects in schools. Moreover, the intention is to provide teachers with an experiential understanding on how to apply and use new teaching practices as an instructional framework that could shape up STEM education implementation in Saudi Arabia. This can be achieved by restructuring and extending the period of teachers development programs and workshops where teachers not only learn about the new instructional practices but also get proper training on how to effectively implement them in their practices. Many of the internal barriers pointed out by the participants in this research study might be overcome through more professional development programs in order to familiarize teachers on applying new required teaching practices. However, these internal barriers can be addressed, changing the factors that contribute to external sources of resistance that would require substantive changes in systemic levels.

Findings have produced vital insights for teachers, school administrators, teachers' education, and researchers in terms of preparing, empowering, and supporting teachers to meet up and work crosswise over disciplinary restrictions. Several points were concluded from investigating mathematics and science teachers' perceptions of the new mathematics and science curriculum as a step towards the implementation of STEM education. Firstly, a successful STEM implementation is necessary to occur along with a transformation in teacher's part from acting as transmitters of information to that of facilitators of learning. Therefore, helping students recognize relevant sources of knowledge to solve real world problems. Secondly, administrators, who are keen on interdisciplinary STEM programs, need to encourage teachers' professional development programs and competency with new instructional approaches by creating strong structures and instruments. In addition, administrators must perceive the internal and external barriers that teachers face when attempting to actualize an innovative approach and provide encouragement; support and professional development activities that help them overcome these barriers. Finally, more research is required to investigate new instructional approaches that are required for the success of the new mathematics and science curriculum; hence, it results in STEM implementation in Saudi Arabia. As the true potential of STEM education reform lays in the opportunity to affect change in teacher practice. Coordinated STEM training is an approach that expands on characteristic associations between STEM subjects for the goal of advancing students' comprehension of each discipline by expanding on students' previous knowledge. Likewise, by expanding students' comprehension of STEM trains through introduction to socially significant STEM settings and by making STEM disciplines and vocations more available and interesting for students (Wang, Moore, Roehrig, & Park, 2011).

Results concluded from qualitative and quantitative analysis demonstrated that instructional practices required for teaching new mathematics and science curricula from the Ministry of Education, were equivalent to those required for the implementation of STEM education. In order to overcome the barriers of STEM implementation in Saudi Arabia, the Ministry of Education needs to increase the exposure of STEM concept among students and teachers at all levels.

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Appendix 1.

Teachers' Interview Questions

A. Demographic Information

1) Gender
2) Years of teaching experience
3) Nationality
4) Qualification
5) Subject taught

B. Teacher Background and perceptions

1. Are you familiar with the concept "STEM education? Please explain your answer.
2. Do you believe that the new mathematics and science curricula is a form of STEM education? How?
3. Do you have experience in teaching the old mathematics and science curricula? If your answer is yes, did you experience differences in your coursework and instructional approaches required for the implementation of the new curricula compared to the old one?
4. In your opinion, in the new curricula does the Ministry of Education aside from connecting mathematics and science subjects to real life scenarios, focuses on STEM implementation (STEM subjects integration) in their annual visits?
5. Do you believe teachers are qualified to teach the new mathematics and science curricula? Explain the challenges that faced you as an instructor.
6. As a teacher were you offered any sort of teachers' development programs or workshops for preparation to teach and implement the new mathematics and science curricula? How important do you think is it for teachers?
7. What do you think are the major aspects of the new mathematics and science curricula that are considered as a step towards implementing STEM education?
8. What is your overall perception on the newly implemented science and mathematics curricula?
9. Do you have any additional comments that you would like to share?

Appendix 2

Teachers’ Interview Questions (Arabic)

"١."هل انت على درايه بمفهوم ستيم للتعليم؟

" ٣. هل تعتقد أن المناهج الجديدة للرياضيات والعلوم تعتبر نوع من تعليم الستيم؟ كيف؟

٣. هل لديك خبره في تدريس المناهج القديمة في العلوم والرياضيات؟ إذا كانت الإجابة نعم، هل واجهت اختلافات في المقررات الدراسية والنهج التعليمية المطلوبة لتنفيذ المناهج الجديدة مقارنة مع القديمة؟

٤. في رأيك هل تركز وزارة التعليم على تطبيق نظام ستيم (دمج مواد الستيم) علاوة على ربط مادة العلوم و الرياضيات لأمثلة من واقع الحياة خلال زياراتهم السنوية؟

٥. "هل تعتقد أن المعلمين مؤهلين لتدريس المناهج الجديدة للرياضيات والعلوم؟ اشرح التحديات التي واجهتك كمدرب

٦."كمعلم هل عرضت لأي برنامج/ عرض عليك أي نوع من برامج تطوير المعلمين أو ورش العمل لتحضير تدريس وتنفيذ مناهج الرياضيات والعلوم الجديدة؟ ما هي مدى أهمية هذا التدريب بالنسبة للمعلمين في رأيك؟ "

٧. ماذا تظن هي الجوانب الرئيسية لمنهج الرياضيت والعلوم الجديد التي تعتبر كخطوة نحو تنفيذ نظام ستيم للتعليم؟

٨. ما هو انطباعك بشكل عام على مناهج العلوم والرياضيات الجديدة// التي نفذت حديثاً؟

٩. هل لديك أي تعليقات اخرى ترغب بالمشاركة بها؟

Appendix 3.

Teachers' Perceptions of the New Mathematics and Science Curriculum: As a Step Towards STEM Implementation in Saudi Arabia

Teachers Questionnaire (English)

This questionnaire will be used a part of a doctoral thesis to investigate teachers' perception regarding the newly implemented math and science curriculum as a form of STEM education in Saudi, the answers you provide will be used as research data and analyzed for the purpose of the research understudy. Your cooperation in completing this questionnaire is greatly appreciated. If you have any questions or emphasis regarding the research or the questionnaire, please contact the researcher: Rehafmadani@hotmail.com.

A. Demographic Information

1) Gender
2) Years of teaching experience
3) Nationality
4) Qualification
5) Subject taught

B. Teacher Background

Please indicate how well you are prepared to teach the newly integrated math and science curriculum by choosing the correct answer for the following statements:

Statement	Not prepared	Somewhat prepared	Very well prepared
6) Develop students conceptual understanding of taught subject			
7) Provide deeper coverage of fewer science/math concepts			
8) Make connection between science/ math with other subjects			
9) Lead a class of students using investigative strategies			
10) Encourage students' interest in math/ science			
11) Use assigned textbook as a source rather than a primary instructional tool			
12) Connecting taught subjects with			

students daily life issues			
13) Manage a class of students engaged in hands on/ project based activities			
14) Teaching the newly integrated Math/ Science curriculum			
15) How prepared are you in teaching lessons that appropriately combine STEM subjects			
16) Apply new student centered teaching techniques			
17) Using teaching approaches that focuses on improving students critical thinking and problem solving			
18) Making connections between different STEM subjects when teaching			

C. Teachers' perception

As a teacher please provide your opinion on each of the following statements regarding the emphasis of the newly integrated math and science curriculum on students learning outcomes:

Statement	None	Minimal Emphasis	Moderate Emphasis	Heavy Emphasis
19) Students interest in math/science subjects				
20) Aid in learning basic concepts in math/science subjects				
21) Aid in learning important terms and facts of knowledge				
22) Prepare students for future study in these fields				
23) Learn how to communicate ideas in math/science effectively				
24) Prepare students for standardized tests				
25) Learn about the relation between STEM subjects				
26) Connect math/science to students daily life issues				

27) Make a connection between STEM subjects in problem solving				
28) Effect on students' critical thinking and problem solving				
29) Increase measures of student achievement in STEM subjects that are integrated				

D. Teaching the New Math and Science Subjects in a Classroom.

Please provide your opinion about each of the following statements:

Statement	No Opinion	Disagree	Somewhat Agree	Strongly Agree
30) Teachers are well prepared and equipped to teach the new math/science curriculum				
31) Teachers on your school regularly observe each others classes as a part of sharing and improving instructional strategies				
32) The new Math and science curriculum is contributed to STEM education				
33) Teachers' development programs and work shops were offered before new curriculum implementation				
34) The new curriculum offers students better learning opportunities				
35) The new curriculum is more relevant to students lives and 21century demands				
36) The new curriculum is considered as an improvement in Saudi				

Arabia's education				
37) The new curriculum challenges students by offering complex problems related to real-world scenarios				
38) STEM education has been integrated as something other than adding additional science and mathematics instruction/courses into your school				

E. Open ended questions regarding the newly integrated Math and Science Curriculum:

39) As a teacher are you familiar with the concept "STEM education"?

40) Do you believe that the new curriculum is a form of STEM education?

41) What are the challenges facing teachers in teaching the new math and science curriculum as a form of integrating STEM education into schools?

41) Do you believe that the new curriculum improves the standards of education in Saudi? Please answer with yes or no and explain.

42) From an educational point of view, which do you think is more beneficial to students the old or new math and science curriculum?

Appendix 4.

تصورات المدرسين للمنهاج المضمن حديثاً لمادتي الرياضيات والعلوم : تطبيق لأحد النماذج من منهجية "ستيم" بالمملكة العربية السعودية

<u>إستبيان المدرسين</u>

سيستخدم هذا الاستبيان كجزء من اطروحة دكتوراة بغرض استقصاء قابلية استيعاب وتصور المدرسين لمنهاج مادتي الرياضيات والعلوم والذي تم تطبيقه حديثاً بالمملكة العربية السعودية كأحد النماذج التربوية لمنظومة " ستيم " (العلوم، والتقنية، والهندسة، والرياضيات)، والإجابات المقدمة منكم سيتم استخدامها كبيانات و إخضاعها للتحليل للأغراض البحثية في هذه الدراسة. كما ان تعاونكم في تعبئة هذا الاستبيان سيجد منا كل التقدير. و إذا كان لديكم اي اسئلة أو تأكيدات الرجاء الإتصال بالباحثة:

rehafmadani@hotmail.com

أ. المعلومات الديموغرافية

1) الجنس
2) عدد سنوات الخبرة
3) الجنسية
4) المؤهل
5) المادة التي تم تدريسها

ب. خلفية المدرس

الرجاء تحديد مدى استعدادك لتدريس المنهاج الجديد المطبق لمادتي الرياضيات والعلوم باختيار الاجابة الصحيحة عن العبارات التالية:

العبـــــارة	غير مستعد	مستعد نوعا ما	مستعد جيدا
6) تنمية مدارك ومفاهيم الطلاب عن المادة التي يتم تدريسها			
7) توفير تغطية متعمقة لعدد قليل من المفاهيم المتعلقة بالعلوم و الرياضيات			
8) الربط بين العلوم / الرياضيات و المواد الأخرى.			
9) قيادة طلاب في فصل دراسي باستخدام الاستراتيجيات الاستقصائية			
10) تشجيع الطلاب وتنمية اهتمامهم بالرياضيات / العلوم			
11) استخدام الكتاب المدرسي المخصص كمصدر أكثر من كونه أداة تدريس أساسية.			
12) ربط المواد التي يتم تدريسها بالأمور الحياتية اليومية			
13) إدارة فصل دراسي لطلاب و هم يقومون بنشاطات عملية / مشاريع.			
14) تدريس المنهاج المطبق حديثاً لمادتي الرياضيات / العلوم			
15) ما مدى استعدادك لتقديم دروس تضم بصورة معقولة			

مواد من منظومة "ستيم"؟			
16) تطبيق أساليب تدريس جديدة يكون محور التركيز فيها على الطالب.			
17) اتباع منهجيات التدريس التي تركز على تنمية مستوى التفكير النقدي و حل المشاكل لدى الطلاب.			
18) الربط أثناء التدريس بين المواد المختلفة لمنظومة "ستيم"			

ج. تصور المدرسين

بصفتك مدرس، الرجاء إبداء رايك في العبارات التالية حول التركيز في المنهاج المطبق حديثاً لمادتي الرياضيات والعلوم على ناحية مخرجات التعلم لدى الطلاب:

العبـــــــــــارة	لا يوجد	تركيز مخفف	تركيز متوسط	تركيز شديد
19) اهتمام الطلاب بمواد الرياضيات / العلوم				
20) تقديم المعينات على تعلم المفاهيم الأساسية في مواد الرياضيات / العلوم				
21) تقديم المعينات على تعلم المصطلحات والحقائق المهمة في المعرفة.				
22) إعداد الطلاب للدراسة المستقبلية في هذه الحقول.				
23) تعلم كيفية تبادل الأفكار بفعالية في الرياضيات / العلوم.				
24) إعداد الطلاب للإختبارات الموحدة.				
25) معرفة العلاقة بين مواد منظومة "ستيم"				
26) ربط الرياضيات / العلوم بالأمور الإعتيادية في حياة الطلاب اليومية.				
27) الربط بين مواد منظومة "ستيم" وبين حل المشاكل.				
28) التأثير على التفكير النقدي وحل المشاكل لدى الطلاب.				
29) زيادة معايير تحصيل الطلاب في المواد المطبقة من منظومة "ستيم".				

د. تدريس المواد الجديدة للرياضيات و العلوم بالفصل بالدراسي.

العبـــــــــــارة	لا يوجد رأي	لا أوافق	أوافق الى حد ما	اوافق بشدة
30) لدى المدرسون الاستعداد والتجهيز التام لتدريس المنهاج الجديد لمادتي الرياضيات/العلوم				
31) يقوم المدرسون بانتظام في مدرستك بمتابعة				

دروس بعضهم البعض كنوع من تبادل وتحسين استرتيجيات التدريس.				
32) المنهاج الجديد للعلوم والرياضيات يعتبر إضافة لمنظومة "ستيم" التربوية.				
33) تم تنفيذ برامج وورش عمل لتطوير المدرسين وذلك قبل تطبيق المنهاج الجديد.				
34) يوفر المنهاج الجديد فرص أفضل للتعلم بالنسبة للطلاب.				
35) المنهاج الجديد أكثر ارتباطاً بحياة الطلاب و بمتطلبات القرن 21				
36) المنهاج الجديد يعتبر تحسيناً لمجال التعليم بالمملكة العربية السعودية.				
37) المنهاج الجديد يوفر تحديات للطلاب لأنه يتضمن مشاكل معقدة لها صلة بالواقع المعاش في العالم.				
38) تم تضمين منظومة "ستيم" التربوية ليس فقط باعتبارها أضافة لدروس / دورات العلوم والرياضيات بالمدارس.				

هـ. أسئلة مفتوحة تتعلق بالمنهاج الجديد المطبق لمادتي الرياضيات والعلوم:

39) بصفتك مدرس، هل مفهوم "ستيم" التربوى مألوف لديك؟
40) هل تعتقد بأن المنهاج الجديد هو احد نماذج منظومة "ستيم" التربوية؟
41) ما هي التحديات التي تواجه المدرسين في تدريس المنهاج الجديد لمادتي الرياضيات والعلوم باعتبارها جزء من تطبيق منظومة " ستيم" التربوية بالمدارس؟
42) هل تعتقد بأن المنهاج الجديد يمكن أن يرتقي بمستويات التعليم في المملكة العربية السعودية؟ الرجاء الإجابة بنعم أو لا، مع التوضيح.
43) من وجهة نظر تربوية، وبحسب اعتقادك، أيهما أكثر فائدة بالنسبة للطلاب المنهاج القديم أم الجديد لمادتي الرياضيات والعلوم؟

Appendix 5.

Teachers' perceptions of the new included methodology of Mathematics and Science: implementation of "STEM" methodology in the Kingdom of Saudi Arabia

(Back translation of Arabic questionnaire to English)

Teachers' Questionnaire

This questionnaire will be used as a part of PhD thesis in order to examine teachers ' vision and perception of mathematics and science that has been implemented recently in the Kingdom of Saudi Arabia as one of the educational models of "STEM".
Provided answers by you, will be used as a database and will be subject to analysis for research purposes in this study. Your cooperation to fill this questionnaire will be highly appreciated. If you have any inquiries or confirmation, please contact the researcher: rehafmadani@hotmail.com

A) Demographic information

1) Gender
2) Years of experience
3) Nationality
4) Qualifications
5) Subject taught

B) Teacher background

Please state how you are prepared to teach the new methodology of mathematics and science by selecting the correct answers to the following phrases:

Phrase	Not ready	Somehow ready	Very much ready
6) Development of understanding and perception of students for the taught subjects			
7) Providing intensive coverage of few concepts related to science and math			
8) Connecting between science/math and other subjects			
9) Leading students in classrooms using survey strategy			
10) Encouraging students and enhance their interest into math/science			
11) Using the proper school book as a source more being a main teaching tool			
12) Connecting subjects being taught with daily life issues			
13) Managing a classroom for the students while they are conducting practical activities/projects			
14) Teaching the new implemented methodology of math and science			
15) How you are ready to teach lessons that include a sort of "STEM"?			
16) Implementing new teaching techniques based on			

students centered ones			
17) Following methodologies that focus of developing critical thinking level and solving problems of students			
18) Connecting between different subjects during teaching in "STEM" methodology			

C) **Teachers' vision**

As a teacher, please tell us your opinion in the following phrases concerning focusing on learning outputs for students in the new implemented methodology of mathematics and science:

Phrase	No focus	Slight focus	Middle focus	High focus
19) Students' interest in math and science				
20) Aid on learning basic concepts of math/science				
21) Aid on learning terms and important facts of knowledge				
22) Preparing students for future study in these fields				
23) Learning how to exchange thoughts interactively in math/science				
24) Preparing students for unified tests				
25) Knowing the relationship between subjects of "STEM"				
26) Connecting math/science with daily life issues				
27) Connecting "STEM" with problem solving				
28) effecting of students critical thinking and solving problems				
29) Increase measures of students achievements that are implemented in "STEM"				

D) **Teaching the new material of math/science in the classroom**

Phrase	No opinion	Do not agree	Somehow agree	Strongly agree
30) Teachers are ready and well prepared to teach the new methodology of math/science				
31) Regularly, teachers follow up lessons of each other as a mean of teaching strategy exchange				
32) The new methodology of math/science is considered a new add to "STEM" educational methodology				
33) Programs and workshops were conducted to enhance teachers' capabilities before implementing the new methodology				
34) The new methodology provides better opportunities for students learning				
35) The new methodology is more				

connected to students life and 21st century requirements				
36) The new methodology is considered an enhancement of education field in the kingdom of Saudi Arabia				
37) The new methodology provides challenges for students because it includes complicated problems that are connected to daily life in the world				
38) "STEM" was included not only as an addition to lessons/ courses of science/math in schools				

E) **Open question related to the new implemented methodology of math/science**

39) As a teachers, are familiar with "STEM" as an educational methodology?
40) Do you think the new methodology is one of "STEM"?
41) What are the challenges that might be faced by teachers in teaching the new methodology of math and science as a part of "STEM" implementation at schools?
42) Do you think the new methodology will make progress to the educational levels in the Kingdom of Saudi Arabia? Please answer with "Yes" or "No" with explanation.
43) Form an educational prospective and in your opinion, which one is more beneficial to students the old methodology or new one for math and science?

Appendix 6

Classroom Observation Guide

Date:

Time:

Duration:

Grade:

Subject:

Gender:

Total number of students:

Statement	Yes/No	Indicators	Comments
A. Teaching strategies: How well did the teacher cover the following teaching approaches in class?			
Give an introduction of the new topic			
Recap on previous topic (session) to build and connect information			
Relate taught subjects with students daily life issues			
Make connection between science/ math with other subjects			
Encourage students' interest in math/ science			
Develop students conceptual understanding of taught subject			
Lead a class of students using investigative strategies			
Use assigned textbook as a source rather than a primary instructional tool			
Applying new student centered teaching techniques			
Using teaching approaches that focuses on improving students critical thinking and problem solving			
Making connections between different STEM subjects when teaching			
Communicate ideas in math/science effectively			
Increase measures of student achievement in STEM subjects that are integrated			
Students are challenged			
Prepare students for standardized tests			

Students are encouraged to work in groups			
Encouraging student interactions as debates and class discussions			
STEM education has been integrated as something other than adding additional science and mathematics instruction/courses into your school			
B. Teacher's qualifications			
Teacher is well prepared and equipped to teach the new math/science curriculum			
Teacher seems qualified well informed specifically on the taught subject			
Manage a class of students engaged in hands on/ project based activities			
Speaks loudly and Cleary			
Has the talent of keeping students interested			
Has the imagination and skill to interact with students			
Encourages students input and class discussion			
Teacher maintains encouraging eye contact			
C. Learning environment			
Student can see & hear teacher clearly			
Student can see & hear resources used			
Adequate space to maneuver independently			
Resources are available and labeled clearly to aid independent use.			
Suitable furniture (adjustable chair or desk)			
Overall healthy classroom environment			

Appendix 7

Sample of some of the emails that were sent to different schools in Saudi Arabia to help distribute the online questionnaire, among high school mathematics and science teachers.

outlook.live.com

Reply | Delete Junk | ...

rehaf madani
Wed 2/10/2016, 7:23 PM
thuraya@kadiandramadi.com

Reply

Sent Items

arabic qestionnaire .doc
68 KB

BUID letters.pdf
478 KB

2 attachments (547 KB) Download all Save all to OneDrive - Personal

Dear Mr Bassam,

My name is Rehaf Madani, i am a doctorate candidate at the British University in Dubai and working on my thesis on "Teachers perceptions of the New Math and Science Curriculum; A Form of STEM Education in Saudi Arabia". I am using a mixed method design (using both qualitative and quantitate methods).

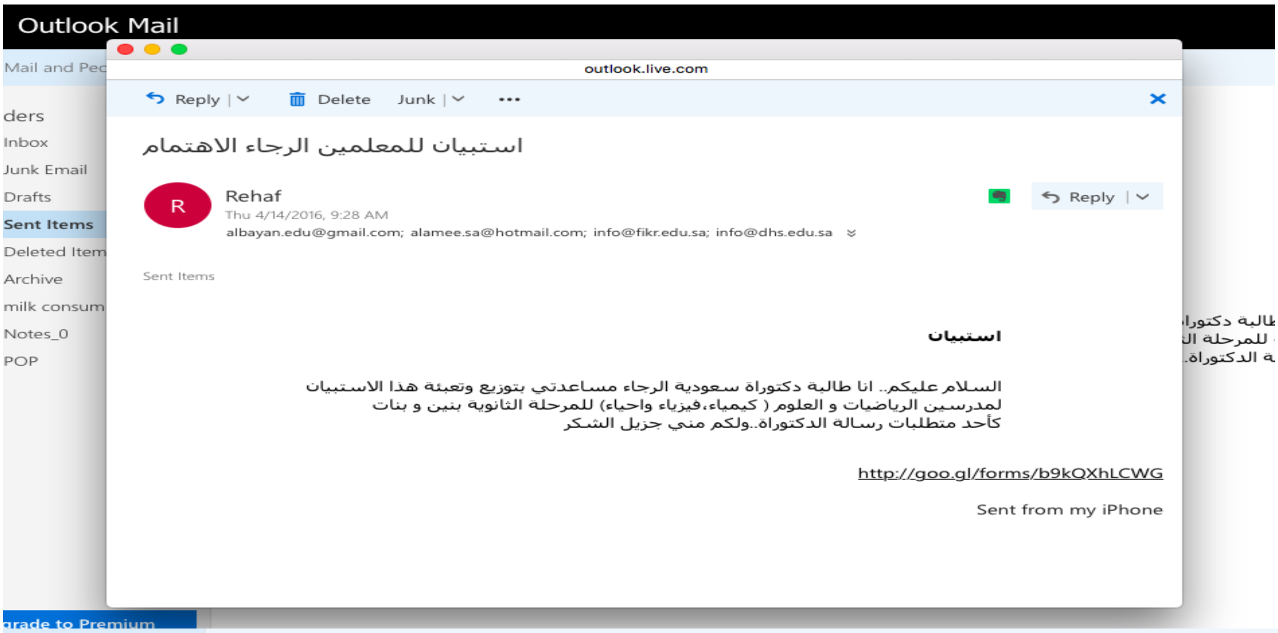
Im writing this letter to request your permission to have access to Dar Althikir high school math and science teachers to complete a survey for the quantitative section. As for the qualitative, i know due to our country's regulations it would be difficult to interview the teachers and attend and observe the classes personally, therefor, i would request to interview the teachers (1 science and 1 math) over the phone and send a representative to observe or record their class.

Attached is a formal letter from the university to confirm my required work and to request a granting of school access.

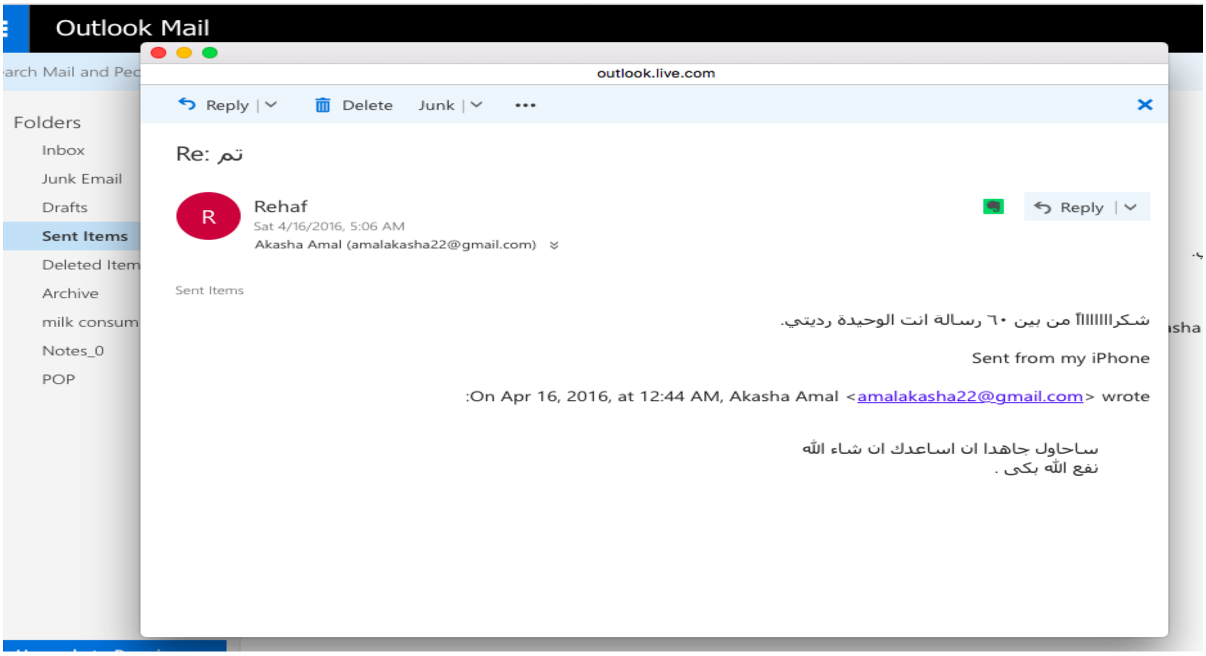
In addition, i have attached the survey for all high school math and science teachers to fill out.

Appreciate all the support that you can provide me,

regards,
Rehaf


Outlook Mail
outlook.live.com
Reply
Delete
Junk
استبيان للمعلمين الرجاء الاهتمام
Rehaf
Thu 4/14/2016, 9:28 AM
albayan.edu@gmail.com; alamee.sa@hotmail.com; info@fikr.edu.sa; info@dhs.edu.sa
Sent Items
Inbox
Junk Email
Drafts
Sent Items
Archive
Notes_0
POP
استبيان
السلام عليكم.. انا طالبة دكتوراة سعودية الرجاء مساعدتي بتوزيع وتعبئة هذا الاستبيان
لمدرسين الرياضيات و العلوم (كيمياء،فيزياء واحياء) للمرحلة الثانوية بنين و بنات
كأحد متطلبات رسالة الدكتوراة..ولكم مني جزيل الشكر
http://goo.gl/forms/b9kQXhLCWG
Sent from my iPhone


Search Mail and People
New
Reply
Delete
Archive
Move to
Categories
Undo
Folders
Inbox 179
Junk Email 208
Drafts 22
Sent Items
Deleted Items 15
Archive
Notes_0
POP 1896
استبيان اتمنى مساعدتكم
Rehaf Madani
Mon 5/2/2016, 5:15 AM
nis_riyadh08@yahoo.com
السلام عليكم.. انا طالبة دكتوراة سعودية الرجاء مساعدتي بتوزيع وتعبئة هذا الاستبيان لمدرسين الرياضيات و العلوم (كيمياء،فيزياء واحياء) للمرحلة
الثانوية بنين و بنات في المدرسة
كأحد متطلبات رسالة الدكتوراة قبل انتهاء الفصل الدراسي...ولكم مني جزيل الشكر و التقدير
http://goo.gl/forms/b9kQXhLCWG


Outlook Mail
outlook.live.com
Reply
Delete
Junk
Folders
Inbox
Junk Email
Drafts
Sent Items
Archive
Notes_0
POP
Re: تم
Rehaf
Sat 4/16/2016, 5:06 AM
Akasha Amal (amalakasha22@gmail.com)
Sent Items
شكراااااا من بين ٦٠ رسالة انت الوحيدة رديتي.
Sent from my iPhone
On Apr 16, 2016, at 12:44 AM, Akasha Amal <amalakasha22@gmail.com> wrote:
ساحاول جاهدا ان اساعدك ان شاء الله
نفع الله بكى .

Appendix 8.
BUID Letter

الجامعة البريطانية في دبي
The British University in Dubai

14 September 2015

To Whom It May Concern

This is to certify that Mrs Rehaf Anas Madani with ID number 2013121010 is a registered full-time student on the Doctor of Education programme in The British University in Dubai since September 2013.

Mrs Madani is currently working on her research titled "Investigating Teachers' Perception in the Integrated Math and Science Curriculum: A Form of STEM Implementation in Saudi". She is required to gather data through interviews and classroom observations. Your permission to conduct her research in your organisation is hereby requested. Further support provided to her in this regard will be highly appreciated.

This letter is issued on Mrs Madani's request.

Yours sincerely,

Amer Alaya
Head of Student Administration

www.buid.ac.ae
P O Box 345015, Block 11, 1st & 2nd Floors, Dubai International Academic City, Dubai, United Arab Emirates
Tel. +971 4 391 3626, Fax +971 4 366 4698