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Investigating Saudi Arabian High School Science Teachers Perceived Challenges and Concerns Related to the Integration of Science Content, Technology, Engineering, and Mathematics (STEM) into Science Teaching

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Investigating Saudi Arabian High School Science Teachers Perceived Challenges and Concerns Related to the Integration of Science Content, Technology, Engineering, and Mathematics (STEM) into Science Teaching

by

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Dedication

I dedicate this dissertation to:

- **My mother for whom I am grateful for the many sacrifices she has made**
    - My wife, Asma Alturiky
        - My sons, Salman, Mohammad, and Basem
            - My daughters Reham, Laiyan, and Acille
                - My extended family
                    - STEM education community

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Abstract

Investigating Saudi Arabian High School Science Teachers Perceived Challenges and Concerns Related to the Integrating of Science Content, Technology, Engineering, and Mathematics (STEM) into Science Teaching

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Since the establishment of Saudi Arabia, the educational system has gone through numerous reform efforts to improve teachers' practice and students' learning. One of the key challenges facing the educational system in Saudi Arabia is the question of how to prepare teachers to use innovative approaches in science education. Several studies have examined science teachers' concerns related to teaching and learning in general; however, few studies have directed specific attention to science teachers' concerns about curriculum integration. Therefore, this study investigated Saudi Arabian high school science teachers' perceived challenges concerning the integration of separate domains within STEM, including science content and pedagogy, technology, engineering, mathematics, and STEM as a whole. This study also explored potential differences in teachers' perceived challenges based on their gender and geographical region.

The researcher collected data from six geographic regions of the Kingdom of Saudi Arabia: Makkah, Tabuk, Aseer, Hail, Kahrj, and Zulfi. These regions were purposefully selected to reflect the geographic and diverse views of teachers across the Kingdom of Saudi Arabia. An explanatory sequential mixed methods design – including quantitative and qualitative methods— was conducted to investigate Saudi Arabian high school science teachers' perceived challenges regarding integrated STEM instruction. The quantitative data were collected from 1,207 participants using four scales: science content and pedagogy integration, technology integration, engineering integration, and mathematics integration. The qualitative data were collected from twenty participants through face-to-face interviews. Descriptive statistics and grounded theory methodology were conducted to analyze data obtained from the participants.

Results revealed that science teachers rated themselves as 1) fairly competent in the areas of science content and pedagogy integration and mathematics integration; 2) having fairly low competence in the area of technology integration; 3) "undecided" in the area of engineering integration; 4) slightly incompetent with regard to the integration of other science disciplines (physics, chemistry, biology, and geology) into science teaching practices; and 5) generally unfamiliar with the integration of STEM in science teaching. The findings of the study revealed no significant difference among participants that can be attributed to gender or geographic region. Other challenges from the qualitative study are presented, such as teachers' negative misconceptions and attitudes toward integrative approaches, students' lack of skills and knowledge that are required for successful STEM integration, curricula incompatibility with STEM approaches, and the lack of resources required for integrative activities. The results of the study suggest an implementation of a systemic reform that focuses on STEM education in Saudi Arabia. The findings of this study may have significant implications for policymakers and educators who are considering implementing integrative approaches in science education.

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Chapter One: Introduction

INTRODUCTION AND STATEMENT OF THE PROBLEM

The educational system in Saudi Arabia has gone through several stages of improvements. The first development of science education started in 1975 when the science curricula (physics, chemistry, biology, and geology) were designed and improved by experts from the American University of Beirut (AUB). After implementing those curricula for more than thirty years, educational experts in Saudi Arabia evaluated the curricula and concluded that these curricula did not reflect the current and future social, cultural, and economic needs of Saudi society (Almazroa, Aloraini, & Alshaye, 2012; Al-Ghanem, 1999; Almannie, 2012). Also, the old science curricula and locally developed textbooks were criticized for the teacher-centered pedagogies. These pedagogies encourage memorization and fail to enhance student learning by eschewing modern teaching methodologies such as attaining knowledge through observing, classifying, comparing, and making connections accross disciplines (Alghamdi, Al-Salouli, 2012).

In 2008, educators in the Ministry of Education (MoE) in collaboration with the Obeikan Research Development Company (https://ww.bayt.com/en/company/obeikan-research-and-development-142518-9323/) adopted, translated, and modified textbooks prepared by the American publishing company McGraw Hill-Ryerson (https://www.mheducation.com/home.html). The fundamental reason for this change was to promote science and mathematics instruction that would improve students' learning using inquiry-based and integrated approaches to make meaningful connections to students' real-life experiences (Aldahmash, Mansour, Alshamrani, & Almohi, 2016; Alghamdi, Al-Salouli, 2012; Alshaye & Abdulhameed, 2011).

Besides curriculum improvement, new supplemental instructional materials and professional development opportunities for teachers of science and mathematics were provided to enhance science and mathematics teaching practices (Qablan, Amansour, Mansour, Al shamarani, Aldahmas, & Sabbah, 2015).

Despite having implemented these curricula, studies such as *The Evaluation Study of Science and Mathematics Development Project in Science Education in the Kingdom of Saudi Arabia, Third Phase Report* (2015) and *Diagnostic Reviews of Education at the Gulf Cooperation Council* (2009) have indicated that students still demonstrate low performance in science and mathematics in local and international tests (see Appendix 1 and 2). Those studies also report a lack of utilizing innovative approaches in science teaching that focus on curriculum integration. Also, teachers in Saudi Arabia do not have sufficient opportunities to express their concerns (perceived challenges) related to the integration across different science disciplines as well as the integration of technology, engineering, and mathematics and STEM as a whole in their science instruction (El-Deghaidy & Mansour, 2015).

The integration of science, technology, engineering, and mathematics is a growing area in developed and developing countries. Such integration aims to equip teachers with integrative teaching skills that "reduce the barriers between traditional subject matter" (Voltorta & Berland, 2015, p. 16) and prepare students for the global economy of the 21st century (Yakman, & Lee, 2012). The idea of integrating mathematics, engineering, and technology into science teaching has been discussed by many researchers and educators (Davison, Miller, & Metheny, 1995; Lonning & DeFranco, 1997). The findings of these studies revealed that teaching science using an integrative approach has many potential benefits for students, such as increasing students' motivation, enhancing conceptual understanding of the content knowledge, making students' experiences more relevant to the real world they encounter in everyday life (Mathison & Freeman, 1998), improving students' achievement (Foutz, Navarro, Hill, & Thompson, 2011; Rethwisch, Starobin, Laanan, & Schenk, 2012), and enhancing students' attitudes toward STEM subjects (Tseng, Chang, Lou, & Chen, 2013).

The most current standards that focus on the integrative approach in science education are *The Next Generation Science Standards* (NGSS Lead States, 2013), which are academic science standards developed based on a *Framework for K-12 Science Education Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012). This framework also calls for science integration as it is practiced and experienced in real-world contexts.

In regard to integrating engineering into science teaching, *The Next Generation Science Standards (NGSS)* report emphasizes the importance of integrating the engineering design into science teaching. Integrating engineering design begins with defining a problem, then proposing realistic solutions, and then reviewing and developing those solutions in suitable ways. *A framework for K–12 science education: Practice, crosscutting concepts, and core ideas* (National Research Council, 2012) indicates that engineering design needs to be integrated into science teaching to help students make successful decisions when they encounter critical problems:

> We anticipate that the insights gained and interests provoked from studying and engaging in the practices of science and engineering during their K-12 schooling should help students see how science and engineering are instrumental in addressing major challenges that confront society today, such as generating sufficient energy, preventing and treating diseases, maintaining supplies of clean water and food, and solving the problems of global environmental change. (NRC, 2012, p. 9).

In addition to incorporating engineering into science teaching, *A Framework for K-12 Science Education* has included technology as a comprehensive component of teachers' practices. Technology in *The Next Generation Science Standards (NGSS)* does not only mean digital devices, but also includes any tool that contributes to fulfilling human wants:

> All types of human-made systems and processes—not in the limited sense often used in schools that equates technology with modern computational and communications devices. Technologies result when engineers apply their understanding of the natural world and of human behavior to design ways to satisfy human needs and wants. (NRC, 2012, p. 11-12)

Integrating technology into mathematics and science teaching enhance teaching practices and students' learning (The National Council of Teachers of Mathematics, 2000). Similarly, mathematics skills are essential in all science disciplines such as physics, chemistry, biology, and earth science. Therefore, The NGSS provides an important opportunity to improve science education and teachers' practices in terms of coordinating science standards with Mathematics Common Core State Standards (CCSSM). Integrating mathematics into science provides students with practical and concrete examples of mathematical skills that can be applied in the real world. This, in turn, leads to enhanced student learning and understanding (Watanabe & Huntley, 1998). Other studies revealed that integrating both engineering and mathematics into science teaching improves students' learning in mathematics and science (Schaefer, Sullivan, & Yowell, 2003).

Since science, technology, engineering, mathematics, and STEM integration is considered a new innovation, it will inevitably generate challenges and concerns among science teachers (Stohlmann, Moore, & Roehrig, 2012; Wang, Moore, Roehrig, & Park, 2011; Berland and Busch, 2012). This new innovative approach requires a wide range of skills and knowledge related to science content and pedagogy, technology, engineering, and mathematical skills. Also, several studies indicate that science teachers lack essential skills and pedagogies when it comes to science, technology, engineering, and mathematics integration. These studies call for investigating teachers' concerns to design effective continuing professional development programs (CPDP) that address science teachers' concerns and enhance students' learning (Nedelson, Callahan, Pyke, Hay, Dance, & Pfiester, 2013; Stohlmann, Moore, & Roehrig, 2012; El-Deghaidy & Mansour, 2015).

When it comes to common practice throughout many Arab nations, including Saudi Arabia, subjects such as science, technology, engineering, and mathematics are taught separately through a discipline-based approach with very limited connection among those disciplines (El-Deghaidy & Mansour, 2015). Therefore, to help science teachers in Saudi Arabia make the best use of science content, technology, engineering, and mathematics (STEM) integration, it is essential to investigate Saudi Arabian high school science teachers' concerns (perceived challenges) related to the integration of STEM in science teaching. It is anticipated that the results of such an investigation will help practitioners, administrators, researchers, and policymakers highlight the importance of understanding and addressing science teachers' concerns related to improving integrative approaches to science education at the K-12 school level in Saudi Arabia.

Statement of the Problem

Science education in Saudi Arabia went through several stages of reforms starting with textbooks and instructional supplies. However, science teachers' concerns with regard to the integration of separate domains within STEM, including Science content and pedagogy, technology, engineering, mathematics, and STEM as a whole, have been not explored.

Investigating science teachers' concerns related to STEM integration will lead to building a constructive and comprehensive framework that facilitates integrative approaches in Saudi Arabia.

RESEARCH QUESTIONS

1. What are the most important challenges and needs perceived by Saudi Arabian high school science teachers in relation to the integration of the following:
    a. Separate domains within STEM, including Science content and pedagogy, technology, engineering, and mathematics?
    b. STEM as a whole?
2. Are there differences in perceived challenges and needs in terms of gender and geographic region?

PURPOSE OF THE STUDY:

The purpose of this study was to investigate, document, and analyze the most important perceived challenges and concerns of high school science teachers in Saudi Arabia related to the integration across different science disciplines as well as the integration of technology, engineering, mathematics, and STEM as a whole into their science instruction.

THE IMPORTANCE OF THE RESEARCH

The global competitiveness of developed and developing countries depends on STEM-related fields as integrated subjects (NRC, 2012; NGSS Lead States, 2013). Since STEM integration is considered a new concept, especially in the Arab world, it is prone to pose challenges that may affect science teachers' daily practices (El—Deghalidy, Mansour, 2015) and hinder them from utilizing integrative approaches in science teaching.

Therefore, investigating high school science teachers' perceived challenges and concerns regarding the implementation of integrative approaches in science education will assist future plans for reforming science education and contribute to establishing professional development opportunities that enhance STEM integration in science instruction.

The educational system in Saudi Arabia is centralized (El-Deghaidy, Mansour, & Alshamarani, 2014) and few studies have investigated the factors that hinder science teachers from integrating technology, engineering, mathematics, and STEM as a whole into science teaching in the developed and developing countries. Investigating Saudi Arabian high school science teachers' concerns (perceived challenges) related to the integration across different science disciplines as well as the integration of technology, engineering, and mathematics into their science instruction will help educational policymakers and educators in Saudi Arabia, the Gulf Cooperation Council (GCC) countries, the Arab world, and other countries applying similar educational systems and contextual factors (Falk & Guenther, 2006) to recognize those perceived challenges and to advocate for suitable professional development programs and solutions that could improve science teachers' practices and ultimately students' learning.

STUDY LIMITATIONS

This study contributes to the existing literature that explores high school science teachers' challenges with regard to the integration of science, technology, engineering, and mathematics in science teaching. As with any study, there are limitations that might impact the research results. This study was limited by the following factors: (a) instrumentation and (b) inability of the researcher to directly interview female teachers due to cultural reasons.

First, data for this study were collected using self-report questionnaires and interviews. The validity and reliability of the four questionnaires, including the translated version, have been established; however, the absence of a precise definition for each item might lead teachers to select neutral positions (neither agree or disagree). If the questionnaires are used again, a clear and precise definition for each anticipated new item will be provided, which would eliminate the neutral choice "neither agree or disagree." Also, professional development programs focusing on integration could be introduced to the teachers before they take the questionnaires. However, the use of an explanatory sequential mixed methods design helped the researcher explore teachers' misconceptions and challenges with regard to the integration of science, technology, engineering, mathematics, and STEM as a whole.

Secondly, the researcher could not interview the female science teachers in the Zulfi and Makkah regions due to cultural barriers. Therefore, female teachers were interviewed by two female physics and chemistry supervisors in these regions. Interviewing female teachers directly could help the researcher gain more rich and in-depth information with regard to the integration of science, technology, engineering, and mathematics in science teaching.

STUDY ASSUMPTIONS

This research study is organized according to the following assumptions: 1) the high school teachers are partially implementing integrated STEM instruction, 2) participants had received content, pedagogical, technological, mathematical, and engineering education pre- and/or in-service professional development programs prior to conducting this study, and 3) that the participants provide honest and candid responses.

METHODOLOGY AND INSTRUMENT

Explanatory sequential mixed methods design – including quantitative and qualitative methods— was conducted to investigate Saudi Arabian high school science teachers' perceived challenges regarding the integration of science, technology, engineering, mathematics and STEM as a whole in science teaching.

The quantitative method utilized a questionnaire that consisted of 5 domains, 49 Likert-type questions, and four open-ended questions. The questionnaire aimed to explore high school science teachers' challenges regarding the integration of science, technology, engineering, and mathematics in science teaching. 1,207 science teachers completed the questionnaires through the administration of a web-based survey through Qualtrics (Qualtrics.com) and then data were imported into SPSS for analysis.

The qualitative method used a case study to explore high school science teachers' perceived challenges related to the integration of science, technology, engineering, mathematics, and STEM as a whole. The research sample consisted of twenty male and female science teachers from the region of Makkah and the district of Zulfi. Science teachers were interviewed using 20 open-ended and semi-structured questions, and then participants' responses were recorded and recoded based on the most commonly reported perceived challenges across all science teachers in the two regions.

DEFINITIONS OF TERMS

The definition of integration in the current educational systems is challenging and diverse because of the absence of consensuses regarding the conceptions of integration in the research literature (Dowden, 2007). Therefore, for this study, the researcher adopted the following definitions:

Science content integration: content integration refers to any activity or lesson that aims to simultaneously address science objectives from more than one curricular perspective (physics, chemistry, and biology) using an interdisciplinary approach.

Technological Integration: technological integration is defined as the "ability to use, manage, understand, and assesses technology" (International Technology and Engineering Education Association, 2007, p. 7). Technology refers to "any modification of the natural world made to fulfilling human needs or desires" (National Research Council, 2012, p.202)

Engineering integration: Engineering integration is defined as the design under constraints (Wulf, 1998), which mostly embraces the laws of nature that practically guide scientists in their efforts to solve current and future problems utilizing engineering design process.

STEM integration (coordination): STEM integration is defined as the teaching and learning of the content and practices of disciplinary knowledge, which include science and/or mathematics through the integration of the practices of engineering and engineering design of relevant technologies (Johnson, Peters-Burton & Moore, 2016. p.23)

Sanders (2009) described the *integration of science, technology, engineering, and mathematics* as "approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects" (p. 21). Moore et al. (2014) defined *STEM integration* as "an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems" (p. 38). Tsupros, Kohler, & Hallinen (2009) defined *STEM education* as: "an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy" (p.20).

Need: Need is defined as the desire on the part of the teacher that is necessary for the improvement of science teaching. Failure to address this need is considered as an obstacle that hinders the effectiveness of teaching.

Science Teachers: A science teacher is defined as an individual who is trained and licensed to teach physics, chemistry, biology, or geology to students in 10^{th}, 11^{th}, and 12^{th} grades.

Self-efficacy: Self efficacy is defined as the "beliefs in one's capabilities to organize and execute the courses of actions required to produce given attainments" (Bandura, 1997, p. 3).

The following is an overview of the chapters comprising this study:

Chapter Two: Review of Literature. Chapter Two contains a review of literature and studies focusing on curriculum integration, the integration of science, trichology, engineering, and mathematics in science teaching, addressing teachers' needs and concerns with regard to the challenges that hinder science teachers from conducting integrative approaches in science teaching.

Chapter Three: Methodology of the Study. Chapter Three lays out the research design and methodology with a description of the quantitative and qualitative methods used in the study.

Chapter Four: Findings of the Study. Chapter Four demonstrates the final results of the comprehensive study. The results are given in terms of investigating the perceived challenges that hinder science teachers from conducting science, technology, engineering, mathematics, and STEM integration as a whole in science teaching.

Chapter Five: Summary, Conclusions, and Implications. This chapter contains a summary of the findings, interpretations, implications of the study, conclusion, and recommendations for addressing science teachers' challenges with regard to the implementation of integrative approaches in science teaching. Also, this chapter involves a suggested framework for professional development that focuses on STEM education.

Chapter Two: Literature Review

This chapter provides a review of the literature and research in the area of science, technology, engineering, and mathematics integration. Specifically, it sheds light on curriculum integration models and describes the challenges that the high school science teachers perceive when they implement integrative approaches across different science disciplines as well as when they integrate technology, engineering, mathematics, and STEM as a whole into their science instruction.

This chapter begins with a historical overview of science and mathematics education in Saudi Arabia, including an overview of preparation and professional development programs offered to science teachers. The next section explains curriculum integration and develops a conceptual framework for the integration of science content, technology, engineering, and mathematics instruction. Finally, this chapter discusses science teachers' self-efficacy concerning the challenges that they may encounter while conducting integrative approaches that aim to build meaningful connections among science, technology, engineering, and mathematics in science teaching. The researcher found that no studies have conducted applicable quantitative and qualitative methods to study the challenges that Saudi Arabian high school teachers perceive when they integrate STEM into their teaching.

Science and Mathematics Education in Saudi Arabia

Saudi Arabia is a Middle Eastern country, located in southwestern Asia. Historically, the earliest education organization began in the seventh century with the purpose of teaching Arabic and Islamic culture. In 1924, formal education started to be established by the Directorate of

Education (DOE). When the Ministry of Education (MOE) was established in 1953, the educational system started improving. Teaching science in public schools started in 1926. Textbooks were developed in different ways. In 1965, Arab educators working in Saudi Arabia developed science curricula. In 1975, science textbooks were developed by Educational Center for Science and Mathematics at the American University of Beirut (AUB) (Al-Abdul Kareem, 2004).

These instructional materials have been criticized for their teacher-centered approaches and their questionable effects on students' conceptual understanding. As a result, in 2007, the $2.4 billion King Abdullah bin Abdul-Aziz Project for Public Education Development (Tatweer) was established (Tatweer, 2010). The main purpose of Tatweer was to improve the entire educational system, thereby generating an efficient workforce within a powerful and contemporary economy. Tatweer's public schools are considered an innovation within the Saudi education system because they utilize theories associated with professional community, self-planning, evaluation, and continuous professional development (Alyami, 2014).

In 2008, the Ministry of Education reformed the science curriculum across all the educational stages by adapting and translating instructional materials from American publishing company McGraw-Hill Ryerson. The primary purpose of this reform was to improve student achievement and implement new approaches based on emerging research in pedagogy, such as scientific investigations using inquiry-based learning and project-based learning (Aldahmas, Mansour, Alshamrani & Almohi , 2016).

In 2011, the Ministry of Education (MOE) began to implement the School Development Model (Tatweer Schools, Phase 2). The school development model was based on the following principles: excellence for all, accountability for all, professionalism, transparency and clarity for all (King Abdulla Bin Abdul-Aziz Project for Public Educational Development/Tatweer, 2011).

In this model, students pursuing high school diploma/ science pathway are required to study 200 credit hours (see Appendix 3). These hours include a wide variety of subject matter such as physics, chemistry, biology, geology, and ecology. However, Alyami (2014) reported that lack of human resources, insufficient technologies, and change resistance were the most important challenges that hinder the implementation of the School Development Model (Tatweer Schools: Phase Two).

In summary, the government of Saudi Arabia has been encouraging and supporting educational reform at K-12 level since 2007; however, these educational reforms should focus on a systemic reform that embraces all components of the educational system. The systemic reform literature suggests five conceivable pathways that aim to build capacity within the broader systemic reform approaches. These pathways are:

> [A]articulating a vision for reform, providing instructional guidance toward the realization of that vision, restructuring governance and organizational structures so as to facilitate learning and more effective delivery of services, providing needed resources, and establishing evaluation and accountability mechanisms that provide incentives for improvement while addressing problems and barriers (Goertz, Floden, & O'Day, 1996, p. xiii)

Science Teacher Preparation and Professional Development in Saudi Arabia

After graduating from discipline-oriented teacher-education institutes, Saudi Arabian teachers start to teach specific science subjects (i.e., biology, chemistry, physics, and geology) in public schools (El-Deghaidy & Mansour, 2015). When it comes to teachers' practices, lecture-based teaching is pervasive among teachers, with very little coordination or integration across science disciplines, subject matter, and interactive technology. Some attribute poor student performance to an inadequate supply of qualified teachers (Kuenzi, 2008).

In 1975, the Ministry of Education started to provide teachers with Continuous Professional Development programs (CPD) (El-Deghaday, Mansour, & Alshamrani. 2014). These programs included national and international teacher training scholarships. However, training sessions often focused on theoretical pedagogical knowledge and generally overlooked actual teachers' practical needs and concerns (Mansour, Alshamrani, Aldahmash, & Alqudah, 2013). Qablan, Mansour, Alshamrani, Aldahmash, & Sabbah (2015) describe training programs as, "neither well organized nor… systematic. Rather, they are scattered and disorganized. The Ministry of Education does not have a clear vision for the science teachers' professional growth or [the continuous professional development programs] CPD" (p. 620).

Given the current limitations of professional development programs for science and mathematics teachers, researchers have suggested that these programs could be improved by focusing more on subject matter content knowledge (Cohen & Hill, 1998). A research analysis conducted by the American Educational Research Association (AERA, 2004) indicated that successful professional development programs focus on explaining how students learn, introducing instructional practices that are specially related to helping students understand subject matter, and strengthening teachers' knowledge of subject matter content (Asghar, Ellington, Rice, Johnson, & Prime, 2012). Similarly, Lemake (1990) indicates that researchers should investigate science teachers' needs and design continuous professional development programs based on those needs and concerns. This approach is considered a remedy for the unsuccessful professional development programs that are currently in place.

TEACHER KNOWLEDGE AND PRACTICE

Teaching effectiveness cannot be developed without improving teachers' knowledge and skills (Borko, 2004; Loucks-Horsley, 1987). Teachers' knowledge is considered one of the most important factors that influence teachers' practices and students' achievements (Fennema & Franke, 1992). The importance of teachers' knowledge leads researchers to study how instructors teach and influence their students. Several frameworks have been introduced to understand and conceptualize teachers' needs and prepare teachers for successful practices. These frameworks include Pedagogical Content Knowledge (PCK), Pedagogical Technological Content Knowledge (TPACK), and the integration of science, technology, engineering, and mathematics integration (STEM). All of these frameworks depend on theories associated with curriculum integration. Therefore, the next section focuses on defining models of integration.

DEFINING CURRICULUM INTEGRATION

Curriculum integration aims to build implicit and explicit connections among different disciplines to help learners build conceptual understanding of a specific phenomenon. The basic definition of curriculum integration was introduced by Humphreys, Post, and Ellis (1981), who stated, "An integrated study is one in which children broadly explore knowledge in various subjects related to certain aspects of their environment" (p. 11). Shoemaker (1989) defines an integrated curriculum as follows:

> Education that is organized in such a way that it cuts across subject-matter lines, bringing together various aspects of the curriculum into meaningful association to focus upon broad areas of study. It views learning and teaching holistically and reflects the real world, which is interactive (p. 5).

Even though the definitions of an integrated curriculum seem straightforward, teachers and researchers still face difficulties in agreeing on a clear, practical, and standard definition of integration and how it should be implemented (Furner & Kumar, 2007; Stinson, Harkness, Meyer, & Stallworth, 2009; Czerniak, Weber, Sndmann, & Ahern, 1999; Huntley, 1998). This disagreement occurs because curriculum and instruction integration can be conceptualized based upon several factors, such as the nature of content knowledge and how integration is being implemented (Stinson et al., 2009).

MODELS OF CURRICULUM INTEGRATION:

Research literature related to curriculum integration indicates that there is confusion about how to implement integration in practice and a lack of obvious frameworks that guide educators to employ integrative approaches in their teaching (Czerniak, Weber, Sndmann, & Ahern, 1999; Huntley, 1998). Several researchers have described curriculum integration as a continuum of integration.

Fogarty (1991) described ten levels of integration, as illustrated in Figure 2.1. These ten levels aim to categorize different models of curriculum integration based on teaching practices and curriculum development. These levels are as follows: 1) fragmented integration focuses on separate and distinct disciplines such as mathematics or science; 2) connected integration focuses on related topics within a discipline; 3) nested integration targets social, thinking, and contents skills within a subject area; 4) sequenced integration aims to teach topics separately, but arranges and sequences them to provide a broad framework for related concepts; 5) shared model integration focuses on teaching and planning two disciplines that share concepts, skills or attitudes; 6) webbed model integration focuses on thematic teaching, using a theme as a base for instruction in many disciplines, 7) threaded model integration incorporates thinking skills, social skills, multiplied intelligences, and study skills throughout the disciplines; 8) integrated model integration combines multiple disciplines to examine the connections among them; 9) immersed integration encourages learners to integrate several skills by viewing all learning through the perspective of one area of interest; and 10) networked model integration allows learners to direct the integration process by selecting a network of experts and resources.

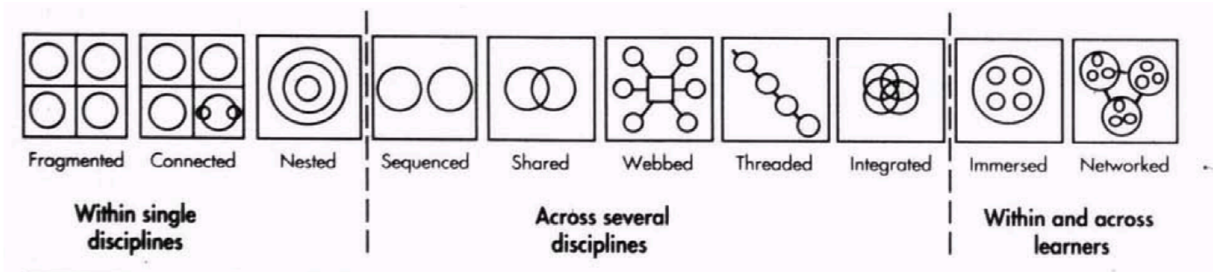


Figure 2.1: Curriculum integration models. from Fogarty, 1991, p. 62.

Similarly, Drake (1993, 1998) divided curriculum integration into three approaches: 1) multidisciplinary, 2) interdisciplinary, and 3) transdisciplinary as shown in Figure 2.2. In a multidisciplinary approach, students are required to draw thematic connections between or among subject areas. An interdisciplinary approach requires students to build connections among several disciplines while focusing on one central theme. They are eventually required to apply their knowledge from different disciplines to address a common research problem. Jacobs (1989, pp. 3-4) defines interdisciplinary learning as "a knowledge view and curriculum approach that consciously applied methodology and language from more than one discipline to examine a central theme, issue, problem, topic, or experience." Finally, the goal of the transdisciplinary approach is to expose students to a real-life problem. This strategy enhances students' motivation and enables them to apply their knowledge and skills to solve a real-life research problem, considering social, economic, environmental and other factors that might negatively or positively influence the final outcome.

Stokols et al. (2008) also described integration as a continuum. They divide this continuum into unidisciplinary, multidisciplinary, interdisciplinary, and transdisciplinary approaches, as illustrated in Figure 2.2. These terminologies are derived from two parts: prefix and the word discipline. The word discipline is defined as “of or relating to a particular field of study” (Merriam-Webster’s, 2015). The prefix uni- means “one or single” (Merriam-Webster’s, 2015). The prefix intra- means “within or between” (Merriam-Webster’s, 2015). The prefix inter- means “between: among: in the midst (Merriam-Webster’s, 2015). The prefix multi- means “many: much: more than two” (Merriam-Webster’s, 2015). The prefix trans- means “across: beyond” (Merriam-Webster’s, 2015).

Stokols et al. (2008) suggested that in a unidisciplinary approach, researchers from a single discipline work together to solve a research problem. In a multidisciplinary approach, researchers from different disciplines work independently in a sequential process to solve a research problem. In an interdisciplinary approach, researchers from several disciplines work jointly in an interactive process to solve a research problem. In a transdisciplinary approach, researchers from several disciplines work together to develop a conceptual framework that contributes to addressing a real-world problem. The goal of this last approach is to solve a research problem using an integrative process.

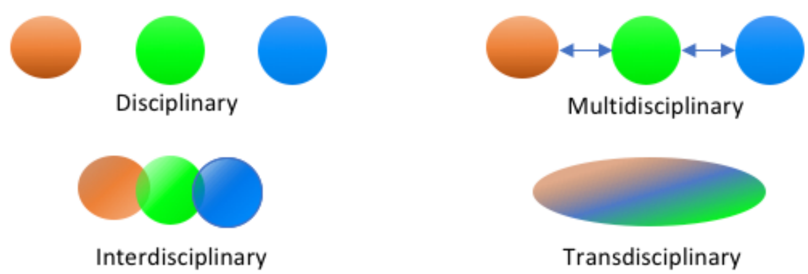


Figure 2.2: Curriculum integration approaches

Fogarty (1991), Drake (1993, 1998), and Stokols et al. (2008) studied the continuum of curriculum integration from different perspectives. The ideas of Drake (1991, 1998) and Stokols et al. (2008) regarding multidisciplinary approaches are similar to Fogarty‘s webbed approach, which stated that integration can be achieved by identifying thematic connections among several disciplines. An interdisciplinary approach resembles integrated models that emphasize the fact that concepts and skills are practiced in an integrated approach. Finally, the transdisciplinary approach resembles the immersed model, which emphasizes applying students' conceptual understanding to real-world problems.

As stated previously, depending on each specific situation, teachers can employ the approaches that fit with the context of learning and fulfill students' needs. Drake (1998) suggested, "One position is not superior to another: instead, different approaches are more appropriate than others according to the context in which they are used" (p. 19). To put it in another way, the integrated curriculum has been investigated; however, there is no consensus on the nature of designing and employing integration in science education. Nonetheless, the terms "curriculum integration," "interdisciplinary," "integrative approach," and "integrated curriculum" have similar meanings among researchers, and they are used interchangeably (Youm, 2007).

In this study, the researcher has adopted interdisciplinarity as a conceptual framework to build a research agenda that will identify ways for science teachers to employ integrative approaches. In addition, this research will explore teachers' perceptions of the challenges regarding the implementation of science, technology, engineering, mathematics integration, and STEM as a whole in science instruction.

THE NEED FOR CURRICULUM INTEGRATION:

Science, technology, engineering, and mathematics curricula are necessary to prepare students for the global economy of the 21st t century. Science researchers call for designing and employing integrative approaches among these disciplines in order to increase teachers' capacity to teach science content in a way that creates meaningful and conceptual understanding (PCAST, 2010) and enhances students' achievement (AAAS, 1993, 1998; ITEA, 2000; NRC, 2012).

The performance of Saudi Arabian students in STEM subjects is lacking compared to students' performance in other countries, particularly developed countries. Data from the Trends in International Math and Science Study (National Center for Education Statistics, 2015) demonstrate that in 2015, Saudi fourth-graders' average score in science was 390, which was lower than the average scores of students in 50 education systems and higher than the average scores of students in only two educational systems (see Appendix 1 and 2). Similarly, fourth-graders' average score in math was 283, which was lower than the average scores of students in 51 education systems and higher than just two countries (Stephens, Landeros, Perkins, & Tang, 2016).

Science scholars who advocate for curriculum integration in science teaching emphasize that teachers' practices should shift from teacher-centered approaches to student-centered approaches (Furner & Kumar, 2007). Similarly, Marklin and Wood (2007) advocate for interdisciplinary approaches, in which teachers from different backgrounds collaborate to design activities that embrace standards from different disciplines to support students' conceptual understanding.

Integrative approaches that include project-based learning provide experimental experiences that support learners' understanding by making learning more relevant, enhancing better retention, and promoting student success (Lee, 2007). Also, integrated curricula have been found to increase students' motivation and dedication to learning science (Furner & Kumar, 2007). This may be attributed to the fact that integrated instruction link students' practices to real-world problems (Youm, 2007), thereby stimulating students' thinking and productivity.

Differently, some studies suggest that curriculum integration may not be the remedy for the current educational problems that are facing science teachers practices and student learning. Studies such as McGlynn (2007) found that the expenditure directed to the implementation of integrated approaches to science teaching in Northern Ireland has not corresponded with the desired results. In fact, the implementation of integrative approaches requires extensive ongoing professional development programs that provide teachers with the content knowledge and pedagogical skills required for an effective integrative approach (Furner & Kumar, 2007). Therefore, it is critical to explore the challenges that may hinder science teachers from employing integrative approaches in science teaching, and then provide them with suitable curricula that include professional development programs that enhance the practices of integration. Studies should also be conducted to study the outcomes of students' learning and attitudes to determine whether integrative instruction is worth the expenditure on training and other costs.

The first step for enhancing STEM integration is improving science teachers' Pedagogical Content Knowledge (PCK). The following section will review research focused on strengthening and evaluating PCK among science teachers and how to employ PCK as an initial step for the implementation of integrative approaches in STEM education.

Science Content and Pedagogy Integration (SCPI):

In the early history, education scholars asserted the importance of teacher knowledge of subject matter and examined teachers' preparation based on content knowledge they had attained (Shulman, 1986). More recently, researchers have focused on pedagogical knowledge, such as understanding of teaching methods and the design of assignments and curricula (Ball & McDiarmid, 1990). Today, integrated curriculum scholars recognize that both content (subject matter) knowledge and pedagogical knowledge are essential for effective teaching and student learning (Reynolds,1992). Besides content and pedagogical knowledge, Shulman (1988) suggested that teaching expertise should be designed and evaluated based on PCK, as illustrated in Figure 2.3. PCK includes the knowledge of teaching methods with respect to subject matter content. Shulman conceptualized the PCK framework to examine the specialized knowledge that distinguishes the teacher from the content specialist and defined PCK as ‘‘an understanding of how particular topics, problems, or issues are organized, presented, and adapted to the diverse interests and abilities of learners, and presented for instruction’’ (Shulman, 1986, p. 8). In this study, the operational definition of PCK is:

> [T]he combination of knowledge and skills required for the tasks performed in teaching students effectively; it goes beyond knowledge of subject matter per se to include an understanding of difficulties students often have in mastering the subject and techniques for overcoming those difficulties. (Mislevy, Smith, & Gerard, 2015, p. 29)

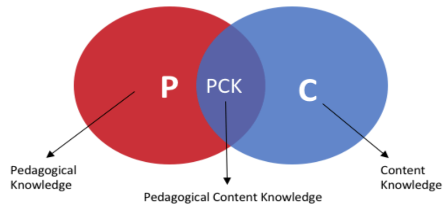


Figure 2.3: The two circles representing pedagogical and content knowledge

Cochran, DeRuiter, and King (1993) described and proposed a modification of Shulman's PCK framework based on a constructivist perspective. The essence of the constructivist approach can be summarized by two principles:

> Knowledge is actively constructed by the cognizing subject, not passively received from the environment; and coming to know is an adaptive process that organizes one's experiential world; it does not discover an independent, pre-existing world outside the mind of the knower"" (Lerman, 1989, p.221).

In addition, the constructivist perspective emphasizes the continuous integration of learning. This principle is derived from Piaget's theory of equilibration (Piaget, 1977), which demonstrates the inner sense of balance between old and new thoughts.

The modified model of pedagogical content knowing (PCKg) suggested by Cochran et al. (1993), shown in Figure 2.3, has been applied as a framework for teaching and teacher preparation. This model consists of four domains: 1) knowledge of subject matter, 2) knowledge of pedagogy, 3) knowledge of environmental context, and 4) knowledge of students. Based on the constructivist approach, this definition of pedagogical content knowing emphasizes that teachers must improve their content knowledge and pedagogical knowledge in the context of the other components: knowledge of environmental context and knowledge of students.

This modified framework requires conceptually integrated instruction across subject area courses besides the knowledge of other content, which "refers to a teacher's non-target content knowledge that is not directly related to the subject being taught (the target content)" (Cochran et al., 1993, p. 267). The inclusion of other content subject matter and conceptually integrated instruction can support curriculum integration and positively affect teachers practices and students' learning if these disciplines are being meaningfully integrated in terms of content and pedagogical knowledge. This model, illustrated in Figure 2.4, emphasizes the fact that science curricula (i.e. physics, chemistry, biology, and geology) are intertwined.

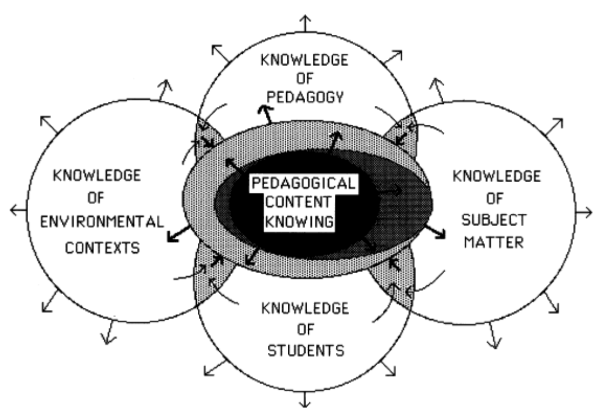


Figure 2.4: Developmental model of pedagogical content Knowing (PCKg). From Cochran, DeRuiter, & King, 1993, p.268.

To illustrate, the most effective way of preparing science teachers to teach through an integrated inquiry-based approach is to improve their pedagogical content knowledge and introduce them to authentic scientific investigations of real-world problems. Effective teaching requires a combination of “deep, flexible content knowledge, pedagogical content knowledge, and reflective practices” (Johnson, Peters-Burton, & Moore, 2015; p. 27). One challenge to implementing integrative instruction is that high school science teachers typically rate themselves as experts in their own content, but often believe they are underprepared in other disciplines (Berlin, 1994; Pang & Good, 2000; Venville, Wallace, Rennie, & Malone, 2002).

This first question of the present study aimed to explore science teachers’ perceptions of the challenges that hinder them from implementing science content and pedagogy integration based on the model of content knowing (PCKg) suggested by Cochran et al. (1993). This model was utilized because it incorporates the main components of integrative approaches used for exploring science teacher preparation and challenges in terms of science content and pedagogy integration in the context of the knowledge of environmental context and the knowledge of students. The next section will focus on the integration of technology in science education.

Technology Integration (TI):

The National Education Technology Plan (NETP, 2010), American Association for the Advancement of Science (AAAS, 1989, 1993), and National Research Council (NRC, 1996) recommended the integration of technology in all levels of the educational system to enhance science teachers’ practices and students’ conceptual understanding.

The term “technology” can be interpreted in several ways. These include the narrow view that focuses on just the use of educational technology (Cavanag & Trotter, 2008) and the comprehensive view that goes beyond the use of instructional technology to incorporate a broader body of technological knowledge, skills, and practices (Pringle, Dawson, & Ritzhaupt, 2015). Mitcham (1994) indicates that technology instruction comprises a range of activities that include designing, making, and using technology.

Technologies such as probes, computers, digital whiteboards, and smartphones have the potential to maximize students' knowledge from across multiple fields of study (Herschbach, 2009), promote students' understanding of science phenomena (NRC, 1996), successfully engage them in the learning process (Blumenfeld et al., 2000), and increase their mathematical and ecological understanding (Childress, 1996). As technologies become increasingly accessible, it is essential for science teachers to employ integrative approaches that illustrate and reinforce science concepts, promote student learning, and enhance the problem-solving and data analysis skills that are required for 21st -century learners. (Guzey & Roehrig, 2009; Slykhuis & Krall, 2011).

As stated previously, Shulman (1986) did not include technological knowledge as an explicit component of his PCK framework. Consequently, Mishra and Koehler (2006) elaborated on Shulman's work by adding technological knowledge (TK) to the pedagogical content knowledge framework (PCK), as illustrated in Figure 2.5. The new framework, Technological Pedagogical Content Knowledge (TPACK), represents teachers' expertise in content, pedagogy, and technology, as well as the intersections among these components.

The three major components of the TPACK framework include: (1) content knowledge (CK) which refers to the subject area understanding; (2) pedagogical knowledge (PK) which refers to the processes and methods of teaching and learning; and (3) technological knowledge (TK) which refers to knowledge about technologies for use in teaching and learning.

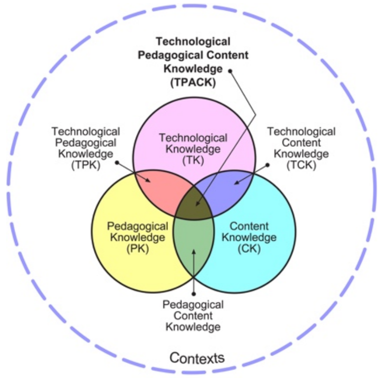


Figure 2.5: The seven components of the TPACK framework. From http://tpack.org.

Childress (1996) presented an example of how to integrate technology into science and mathematics using a disciplinary approach. The study investigated whether Technology, Science and Mathematics (TSM) curriculum integration improves students' abilities to solve technological problems. There were 17 eighth-grade technology education students who participated in designing and building a device that efficiently transforms wind energy into electrical energy. The TSM framework employed in this study aimed to integrate science and mathematics knowledge and skills to solve a technological problem. Students utilized several technologies as tools to create a device that transforms wind energy into electrical energy. Problem-solving methods were implicitly included to help students achieve their goals.

Petrosino, Sherard, Harron, and Stroup (2018) investigated 300 students' capacities to conduct a participatory agent-based modeling and simulation program, developed for STEM Education as part of the group-based cloud computing (GbCC).The study aimed to enhance learning technologies using GbCC and to develop pedagogical and technological teaching methods in a social and generative learning environment using GbCC Wolves-Sheep Predation model through NetLogo Web(https://ccl.northwestern.edu/netlogo). The findings of the study demonstrated that the integration of technology using the GbCC Wolves-Sheep Predation model enhanced students' conceptual understanding and motivation. Students were able to conclude that wolves are essential to keeping Yellowstone healthy. The main challenges that students experienced during this project were web site crashes and confusion about web site components. The study recommended that instructors provide students with sufficient time to explore and collaborate as they research the uses of modeling.

According to Childress (1996) and Petrosino et al. (2018), technology can be viewed as a tool or a process that aims to solve concurrent issues with an emphasis on social, economic, and scientific issues. In these studies, the engineering design process was not explicitly included, but the processes of designing and building the device were implicitly implemented. The following section will discuss the integration of engineering into science teaching, with an emphasis on the engineering design process as a practical connector between science, mathematics, and technology.

Engineering Integration (EI):

The Latin source of "Engineering" is ingeniare, which means design or device (Flexer, 1987). Despite the practical importance of engineering as a way to link science, mathematics and technology, the integration of engineering into science teaching has been neglected at the K-12 level for several decades (Misko, 2011). Katehi, Person, and Feder (2009) stated,

> K–12 engineering education has slowly been making its way into U.S. K–12 classrooms. Today several dozen different engineering programs and curricula are offered in schools around the country. In the past 15 years, several million K–12 students have received some formal engineering education, and tens of thousands of teachers have attended professional development sessions to learn how to teach engineering-related coursework (p. 5).

Many recent calls for the improvement of K-12 science teaching and learning have focused on the need for integrative approaches to fulfill the United States' needs for skillful science and engineering professionals to keep the nation competitive in the international arena. These calls have come from organizations including the Next Generation Science Standards (NGSS), National Science Foundation, National Research Council, and the National Academy of Science. The report Engineering in K–12 Education issued in 2009 by the National Academy of Engineering and the National Research Council (Katehi et al., 2009) provided a roadmap of engineering education in K–12 schools. Based on the report, the committee for the integration of engineering in K-12 schools established three fundamental principles: 1) engineering design should be emphasized in K-12 engineering education, 2) K–12 engineering education should incorporate essential and developmentally appropriate mathematics, science, and technology knowledge and skills, and 3) K–12 engineering education should promote engineering “habits of mind.”

Research supports this report’s first principle that engineering design, as a pedagogical approach, should be emphasized in K-12 engineering education. Several studies suggest that engineering instruction at the K-12 level should focus on Engineering by Design (Locke, 2009; National Research Council, 2009; Yaser, Baker, Robinson, & Robert, 2006) since this subject can provide the ideal STEM content integrator (NAE and NRC, 2009; NRC, 2012) and provides a way for teachers to begin incorporating engineering into science instruction. Although there are many models that describe the systemic steps of the engineering design process, most models begin with identifying the research problem and end with a final product that solves that problem, as illustrated by Figure 2.6.

The engineering design process varies from the scientific method. Scientists use the scientific method to create explanations and predictions about real-world phenomena, while the engineering design process is used to create realistic solutions for contemporary problems. Nadelson, Seifert, and Hendricks (2015) indicated that the NGSS practice standards for science and engineering consist of the following:

1. Asking questions (for science) and identifying the problem or objective (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information (p. 5)

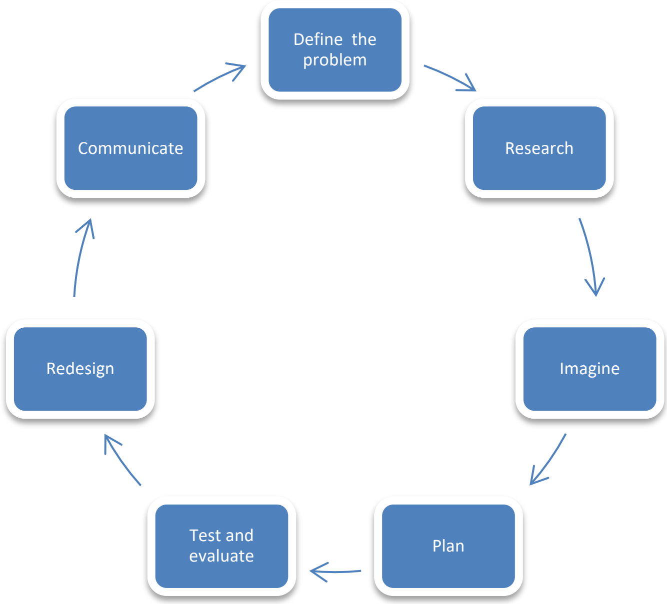


Figure 2.6: Engineering design process in engineering education

As reported by Standards for Technological Literacy: Content for the Study of Technology (ITEEA, 2000), the engineering design process has a number of characteristics: the design guides researchers clearly and explicitly, it has specifications and constraints, and it enables students to think systemically, with the ability to easily repeat any step and stage (Honey, Pearson, & Schweingruber, 2011). The expected outcomes of implementing engineering by design include promoting students' engagement with, and meaningful understanding of, different STEM disciplines. This engagement and understanding lead to increased student interest and achievement in science and mathematics (Velasquez-Bryant, 2006; Katehi et al., 2009), creative thinking, problem solving, and productive communication (Erwin, 1998; Katehi et al., 2009; Lewis, 2006; Roth, 2001; Thornburg, 2009). Also, the engineering design process develops students' awareness and understanding of engineering, enables them to practice engineering skills, enhances their technological literacy (Stohlmann, 2012), and prepares them to pursue a wide variety of STEM jobs (Baroks, Lujan, & Strang, 2012).

The report's second key principle is that K–12 engineering education should incorporate essential and developmentally appropriate knowledge and skills in the areas of mathematics, science, and technology. Science content and pedagogies such as experimentation and project-based learning support the implementation of engineering education due to the fact that science is the primary vehicle for the integrative process that embraces technology, mathematics, and engineering. In the area of mathematics, mathematical concepts and computational thinking such as algebra and geometry support the engineering design process. Moreover, technology as a tool or process contributes to creating the final product; provide opportunities for forward and reverse engineering; and take into account the social, environmental, economic, and ethical factors that affect decision-making with regard to the research problem (Katehi, Pearson, & Feder, 2012).

The committee on a Conceptual Framework for K-12 Science Education: Practices, Core Ideas, and Crosscutting Concepts (Framework) identifies seven crosscutting concepts that connect the concepts among STEM disciplines to help students create a conceptual understanding of a natural phenomenon. The seven crosscutting concepts (themes) presented in Chapter 4 (p. 84) of the Framework are as follows: 1) patterns, 2) cause and effect, 3) scale, proportion, and quantity, 4) system and system models, 5) energy and matter, 6) structure and function, and 7) stability and change.

The report's third principle is that K–12 engineering education should promote engineering "habits of mind." These habits of mind are highly crucial for 21st-century students. They include: (1) systems thinking, (2) creativity, (3) optimism, (4) collaboration, (5) communication, and (6) ethical considerations (Katehi et al., 2012).

Many initiatives have been introduced to support the inclusion of engineering in science teaching. Two of the most prominent examples are Project Lead the Way (PLTW) and Engineering is Elementary (EIE).

Project Lead the Way (PLTW) began working in 1999 in cooperation with High Schools That Work (HSTW) to implement an educational career that would equip students with knowledge and skills to help them pursue postsecondary studies related to engineering. Schools that adopt Project Lead the Way (PLTW) are asked to enroll their students in specific mathematics and science curricula and to fulfill the following additional requirements: 1) require teachers to attend intensive professional development programs that enhance their knowledge of instructional methods and student assessment, 2) designate laboratories with the equipment and instructional materials that meet the curricular standards, and 3) provide staff (such as guidance counselors) with professional development programs that help them prepare students to pursue further education in engineering-related fields (Bottoms & Uben, 2007). The outcomes of this project revealed that students who enrolled in two or more PLTW courses achieved remarkably higher scores in reading, mathematics, and science on a NAEP-referenced assessment than other career/technical students (Bottoms & Anthony, 2005)

A similar program called Engineering is Elementary (EiE) began in 2003. This program is based on the idea that children are born engineers; they love discovering how things work, designing, assembling, and disassembling. The project aims to 1) enhance students' technological knowledge, 2) improve teachers' practices regarding the integration of engineering and technology in teaching, 3) enhance engineering education among elementary schools in the United States, and 4) conduct studies that enhance engineering education at the elementary school level. The EiE team determined the program's essential knowledge and skills, which include technological and engineering literacy, engineering fields, troubleshooting, and solving engineering problems using the engineering design process (as illustrated by Figure 2.7).

Figure 2.7: The EiE engineering design process.

In summary, many reports and initiatives advocate for the integration of engineering in science teaching using the engineering design process. The engineering design process requires an interdisciplinary approach that incorporates knowledge from science, mathematics, and technology and provides opportunities to locate the intersections and build connections among STEM disciplines in order to enhance science teachers' practices and students' learning. The next section will discuss ways how to integrate mathematics into STEM education.

Mathematics Integration (MI):

Mathematics is central to science, engineering, and technology education. Students studying science including physics, chemistry, biology, and geology are required to effectively integrate mathematics into science instruction. Common Core State Standards for Mathematics (CCSSM) and the Next Generation Science Standards (NGSS) have called for deeper connections among the STEM subjects

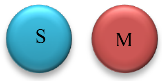
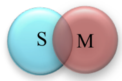
Studies' findings indicate that incorporating mathematics skills into science teaching provide students with convinced rationales to learn mathematics and clearly see the intersections among STEM disciplines (Burghardt and Hacker 2004). Tillman et al. (2014) found that students achieved better on mathematical content assessments when they have opportunities to incorporate engineering design and prototyping solutions using innovative technology such as 3D printing technology. Williams (2007) pointed out to the importance of contextual teaching since it can promote conceptual understanding of mathematics skills due to the fact that students do not just want to get mathematical problem solved, but "also they need to learn mathematics in the first place; they want to know how mathematics is relevant to their lives" (p. 572). McBride and Silverman (1991) assured that such integration between science and mathematics are essential for the following reasons:

> Science and mathematics are closely related systems of thought and are naturally correlated in the physical world; science can provide students with concrete examples of abstract mathematical ideas that can improve learning of mathematics concepts; mathematics can enable students to achieve deeper understanding of science concepts by providing ways to quantify and explain science relationships; science activities illustrating mathematics concepts can provide relevancy and motivation for learning mathematics. (pp. 286-287)

The integration of mathematics into science teaching can help students learn through different modes; however, achieving this integration in practice remains a key challenge for science researchers and teachers. There is currently no consensus among educational scholars regarding how best to implement curriculum integration, including mathematics integration, within science teaching. However, research findings do provide several conceptual models that offer educators guidance on how to integrate mathematics into science instruction (Fogarty, 1991; Huntly, 1998; Hurley, 2001; Lonning & DeFranco, 1997).

Huntley (1998) suggests a theoretical framework for conceptualizing science and mathematics integration using three terminologies: intradisciplinary, interdisciplinary, and integrated (as illustrated in Table 2.1). An intradisciplinary curriculum focuses on the integration of concepts from only one discipline, such as mathematics or science. An interdisciplinary curriculum focuses on the implicit integration of more than one subject matter; however, the disciplinary focus varies based on the purpose of the intended integration. Huntley uses the analogy of "foreground/background" to conceptualize this interdisciplinary approach: "the discipline that is to be mastered is foreground (i.e., of primary importance), and the discipline used to establish relevance or context is background (i.e., of secondary importance)" (p. 321). In contrast, an integrated curriculum focuses on making explicit connections among two or more disciplines by giving the same attention to each one; the disciplines thus play synergistic roles in students' comprehension of a scientific phenomenon.

Table 2.1: Matrix of Intradisciplinary, Interdisciplinary, and Integrated Education

Integration Type		Focus of Instruction		Connections Between Disciplines During Instruction	
		One Discipline	More than One Discipline	One Discipline	More than One Discipline
Intradisciplinary		√		√	
Interdisciplinary		√		√	
Integrated			√		√

Note. Modified from Huntley, 1998, p. 321

Huntley suggests a practical conceptual framework based on her findings on science and mathematics integration combined with those of the Education Development Center (1969). Five integrative approaches (Figure 2.8) have been defined to address various interaction models based on the degree of overlap between the content and pedagogy of science and mathematics: a) mathematics for the sake of mathematics; b) mathematics for the sake of science; c) mathematics and science; d) science for the sake of mathematics; and e) science for the sake of science. The intradisciplinary approach includes teaching mathematics for the sake of mathematics and science for the sake of science. Teaching mathematics for the sake of mathematics focuses on teaching mathematics courses that presents mathematics as a formal system, while teaching science for the sake of science focuses on teaching courses in which science subjects and methods are dominant. When it comes to the interdisciplinary approach, mathematics with science and science with mathematics are employed based on the degree of overlap between the two disciplines. Science with mathematics emphasizes mathematics as a tool for solving a scientific problem, while mathematics with science focuses on utilizing science to create context and relevance for a mathematics problem. On the other hand, the integrated approach which includes both mathematics and science emphasizes a high level of coordination between the two disciplines to explain a real-world phenomenon

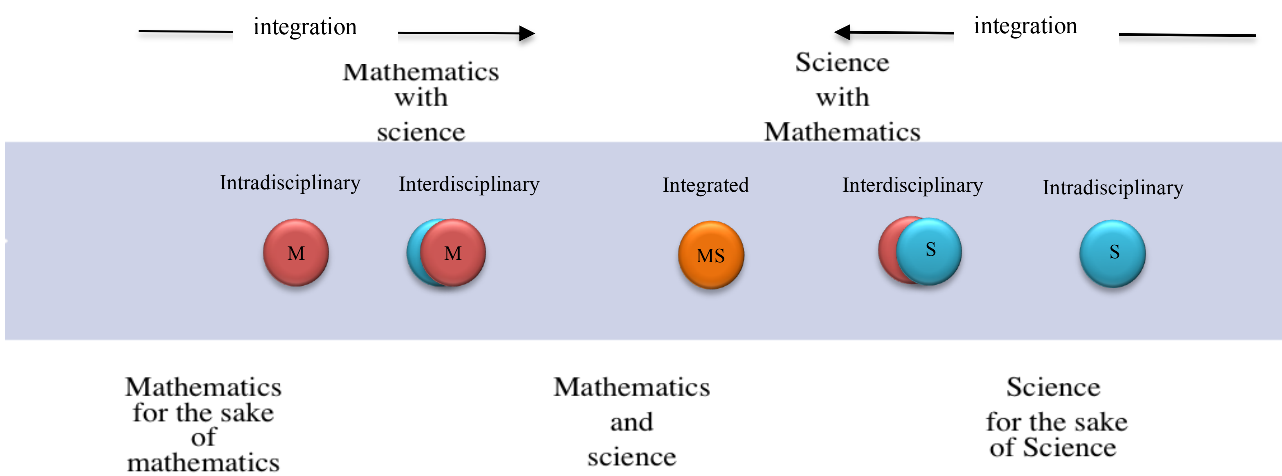


Figure 2.8: Mathematics and Science Continuum. Modified from Huntley, 1998, p. 321.

Davison, Miller, and Miller (1995) described five different aspects of the integration of science and mathematics: 1) discipline-specific, 2) content specific,3) process, 4) methodological, and 5) thematic integration. Discipline-specific integration involves incorporating two or more branches of a specific discipline, such as mathematics or science. This kind of integration is recommended and used widely when students are required to learn basic concepts, skills, and procedures related to one subject matter. Content-specific refers to selecting specific curriculum objectives (one from science and one from mathematics) in order to solve a research problem. Process integration refers to solving research problems using real-world projects and activities. Process integration includes the implementation of scientific processes and mathematics standards in teaching science as shown in Table 2.2. Methodological integration refers to the ability to integrate learning theories and teaching approaches. For example, science teachers can conduct a scientific inquiry approach such as learning cycle with mathematics that developed under constructivist theory to solve real-world problems. Thematic integration is similar to cross-cutting integration where one theme is selected so that it becomes the medium for integrating concepts from several disciplines. For example, when using oil spills as a theme, surface area for each oil spill can be calculated using mathematics skills, while environmental issues can be investigated through science including chemistry, biology or other disciplines.

Table 2.2: The Process of Integration

Scientific Processes	Mathematics Standards
Observing	Problem Solving
communicating	Communication
using space relationships	Reasoning
Using time relationships	Estimation
Classifying	Number sense and numeration
Using numbers	Whole number operations
Measuring	Whole number computation
Predicting	Geometry and spatial sense
Inferring	Measurement
Controlling variables	Statistics and probability
Interpreting data	Fractions and decimals
Testing hypothesis	Patterns and relationship
Defining operationally	
Experimenting	

Note. From Davison, Miller, and Miller,1995, p. 228

One challenge that science researchers might encounter while studying mathematics integration into science teaching is defining the mathematical knowledge and skills that science teachers require in order to effectively incorporate this integration into their daily practices. The Common Core State Standards for Mathematics (CCSSM) include mathematical standards that mathematicians and other STEM professionals can use for research and problem solving (Nadelson et al., 2015). These standards are: “Making sense of problems and persevere in solving them; reasoning abstractly and quantitatively; constructing viable arguments and critique the reasoning of others; modeling with mathematics; using appropriate tools strategically; attend to precision; looking for and make use of structure; and looking for and express regularity in repeated reasoning (Common Core State Standards Initiative, 2010, p. 6-8). The high school standards specify the mathematics that all students should study, as illustrated by Table 2.3. These standards include number and quantity, algebra, functions, modeling, geometry, and statistics and probability

Table 2.3: *Common Core State standards for High School Mathematics*

High school standards	Subgroup
Number and Quantity	The Real Number System, quantities, the complex number system, and vector and matrix quantities.
Algebra	Seeing structure in expressions, arithmetic with polynomials and rational expression, creating equations, reasoning with equations and inequalities.
Functions, modeling	Interpreting functions, building functions, linear, quadratic, and exponential models, trigonometric functions
Geometry	Congruence, similarity, right triangles, and trigonometry, circles , expressing geometric properties with equations, geometric measurement and dimension, modeling with geometry
Statistics and probability	Interpreting categorical and quantitative data, making inferences and justifying conclusions, conditional probability and the rules of probability, using probability to make decisions.

Students need mathematics skills in order to be successful in other disciplines, particularly science disciplines. Research findings indicate that students' performance in science can be predicted by their performance in mathematics and vice versa (Barnes, 1978; Lloyd, 1977; Udom, 1987). Leopold and Edgar (2008) demonstrate the dependency of chemistry success on what they call "math fluency"

> One of the first college science classes in which students may consistently encounter this difficulty [fluency in mathematics] is second-semester introductory chemistry. In the second semester, the qualitative as well as quantitative aspects of topics such as kinetics, chemical equilibrium, entropy, and free energy, acid-base chemistry, and electrochemistry are expressed in language liberally seasoned with conversational mathematics (Leopold & Edgar, 2008, p.724).

Miles Pickering (1975) found a strong correlation between students' average scores in mathematics and introductory chemistry classes at Columbia. Also, Wiesman (1981) conducted a study of mathematics readiness test among prospective students in chemistry. Students experienced difficulties related to mathematics skills while studying chemical subjects such as Avogadro numbers, converting within the metric system, writing formulas, balancing equations, expressing solution concentrations, etc. The researcher used a test to evaluate the mathematical abilities of students in grades 11-12 who were planning to take chemistry. She listed six mathematical skills that can be measured as a prediction of students' success in chemistry:

- Performing mathematical computations when they are given an algebraic formula.
- Converting word expressions into mathematical ones.
- Recognizing equalities and inequalities.
- Interpreting data graphically.
- Distinguishing between direct and inverse proportions.
- Solving multistep problems by:
  - Perceiving the problem to be solved.
  - Identifying the mathematical principles involved.
  - Performing the appropriate mathematics (Wiesman,1981, p.3).

In summary, an interdisciplinary approach to integrated mathematics and science teaching has been widely advocated and used in different ways throughout the science and mathematics education research. The outcomes of such integration are beneficial for making science and mathematics more relevant to students' lives. The following section will discuss STEM integration as a whole.

PHILOSOPHY OF STEM EDUCATION

The integration or coordination among Science, Technology, Engineering and Mathematics, known as STEM education, is a growing area in both developed and developing countries. This area aims to prepare students for the global economy of the 21st century (Yakman & Lee, 2012). According to Chesky and Wolfmeyer (2015), "STEM" began as "SMET," standing for science, mathematics, engineering, and technology. In 1990, the National Science Foundation (NSF) neologized this acronym in order to emphasize the importance of these four interconnected subjects.

There are many perceptions and definitions of STEM education; however, most of these different definitions share an emphasis on transferring teachers' practices from lecture-based teaching to student-centered learning, using inquiry-based, project-based, and problem-based learning to implement integrated instruction (Barrows, 1994; Barrows & Tamblyn, 1980; Silver, Duncan & Chinn, 2007). Consequently, professional communities of science educators have supported the movement toward integrated STEM education (AAAS, 1998; ITEA, 2000; NAE, 2004, 2005; NRC, 1996, 2012).

Researchers argue that in order to prepare for careers in the 21st century, students must be able to think across disciplinary boundaries and attain a deeper understanding of scientific phenomena (Berry et al., 2005; Stepien & Gallagher, 1993). To that end, schools' leaders must consider adopting integrated instruction that eliminates the artificial boundaries between subjects. It has been argued that students who engage in interdisciplinary practices achieve a deeper conceptual understanding than students who do not (Zeidler, 2002).

STEM integration comprises four components; science, technology, engineering, and mathematics. The National Research Council (2014) defines these components as follows:

> **Science**: is the study of the natural world, including the laws of nature associated with physics, chemistry, and biology and the treatment or application of facts, principles, concepts, or conventions associated with these disciplines. Science is both a body of knowledge that has been accumulated over time and a process—scientific inquiry—that generates new knowledge. Knowledge from science informs the engineering design process.
>
> **Technology** while not a discipline in the strictest sense comprises the entire system of people and organizations, knowledge, processes, and devices that go into creating and operating technological artifacts, as well as the artifacts themselves. Throughout history, humans have created technology to satisfy their wants and needs. Much of modern technology is a product of science and engineering, and technological tools are used in both fields.
>
> **Engineering**: is both a body of knowledge—about the design and creation of human-made products—and a process for solving problems. This process is design under constraint. One constraint in engineering design is the laws of nature, or science. Other constraints include time, money, available materials, ergonomics, environmental regulations, manufacturability, and reparability. Engineering utilizes concepts in science and mathematics as well as technological tools.
>
> **Mathematics**: is the study of patterns and relationships among quantities, numbers, and space. Unlike in science, where empirical evidence is sought to warrant or overthrow claims,

> claims in mathematics are war- ranted through logical arguments based on foundational assumptions. The logical arguments themselves are part of mathematics along with the claims. As in science, knowledge in mathematics continues to grow, but unlike science, knowledge in mathematics is not overturned, unless the foundational assumptions are transformed. Specific conceptual categories of K–12 mathematics include numbers and arithmetic, algebra, functions, geometry, and statistics and probability. Mathematics is used in science, engineering, and technology. (National Research Council, 2014, p. 14)

Looking at the STEM in terms of implementation, it can be used as a guide for improving the nation's economic future by preparing students for 21st-century careers at a macro level. It can be employed as a guide for planning science and mathematics lessons in terms of finding the connections among different disciplines. Researchers at the National Research Council (2014) describe how integrated lessons might be applied in STEM schools:

> …Developing a precise definition of integrated STEM education proved to be a challenge for the committee because of the multiple ways such integration can occur. It may include different combinations of the STEM disciplines, emphasize one discipline more than another, be presented in a formal or informal setting, and involve a range of pedagogical strategies. … . The term integrated is used loosely and is typically not carefully distinguished from related terms such as connected, unified, interdisciplinary, multidisciplinary, cross-disciplinary, or transdisciplinary. Defining integrated STEM education is further complicated by the fact that connections can be reflected at more than one level at the same time: in the student's thinking or behavior, in the teacher's instruction, in the curriculum, between and among teachers themselves, or in larger units of the education system, such as the organization of an entire school (p.23).

THEORETICAL FOUNDATIONS OF STEM INTEGRATION

The ideas of psychological scholars such as Piaget, Dewey, Bruner, Dienes, and others have influenced the establishment of integrative approaches, such as science, technology, engineering, and mathematics (STEM). They contributed to providing theoretical foundations for active learning and maximizing connections across disciplines for solving real-life problems.

These scholars call for experiential education, concrete manipulatives, and multiple representations. Dewey (1966) called for integration and made an argument against teaching subjects in isolation from one another. Also, he assured that students should build a personal connection to their experiences based on practice. Similar to Dewey, Dienes (1960) founded the theory of multiple embodiments that focus on studying the connections among several manifestations of a concept. He acknowledged that concrete experience with making connections among different disciplines is crucial for abstracting mathematical structure.

As a means of extending Dienes work, Lesh (2007) suggested a translation model, which is commonly known as the Lesh Translation Model (LTM). Figure 2.9 illustrates that LTM consists of five nodes indicating distinct representations, or embodiments and the translations between or within the representation. The LTM is not only a model of conceptual understanding, but also a systemic framework for guiding students' learning and understanding.

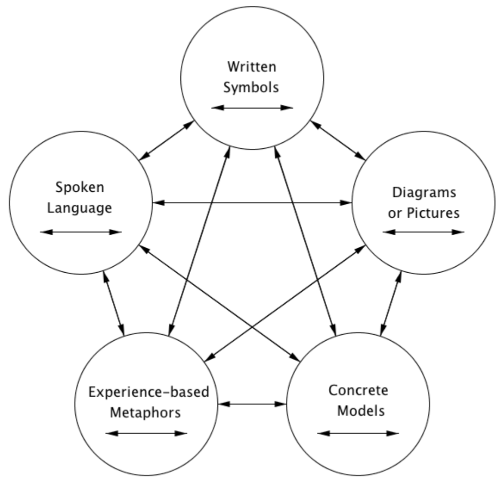


Figure 2.9: The Lesh translation model. Adapted from Glancy and Moore, 2013.

Integrated STEM education aims to build connections among different disciplines so that students can develop a more meaningful understanding of scientific phenomena (Furner & Kumar, 2007; Moore, 2013; Wang, Moore, Roehrig, & Park, 2011; Moore, Guzey, Roehrig). Researchers have recently begun to examine several implications and frameworks for integration. For example, the integration of science, technology, engineering, and mathematics (STEM) (Ashby, 2006). Another example that enhance art skills through STEM is science, technology, engineering, art, and mathematics (Eger, 2013). Moreover, integrating reading with these other frameworks leads to the creation of a STREAM curriculum (Root-Bernstein, 2011).

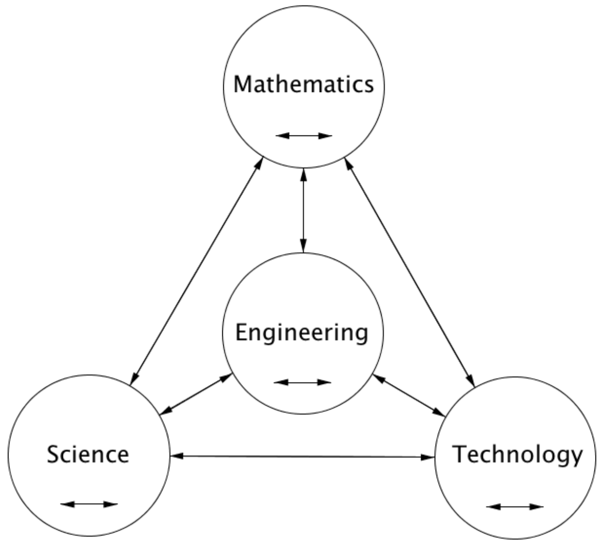


Figure 2.10: Lesh translation model combining STEM disciplines

The Lesh Translation model Combining STEM Disciplines (Figure 2.10) can serve as model for integrated STEM education (Figure 2.10). This model highlights the importance of studying a combination of individual disciplines along with the translations that connect them with each other. Glancy and Moore (2013) summarize the characteristics of STEM Translation Model as follows:

> …. Integrated STEM lessons and activities are at their best when they encourage students to make translations between the ideas of multiple disciplines… Lesh Translation Model provides a way of thinking about individual concepts that span multiple STEM disciplines… Furthermore, a teacher who is considering concepts from the perspective of the STEM Translation Model will perceive student difficulties differently. (pp. 18-19)

In addition to theories developed by Dewey, Bruner, Zoltan and Dienes theories, STEM education can be grounded within the situated cognition theory (Putnam & Borko, 2000) and

Vygotsky's Social Development Theory (Green, 2014). Situated cognition theory emphasizes the fact that people's skills can be constructed and linked to their environment, context, activity, and culture in which they were learned (Robbins & Aydede, 2009). Likewise, STEM researchers argue that authentic and relevant learning takes place when it is grounded within a situated contextual environment (Kelly, Knowles, 2016).

Vygotsky's Social Development Theory is considered one of the foundations of social constructivist theories in teaching and learning. Vygotsky (1978) argues that social learning comes before development. He stated, "every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level; first, between people and then inside the child" (Vygotsky, 1978, p.36). In an integrative approach, science and mathematics teachers generate learning environment with essential instructional materials so that contribute to authentic and conceptual understanding (Green, 2014) as situated learning –using an original instruction— promotes students' interests and academic performance (Wehlage,1993). Authentic instruction consists of five strands: "(1) higher-order thinking, (2) depth of knowledge, (3) connectedness to the world beyond the classroom, (4) substantive conversation, and (5) social support for student achievement" (Green, 2014, p. 103).

CONCEPTUAL FRAMEWORK FOR THE INTEGRATION OF SCIENCE CONTENT & PEDAGOGY, TECHNOLOGY, ENGINEERING, AND MATHEMATICS

Science, technology, engineering, and mathematics (STEM) are not just considered intellectual enterprises. These disciplines are also essential for development and well-being in all areas of our lives, such as medicine, agriculture, medicine, and commerce. Many recent calls for improving teaching and learning have focused on making science and mathematics more relevant for students through enhancing integrative approaches. The following conceptual framework (shown in Figure 2.11) asserts the importance of building implicit and explicit connections among STEM disciplines. This practical framework aims to guide policymakers and educators to include the concept of integration in science standards and textbooks. It can also be utilized to improve teachers' daily practices and build professional development programs that enhance integration in science education.

This conceptual framework used in the present study is based on several previously developed models. These include the Pedagogical Content Knowledge (PCK) model developed by Shulman (1986, 1987), the modified model of Pedagogical Content Knowing (PCKg) developed by Cochran et al. (1993), the Technological Pedagogical Content Knowledge (TPACK) framework developed by Koehler, Mishra, and Yadav (2004). In addition, this framework is informed by curriculum integration approaches, the Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas and other studies (NRC, 2012), the Next Generation Science Standards (NGSS), the Common Core State Standards for Mathematics (CCSSM, 2010), and several initiatives for supporting engineering and technology integration in science education.

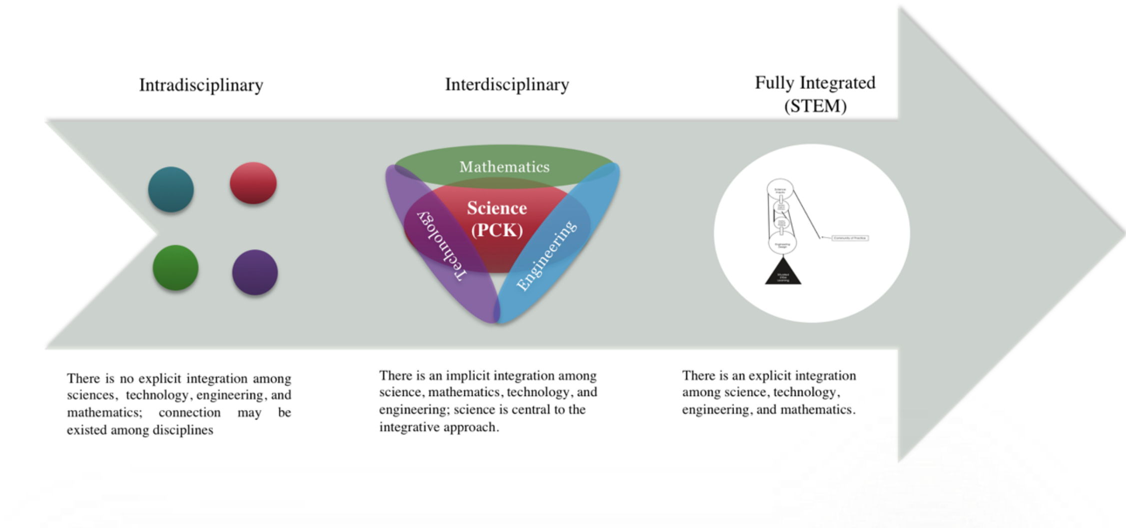


Figure 2.11: The Framework for the integration of science, mathematics, engineering, and technology. Adapted from Barakos, Lujan, & Strang, 2012; Todd, Kelley, 2016.

The framework illustrated in Figures 2.11 and 2.12 describes the integration continuum through intradisciplinary, interdisciplinary, and transdisciplinary (fully integrated) approaches. The intradisciplinary approach focuses on the integration of only one discipline, such as science or mathematics. The interdisciplinary approach emphasizes implicit connections among several disciplines such as science and mathematics, science and technology, or science and engineering; however, science is considered the central focus of this integrative approach. The transdisciplinary (fully integrated) model aims to expose students to explicit integrative approaches that support meaningful, real-world understanding of all STEM subjects.

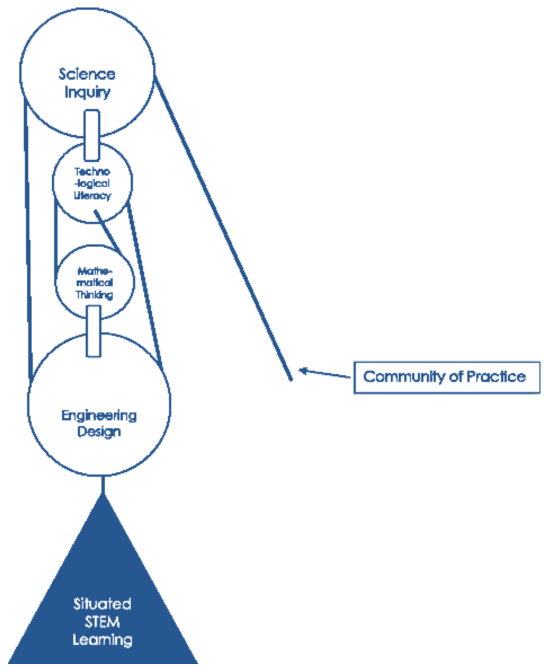


Figure 2.12: The framework of STEM integration (Todd, Kelley, 2016, p.4)

The integration of science and mathematics, science and technology, science and engineering have been previously discussed individually; however, the framework for STEM integration as a whole remains ambiguous and ill-defined in science education. Todd and Kelly (2016) proposed a conceptual framework for integrating STEM as a whole within secondary education, particularly at the high school level. This framework, as illustrated in Figure 2.12, consists of a block and tackle of four pulleys to lift a load. The load in this framework signifies "situated STEM learning," which is grounded in situated cognition theory. The block and tackle pulley system represent five components: 1) engineering design, 2) scientific inquiry, which requires high level of content and pedagogical knowledge. Inquiry is considered the "integral part of teaching and learning in science" (Sampson, Gleim, 2009, p. 465), 3) technological literacy,4) mathematical skills, and 5) a community of practice that enhances collaborative science and engineering practices.

The researcher utilized the frameworks illustrated in Figures 2.11 and 2.12 to guide the design and implementation of the quantitative and qualitative investigation of integrative approaches at the high school level. The primary goal of this study was to provide descriptive and analytical accounts of the widely advocated, yet largely unexplored, phenomenon of integrated STEM education in high school classrooms. Specifically, this study examined perceived challenges to the implementation of integrated STEM education in Saudi Arabia, where many teachers still practice traditional approaches to teaching science. Integration in this context means that mathematics and science are taught together, irrespective of traditional disciplinary boundaries. In addition, technology is integrated into science teaching as a tool and process as well. Engineering design process is the main component of the integration of engineering into science teaching, which aims to construct connections among all other disciplines.

In summary, the study utilized this framework illustrated in Figures 2.11 and 2,12 to build a research agenda for investigating the most important challenges that hinder high school science teachers in Saudi Arabia from conducting integrative instruction using interdisciplinary and transdisciplinary (fully integrated) approaches. The researcher focused initially on investigating high school science teachers concerns related to the integration of science teachers perceived challenges with regard to the integration of science and content pedagogy, then the study focused on exploring their perceived challenges with regard to the integration of technology, engineering, and mathematics into science instruction.

The Need for STEM integration in Saudi Arabia

Saudi Arabia has realized that it is necessary to develop a road map for educational reform. For this purpose, "Vision 2030 and the Transformation of Education in Saudi Arabia" (2016) was designed to transfer the Saudi economy from an over-reliance on oil revenues to a more investment-based model. The strategic objective of the National Transformation Program (NTP) includes several components. One of the most important components is improving students' learning and teachers' practices by achieving the following: (1) improving teachers' Continuous Professional Development (CPD) programs, (2) improving the learning environment, (3) improving curricula and teaching methods, (4) improving students' values and core skills, and (5) educating students to address national development requirements and labor market demands, such as STEM careers required for the future.

The current reform efforts in Saudi Arabia resemble reform efforts in the United States. For example, in the United States, the Next Generation Science Standards (NGSS) and Common Core State Standards-Mathematics [CCSS-M]) have called for more emphasis on STEM as a crucial component of economic development (Nadelson et al., 2015). Similarly, "Vision 2030 and the Transformation of Education in Saudi Arabia" calls for improving the educational system and providing teachers with practical skills that help students improve their values and core skills in order to fulfill the nation's need for STEM professionals.

The report "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Future" (National Academies, 2006) indicates that American students' performance in science and mathematics is lower than that of students in some other countries. Therefore, there is an urgent need to improve instruction so that students in the United States can be better prepared for careers in the 21st century (NRC, 2007). Improving STEM education may help solve several problems that affect teaching and learning. The committee indicates that:

> …[STEM] has become a focus of intense concern within the business and academic communities. The domestic and world economies depend more and more on science and engineering. But our primary and secondary schools do not seem able to produce enough students with the interest, motivation, knowledge, and skills they will need to compete and prosper in the emerging world (NRC, 2007, p. 94)

There is an urgent need to implement integrated STEM education in American public schools, as STEM disciplines currently are taught in separate "silos." Teaching science in this way hinders students from generating meaningful and conceptual understanding. Studies indicate that teaching STEM disciplines through integrated approaches would be more in line with the nature of STEM disciplines as they occur in the students' real live (Wang, 2011).

Researchers argue that an integrated approach to STEM education has several benefits: it is child-centered, it improves higher-level thinking abilities and problem solving, it enhances students' retention (Fllis & Fouts, 2001), it provides opportunities for more relevant and less disconnected instruction, and it offers more simulative experiences for students (Furner & Kumer, 2007). In order to succeed in the technology-rich 21st century, students need to be equipped with a solid STEM education (Holdren, 2013), and this aim can best be achieved by using innovative teaching methods and strategies that focus on building connections among several subjects. Currently, science and mathematics are taught in a separated fashion, where teachers still practice traditional approaches to teaching science and mathematics. Integration in this context means that mathematics and science should be taught together, irrespective of traditional disciplinary boundaries. In addition, technology should be integrated into science teaching as a tool and process. Engineering design process is the main component of the integration of engineering into science teaching.

CONSIDERATIONS FOR STEM INTEGRATION

Integrated STEM education requires several skills and resources that are essential for empowering students to investigate solutions for real-world problems through designing, modeling, and experimentation. Zemelman, Daniels, and Hyde (2005) list ten effective practices for teaching mathematics and science in an integrated approach:

> Using of manipulative and hands-on learning; cooperative learning; discussion and inquiry; questioning and conjectures; using justification of thinking; writing for reflection and problem solving; the use a problem-solving approach; Integrating technology; teacher as a facilitator; and use of assessment as a part of instruction (Stohlmann, 2012, p. 29).

Other studies (such as Jacobs 1989; Lipson, Valencia, Wixson, & Peters, 1993; Leung, 2006) referred to different factors that needed to be considered in an integrative curriculum and instruction. Lake (1994) summarized them as follows:

- Common definitions of terms (such as theme, strand, or outcome)
- Available resources
- Flexibility in scheduling
- Subjects and concepts that will be integrated
- Links between integration and broader outcomes
- Curricular scope and sequence
- How evaluation will occur
- Parent and community support
- Themes that promote the transfer of learning and connections
- Team planning time that is used to exchange information about content, students, special areas of teacher expertise, and teaching methods. (p. 8)

The studies focusing on STEM integration draw attention to the fact that a wide variety of requirements are necessary for successfully implementing STEM integrative approaches. Requirements, for instance, include qualified teachers, the availability of resources, flexible scheduling, and collaboration among teachers.

TEACHERS' SELF-EFFICACY:

According to Social Cognitive Theory (SCT), human performance can be significantly regulated and predicted by recognizing people's forethought. SCT also indicates that social behavior change can be self-controlled. If people believe that they can accomplish a job or assignment, they become more determined to complete it successfully (Bandura, 1986). This theory defines four key factors that influence human practice and behavior: 1) perceived self-efficacy, 2) outcome expectations, 3) goals, and 4) observed impediments and facilitators, as illustrated in Figure 2.13.

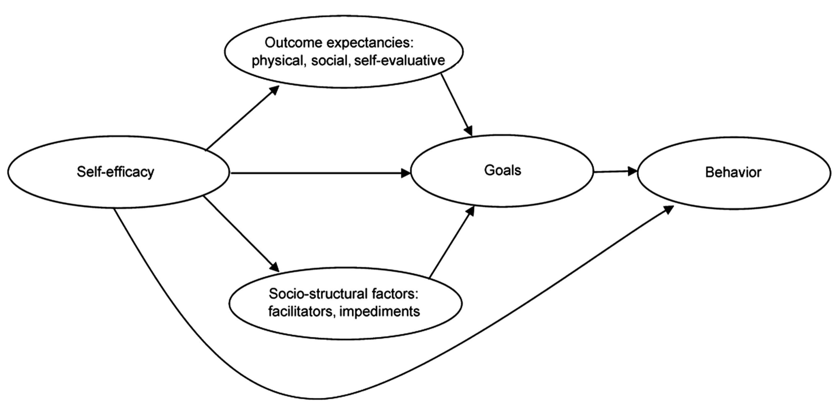


Figure 2.13: An illustration of social cognitive theory. Adapted from Conner & Norman,2005).

The first factor that affects human behavior is perceived self-efficacy, which is the most crucial component of social cognitive theory. Self-efficacy has been an interest of researchers over the past two decades (Dalgerty & Coll, 2006). Self-efficacy refers to “teachers’ belief in [their abilities] to organize and execute the courses of action required to accomplish a specific teaching task in a particular context” (Tschannen-Moran, Hoy, & Hoy, 1998, p. 233). The construct consists of two dimensions: personal teaching efficacy and general teaching efficacy. Personal teaching efficacy refers to a teacher’s feeling of confidence concerning teaching skills and abilities, while general teaching efficacy refers to a teacher’s feeling of being able to control the learning environment despite other external factors, such as students’ intelligence quotient (IQ) and school conditions (Gibson & Dembo, 1984). Together, personal and general teaching efficacy constitute the basis of a teacher’s belief about his or her abilities and skills; this belief can positively or negatively influence teachers’ practices and, in turn, affect students’ learning.

Teachers' self-efficacy beliefs have been widely utilized as a determining factor of teachers’ abilities and students' academic achievement. Teachers who demonstrate a high awareness of efficacy tend to implement innovative instructional strategies, participate in professional development programs, and emphasize student-centered instructional strategies (Lockman, 2006; Tschannen-Moran, Hoy, & Hoy, 1998). Also, several studies have found a positive correlation between teachers’ beliefs, teacher’s performance, and students’ performance (Skaalvik & Skaalvik, 2007). Thus, when self-efficacy is high among teachers, constructive impacts on teachers’ practices and students’ performance can be predicted (Guo, Piasta, Justice, & Kaderavek, 2010)

The second factor that influences human behavior based on Social Cognitive Theory (SCT) is outcome expectancy, defined as a person's prediction about their own outcomes for a specific action (Bandura, 1986). Besides self-efficacy and outcome expectancies, Social Cognitive Theory (SCT) include goals and socio-structural factors such as facilitators and impediments.

The current study aimed to investigate Saudi Arabian high school science teachers' perceived challenges regarding the integration of science, technology, engineering, and mathematics in science teaching. Recognizing these challenges—using the constructs of social cognitive theory. particularly science teachers' self-efficacy and socio-structural factors that facilitate or impede integrative approaches to science teaching—will help researchers and teachers overcome these challenges and pursue integration in science instruction.

BARRIERS TO INTEGRATED STEM INTEGRATION

The integration of science, technology, engineering, and mathematics is a complicated process that requires prerequisite and skills related to content knowledge, teachers' personality, and pedagogical knowledge. Researchers (Park, Cramer, & Ertmer, 2004; Park & Ertmer, 2008; Asghar, Ellington, Rice, Johnson, & Prime 2012) have classified the barriers that impede STEM integration into two categories: internal and external challenges.

The internal challenges encompass issues related to teachers' perceptions, capacity, and knowledge. High school science and mathematics teachers may encounter several difficulties related to subject matter content, technology, engineering design, applying mathematical skills, and limitations in pedagogical skills (Park et al., 2004; Park & Ertmer, 2008).

External challenges include lack of adequate time allocated for each discipline to apply project-based learning, shortages in instructional technologies, excessive reliance on standardized tests for evaluating students and teachers, reliance on measuring low level goals instead of scientific skills, and lack of sufficient skills for assessing integrative approaches (Maxwell, Bellisimo, & Mergendoller, 2001; Meier, Hovde, & Meier, 1996). Moreover, it is hard for science and mathematics teachers to implement integrative approaches while applying centralized textbooks and for separate STEM disciplines that guide teachers to follow specific standards in a limited period of time (Nadelson et al., 2015). Park, Lee, Blackman, Ertmer, Simons, & Belland, (2005) revealed other challenges, such the lack of administrative support with applying integrative STEM approaches.

Concerning the challenges that science teachers may encounter while implementing science content and pedagogy integration using integrative approaches that depend on scientific inquiry instruction, Roehrig (2004) conducted a study of the difficulties that secondary school science teachers experienced when implementing inquiry-based lessons as part of a science-focused induction program. This program, Alternative Support for Induction Science Teachers (ASIST), was developed to enhance inquiry-based instruction at the secondary school level. Fourteen beginning high school science teachers participated in the program. Researchers utilized open-ended interviews, semi-structured interviews about teaching beliefs, monthly classroom observations, and a questionnaire about the nature of science to explore science teachers' beliefs about implementing inquiry-based approaches in science teaching. The findings of the cross-case comparison of the 14 beginning science teachers revealed five main challenges that hinder them from conducting inquiry-based instruction: 1) understanding of the nature of science and scientific inquiry, 2) content knowledge, 3) pedagogical content knowledge, 4) teaching beliefs, and 5) concerns about management, student ability, and motivation.

Science teachers who embrace current views of the nature of science instruction (for example, those who support student-centered pedagogies) tend to practice inquiry-based instruction, while those who held fewer student-centered beliefs tend to implement more traditional methods or structured inquiry lessons. Concerning content knowledge, teachers who specialize in one discipline do not conduct as much project-based learning and tend to follow a prescribed curriculum. On the other hand, having a strong content knowledge is not sufficient for implementing integrative approaches using an inquiry-based science instruction. Such instruction also requires strong content knowledge, student-centered beliefs, and a contemporary view of the nature of science. Interestingly, Roehrig's (2004) study found that the most critical challenges perceived by science teachers were low student ability and motivation toward science.

Concerning technology integration, research findings indicate several constraints that hinder science teachers from using technology integration in science instruction. Many teachers resist the integration of technology into their instruction due to internal and external factors. Minshew and Anderson (2015) conducted a comprehensive study of external and internal barriers that influence technology integration and examined how these barriers affect teachers' perceptions of their own pedagogical practices. This study utilized the TPACK framework, which describes teacher knowledge in three critical domains: content, pedagogy, technology, and the interactions between these domains. The study included 100 students and four teachers from Caldwell Middle School. Data were collected using multiple sources including semi-structured interviews with teachers, field notes and observations, teacher lesson plans, and video data. The findings of the study revealed a number of internal and external barriers that influence teachers' integration of technology into their instruction.

The internal barriers stem from teachers themselves. They include: 1) technology knowledge, 2) perception of technology, 3) perception of practice versus actual practice, and 4) value of technology.

Concerning technology knowledge, many teachers expressed concern that they lacked the skills required to employ technology in science teaching. They attributed this low level of the acquisition of knowledge to three reasons: teachers do not know much about the availability of computer applications, they lack the time required to learn these applications, and they need professional development programs that enhance the integration of technology in science teaching.

Lack of sufficient knowledge about the integration of technology into science teaching might lead to creating a negative perception of technology integration. For example, a teacher indicated that she “found much value in paper-and-pencil practice, something she did not necessarily see in either the Smartboard or the iPad” (p. 351). One teacher in this study utilized a smartboard as a projector screen, disregarding its other distinctive advantages. In addition, some teachers’ perceptions of technology integration were found to differ from their actual practice due to the effect of the circle of influence. For example, one teacher stated that she used a number of technologies in her classroom; however, when researchers observed her actual classroom practices, they found that she just used her laptop and smartboard as a projector along with Microsoft Word processing program. Finally, the value of technology integration is considered one of the most influential factors for teachers’ practice. Teachers who are involved in content-specific professional development programs are more likely to integrate technology into science instruction. In this study, teachers were asked to integrate iPads for 45 minutes a day during a 60-minute class period without paying attention to the pedagogical effects of this integration. The focus was mainly only on technology and the time spent on each lesson.

The external barriers described by participants included lack of internet connectivity and lack of professional development programs that fit teachers' needs. Administrative factors, including policies required for the acquisition of the application and lack of curriculum differentiation, also influenced technology integration in science teaching.

Bingimals (2009) conducted a meta-analysis regarding the barriers to teachers' integration of information and communication technology (ICT) in science instruction. The literature review found several classifications of technology integration barriers. Studies have classified these barriers into extrinsic and intrinsic (Ertmer, 1999), material and nonmaterial (Pelgrum, 2001), or teacher-level and school level (Becta, 2004) Bingimals' study focused on teacher-level and school-level barriers.

The teacher-level barriers include the following:1) lack of teacher confidence, 2) lack of teacher competence, 3) resistance to change and negative attitudes. some teachers lack confidence and feel anxiety about failure because they lack the technological knowledge and skills required for conducting technology integration. Unfortunately, in developing countries such as Saudi Arabia, studies have indicated that science teachers are not well-prepared to integrate technology into science teaching (Al-Alwani, 2005; Almohaissin, 2006). Finally, teachers resist the integration of technology into science teaching due to their attitudes or perceptions about integration. For example, some teachers do not use computers' applications and other technologies because they do not believe that the integration of technology is beneficial.

Bingimals' study (2009) also indicated several school-level barriers that hinder technology integration. These barriers are: 1) lack of time required for preparing lessons and locating computers, 2) lack of opportunities for conducting professional development programs, and 3) lack of access to resources and equipment, such as computers and Internet connections. Al-Alwani (2005) found that one of the most significant barriers facing Saudi science teachers is lack of Internet access and hardware devices.

Unlike *technology integration*, *engineering integration* has received little attention at the national level (Misko, 2011). Engineering education has encountered a number of challenges at the K-12 level. Specifically, Ayyash and Black (2014, p. 75) outlined six challenges: 1) lack of widely accepted vision, 2) lack of formal engineering education programs, 3) lack of informal support to engineering education, 4) uneven treatment of engineering key ideas, 5) the gender gap between girls and boys, and 6) technical difficulties.

Similarly, Siew, Goh, and Sulaiman (2016) investigated the difficulties that high school students encounter while engaging in engineering design process (EDP) activities and what suggestions they offered to overcome these challenges. The participants comprised 89 tenth grade science stream students. Female students accounted for 59.6% of the total of the sample. Data were collected using mixed methods, including qualitative and quantitative approaches, after participants completed a single group intervention STEM-EDP challenge program. Students participating in this program faced challenges pertaining to time, knowledge, skills, and the nature of the assigned activities.

Time allotted for implementing the activities was one of the essential challenges mentioned by students. Students claimed that building a model from a stick is time-consuming and the time allotted for the activity was not sufficient. The second challenge was related to student knowledge and skills. The study found that students had difficulty applying prior scientific skills and knowledge in new situations; they had “weak basic concepts of science” (Siew et al., 2016, p. 489). Finally, the activities were too difficult, requiring higher-level thinking. Since time was the biggest challenge, students suggested that extending the time would effectively help achieve the activity’s goals.

Formal engineering education programs provide teachers with the most current engineering knowledge; however, Katehi et al. (2009) noted that most K-12 teachers do not have an engineering degree. Also, opportunities for dictated engineering professional development programs are “few and far between,” and “the qualifications for engineering educators at the K-12 level have not been described” (Katehi et al., 2009, p. 8). Moreover, the study indicated that there are no pre-service initiatives that aim to provide schools with qualified engineering teachers in their fields. Therefore, the study indicated that there were a need to equip STEM teachers with engineering skills that would help them engage students in meaningful STEM activities.

Providing all students with engineering skills gives them experience with designing and building. Rogers and Portsmore (2004) developed an effective platform to teach engineering in schools. This study indicated that the most critical factors for successful teachers are curiosity, enthusiasm for learning, self-confidence, ability to find answers, and ability to test the validity of solutions. It also indicated that girls and boys are different in terms of applying engineering to real-life experience. In general, "girls tend to design before building, whereas the boys start building before they have thought about designing" (p. 23). This gender difference calls for developing curriculum and teaching methods that are appropriate for each gender.

Research has also identified challenges to the *integration of mathematics* into science instruction. Huntley (1998) explored barriers that hinder science teachers from integrating science and mathematics in middle school classrooms. Students were asked to conduct activities that correspond with the mathematics/science continuum shown in Figure 2.8. In science with mathematics integration, students participated in a laboratory investigation aimed to develop their understanding of density using an integrative approach that emphasizes mathematics as a tool for solving a scientific problem. In this activity, students were asked to use a single beam balance to weigh 10 pennies (w=30 g), and then students were asked to find the weight of each penny using mathematics (w=3). Then the teacher wrote down the density equation (d=m/v) to give students opportunities to think about how to find the volume of each penny. Using a graduated cylinder, students added the 10 pennies to the cylinder to calculate the volume of the 10 pennies (V= 4 ml). Then students were able to calculate the volume of each penny using the average equation (V1= 0.4 ml). The teacher asked the students to apply the formula of density, and they used this formula to find the density of each penny (d= 3/0.4= 7.5 g/ml). Finally, students recognized when an object sinks or floats based on the density of the object and liquid. The four teachers who participated in this study articulated some factors that they considered critical in their shift from traditional approaches to an integrated approach to mathematics and science instruction. These factors are shown in Table 2.4

Table 2.4: *Teachers' Perceptions of Factors Affecting Curricular Integration*

First: Factors that Facilitate Integration of Mathematics and Science	
1) Strong collegial support	Similar professional goals
	Similar personal characteristics
	Similar belief about curriculum and pedagogy
2) Strong and flexible administrator support for team teaching	
	Scheduling of classes
	Proximity of classrooms
	Scheduling of students
	Joint planning time
2) Financial support	
	Acquisition of materials
	Professional development
Second: Factors that limit Integration of Mathematics and Science	
1) Time	
	Coordination of students
	Combined disciplinary content
	Planning for instruction as a team
	Coordination of student assessments
2) availability of instructional models	
3) availability of appropriate curricular materials	
4) system-wide achievement expectations	

Note. From Huntley ,1998, p.327.

Watanabe and Huntley (1998) investigated the challenges perceived by Maryland Collaborative for Teacher Preparation (MCTP) instructors while implementing mathematics and science integration courses. Mathematics and science courses implemented in MCTP were consistent with the interdisciplinary and constructivist approaches. A qualitative study was implemented using semi-structured interviews with 18 instructors from both science and mathematics backgrounds. The participants described a number of challenges that negatively affect the integration of science and mathematics in science teaching. The first factor that prevents teachers from integrating mathematics to science is the lack of sufficient time required for conducting activities that enhance integration. The second factor mentioned by an instructor is that students lack the desire to integrate mathematics into science. One instructor reported that a student "flat out said he does not like math, does not want to do it, and wants to avoid it, and please don't do any math in this course" (p. 23). Another teacher stated that students lack sufficient preparation and readiness to integrate mathematics and science.

When it comes to STEM integration lessons as a whole, Stohlmann, Moore, and Roehrig (2012) investigated challenges faced by middle school teachers. This study explored factors that must be considered for teachers to effectively implement integrated STEM education and examined the main factors that affected implementation of the integrated curriculum Project Lead the Way (PLTW). This study was implemented in a large suburban sixth- to eighth-grade middle school in a Midwestern state. The participants consisted of four PLTW teachers with different subject matter backgrounds: science, mathematics, and technology. All students in this school were enrolled in integrated STEM curriculum and PLTW classes. The data were collected using field notes, classroom observations of each teacher using a structured observation protocol, and informal conversational interviews. A constant comparative method was utilized to analyze the data.

The results of this study were divided into three themes: "teaching, teachers' comfort level, and materials" (p. 31). The four teachers focused on having students collaborate instead of using a teacher-based approach. However, teachers had some difficulties related to the time required for each activity and struggled to guide students' learning. In terms of comfort level, many teachers did not feel confident while teaching PLTW. With regard to materials, students realized that technology could involve many different tools and instruments, including digital technologies. Interestingly, the study indicated that it is not necessary to always include all STEM disciplines to implement integrative STEM education. However, Hershback (2011) argues that teachers who only integrate science and mathematics are merely providing their schools with the "illusion of STEM programming" and that "the STEM acronym has become shorthand for science and mathematics education only" (p. 6).

Asghar, Ellington, Rice, Johnson, and Prime (2012) examined teachers' initial conceptions of Problem Based Learning (PBL), their response to an interdisciplinary STEM-PBL professional development experience, and their perceptions of what facilitates or hinders implementation of interdisciplinary STEM-PBL in their schools. For collecting data, researchers used observation notes, focus group discussions, individual interviews with 12 participants, workshop feedback, and evaluation forms. Results demonstrated the value of PBL as an approach to facilitate conceptual understanding of the content knowledge and help students make connections between different disciplines using an engineering-based approach. Teachers who participated in this study believed that STEM integration could not work without implementing extensive plans that fit into curricula, as "most schools have domain-specific science courses like biology, chemistry, physics" (p. 101). Participants expressed positive attitudes toward PBL because it focuses on real-world problems. In regard to obstacles that teachers encounter while applying PBL, participants indicated that it is challenging for them to coordinate different skills in a specific period of time, as they are responsible for teaching specific subjects based on the curriculum. Moreover, teachers pointed out the difficulty of developing STEM problems. The main sources of resistance can be traced to external and internal factors. The external factors include "the structure of schools, the curriculum, and the way education is organized and evaluated at the state level" (p. 106), while internal factors encompass "teachers' beliefs, capacity, knowledge, and skills" (p. 92) required for integration.

El-Deghaidy and Mansour (2015) investigated science teachers' perceptions regarding STEM education and its interdisciplinary nature. The research aimed to identify the factors that facilitate and hinder integrative approaches. The researchers administered a qualitative instrument using focus group interviews to discuss middle school science teachers' perceptions of STEM education in Riyadh, Saudi Arabia. The findings of the study indicated that all the teachers expressed concerns regarding their lack of readiness to apply STEM instruction in science classrooms. The study found that teachers have a positive attitude in terms of promoting 21st century skills, such as thinking skills, collaboration, problem-solving, and research skills, that could affect students' future and careers. Also, teachers suggested that collaborating with other teachers from different disciplines would promote teachers' knowledge and integrative education in their schools.

With regard to *science teachers' professional development needs and concerns*, multiple studies have been conducted to investigate teachers' challenges and difficulties while teaching science. Mansour, Alshamarani, Al Dahmash, and Al quadah (2013) investigated science teachers' needs for both pedagogical and content knowledge as an attempt to determine the professional development needs perceived by science teachers and science supervisors in Saudi Arabia. The population targeted by the study consisted of 2,701 Saudi science teachers and 66 science supervisors located in four districts: Jeddah, Alzulfi, Alkharj, and Aqewah. A total of 499 science teachers and 66 science supervisors participated. The researchers developed a questionnaire consisting of 39 items related to two domains:(1) science content knowledge needs and (2) pedagogical knowledge and skills needs.

The results revealed strong needs in the following areas: nature of science, scientific inquiry, and modern physics. The science teachers also expressed needs in subjects related to physics, such as electricity and magnetism. In terms of pedagogical needs and skills, the ten top-ranked needs expressed by teachers were: "teaching science through field trips, scientific visits, developing creative thinking among students, teaching science for gifted students, developing science concepts among students, integrating technology into science instruction, planning for teaching, scientific inquiry instruction, teaching science for special needs students, instruction-based problem solving, and using concept mapping." Also, the results indicated that there were no statistically significant differences that could be attributed to the dependent variables such as teaching experience, school level taught, gender, location, and major.

In the same context, Alshaye (2014) investigated the status of teachers' professional development associated with the project of "Development of mathematics and science curriculum for public education in Saudi Arabia," based on the perspective of professional development program providers, who supervise the implementation of the project and provide support for teachers. Data was collected from 202 supervisors using a questionnaire developed for this purpose. The findings indicated that the professional development plan developed by the Ministry of Education was not systemically planned to ensure conducting professional development programs that fulfill teachers' actual needs. Also, research findings revealed that science teachers' professional development needs are estimated at a "high degree." The most needed areas reported by teachers were:1) enhancing experimentation and manipulative activates in science classrooms; 2) integration technology into science teaching. On the other hand, teachers expressed less need for the professional development programs in the following areas: classroom management and integrating science and mathematics with other disciplines. The study indicate that science teachers lack high enthusiasm in involving in professional development programs. This lack of interest might be attributed to the quality of professional development introduced to science teachers so that they were not able to fulfill teachers' needs and concerns.

In an attempt to investigate science teachers' perspectives and needs about Continuing Professional Development (CPD) Programs, Mansour, El-Deghaidy, Al shamrani, and Aldahmash (2014) explored science teachers' perceptions of CPD programs as well as these teachers' pedagogical, professional, and scientific content needs. The study aimed to explore teachers' perspectives with regard to their participation in continuous professional development programs. The study utilized mixed methods: an open-ended questionnaire survey and an interview. The population of the study included science teachers in three regions; Makkah, Taif, and Majmah. 1,052 teachers (46% males and 36% females) participates in the study. The results revealed that science teachers expressed the greatest need for improvement with regard to conducting constructivist approach activities in science teaching, such as hands-on application. Table 2.5 summarized science teachers' professional needs and concerns in four themes and 12 subthemes:

Table 2.5: *Professional Development Needs Reported by Science Teachers*

Main categories	Sub-themes
Pedagogical knowledge	Deepening pedagogical content knowledge
	Responsiveness to the new science curricula reforms
	Classroom management
	Assessment
	Accommodating students' individual differences
Content knowledge	Deepening subject content knowledge
	Practical skills
	Cultural issues related to science education
Information and communication technology (ICT)	Technological pedagogical content knowledge (TPACK)
Professional Skills	Self-development and learning how to learn
	Teacher as a researcher
	Leadership

Note. From El-Deghaidy et al., 2014.

The King Saud University Excellence Research Center of Science and Mathematics Education (2016) administered an extensive study to evaluate the project of "upgrading mathematics and natural science of general education in Saudi Arabia." The study evaluated several dimensions of this project: the study evaluated the quality of the project's implementation in the field and examined the quality of the project outputs by evaluating the academic achievement of students at the end of all three academic levels (elementary, middle, and high school). The study was conducted by five research teams comprising a total of 116 researchers and 244 research assistants. The research team developed several instruments, such as textbook analysis forms, classroom observation forms, interviews, and questionnaires. Research findings indicated that professional development specifications were achieved at a medium level. Furthermore, students' achievement was classified as "beginner".

The results of the studies conducted in Saudi Arabia indicate that science teachers still express great need for professional development programs that enhance teaching and learning. The lack of effective professional development program negatively affected teachers' interests in the current professional development programs, and ultimately students' performance and attitudes toward science.

Summary:

The integration of science, technology, engineering, mathematics, and STEM as a whole has been widely advocated yet remains mostly unexplored, especially in developing countries. This chapter has provided an overview of curriculum integration including STEM integration, with an emphasis on the conceptual framework that guides the present study. This conceptual framework was utilized to guide the design and implementation of a quantitative and qualitative investigation of the perceived challenges that science teachers encounter while conducting integrative approaches to STEM instruction at the high school level.

This chapter has also introduced two essential facts from the literature focusing on curriculum integration. The first fact is that science, technology, engineering, and mathematics are correlated and intertwined, so "we do not see how education in any one of them can be undertaken well in isolation from the others" (AAAS, 1993, pp. 321-322). The second fact is that there is a lack of consensus on defining clear frameworks for STEM integration in K-12 instruction; however, several possible models and frameworks have been introduced. Which is the best? Drake (1998, p.19) answered, "One position is not superior to another: instead, different approaches are more appropriate than others according to the context in which they are used".

Teachers' success in implementing these models depends on a number of factors, such as teachers' knowledge and skills, time, and resources. Consequently, the scientifically literate person is "aware that science, mathematics, [technology], and engineering are interdependent human enterprises with strength and limitation" (Rutherford & Ahlgren, 1990, p. ix). Recognizing the strength and limitation of each model eventually enhances teaching using integrative approaches. The next chapter will focus on the methodological approach utilized to design the study, collect, and analyze the data.

Chapter Three: Research Design and Methodology

The quality of education particularly science and mathematics education in Saudi Arabia has been a national topic for many years. Several national reports and studies expressed deep concerns about science teachers' practices and students' performance in science and mathematics national and international assessments. Therefore, this study aimed to investigate Saudi Arabian high school science teachers' concerns (perceived challenges) related to the implementation of integrative approaches in science instruction. Investigating science teachers' concerns regarding STEM integration will help educators and policymakers design and build professional development programs that enhance teaching practices and then student learning.

RESEARCH QUESTIONS:

The questions that guided the study were:

1. What are the most important challenges and needs perceived by Saudi Arabian high school science teachers in relation to the integration of:
    a. Separate domains within the STEM, including science content and pedagogy, technology, engineering, and mathematics?
    b. STEM as a whole?
2. Are there differences of perceived challenges and needs in terms of gender and geographic region?

RESEARCH DESIGN

A mixed methods approach was adopted to investigate Saudi Arabian high school science teachers' challenges when they implement STEM integrative approaches in science teaching. The researcher utilized an explanatory sequential mixed methods design (Quantitative + Qualitative = Explanation) (Creswell, 2014). Mixed methods design help researchers broaden and deepen the understanding of the complexity of the research questions (Creswell, 2017; Teddlie & Tashakkori, 2009; Greene, 2007). The underlying assumption for selecting a mixed method is that using mixed methods enhances the understanding of the research problem than using either method individually (Creswell & Clark, 2017). Also, this mixed method helped the researcher combining the data from both quantitative and qualitative approaches to draw inferences to the broader population

The mixed methods sequential explanatory design consists of two stages as illustrated in Figure 3.1 and Appendix 4. The first stage is conducting a quantitative measurement questionnaire (numeric) and then followed by the second stage, a qualitative research technique (textual data). The second stage aims to explain and elaborate on the quantitative data obtained in the first stage. In other words, the qualitative method builds on the quantitative method in order to provide the researcher with full comprehension of the research problem. Also, the qualitative method helps the researcher refine and explain the quantitative results especially when unexpected results emerge from the quantitative data (Morse, 1991).

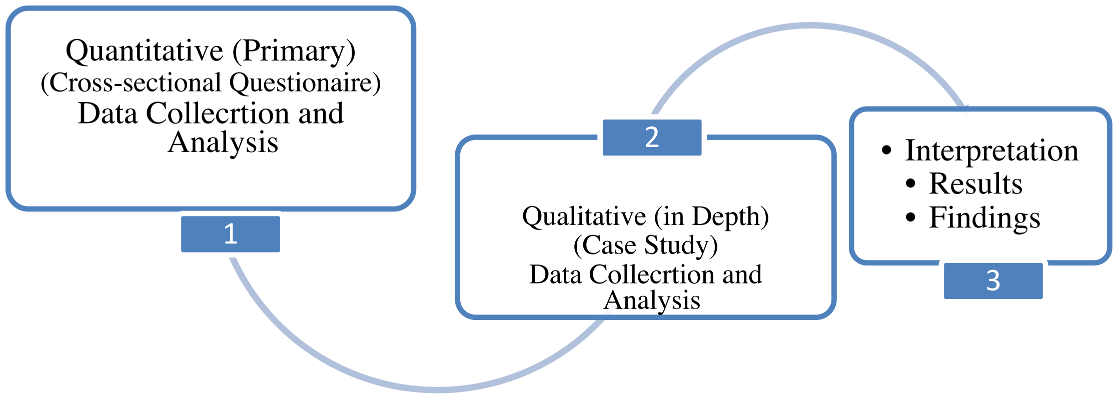


Figure 3.1: Explanatory sequential mixed methods design

In the first stage of the research, quantitative data were collected using a cross-sectional survey design (see Appendix 5) from high school science teachers in the six geographic regions of the Kingdom of Saudi Arabia (Makkah, Tabuk, Aseer, Hail, Kahrj, and Zulfi). Cross-Sectional survey designs were utilized to obtain data that describes attitudes, perceptions, or beliefs of different people in a specific time (Creswell, 2017). The researcher, using the results of the questionnaire, can draw inferences to the broader population as the online survey generates a high percentage of participants (Creswell, 2017). There are several advantages of using online survey research. It allows access to people whom it would difficult to reach in a short time, and it also saves money compared to paper surveys (Wright, 2005).

For the qualitative method, data were collected from twenty science teachers using an interview protocol (See Appendix 6) from the regions of Makkah and Zulfi. These regions were selected due to the availability of a coordinator for each region. Those coordinators helped the researcher work with teachers and conduct the interviews with female teachers. Female teachers were interviewed by female educational supervisors due to cultural reasons.

PARTICIPANTS AND SAMPLING

Participants and sampling in the quantitative stage

This stage targeted high school science teachers in the six educational regions (Makkah, Tabuk, Aseer, Hail, Kahrj, and Zulfi) in Saudi Arabia. These regions were mainly selected because they are part of the partnership program with The Excellence Research Center of Science and Mathematics Education (ECSME). Also, these regions reflect the geographic and diverse views of teachers across the Kingdom of Saudi Arabia as illustrated in Figure 3.2.

At first, the researcher contacted the ECSME in Saudi Arabia in order to help the research get the approval letters for administering the study in the six regions (See Appendix 11, 12,13, and 14). After selecting regions, the center recruited coordinators for each region to help the researcher administer the study with science teachers in each region.

For sampling, the researcher combined the criteria and random sampling strategies. At first, criteria sampling was used to determine the regions that should be part of the study. The random strategies included selecting science teachers who participated in each region. By the end of the study, 1,207 out of 4,360 certified science teachers responded to the questionnaire as illustrated in Tables 4.1 and 4.2.

The percentage of teachers holding a master or doctoral degree among participants was 5.55% and 0.35%, respectively. The experience of the teachers in the profession ranged from less than one year to more than 16 years. The percentage of teachers participating in professional development focusing on technology and engineering integration was 41.54% and 8.7%, respectively.

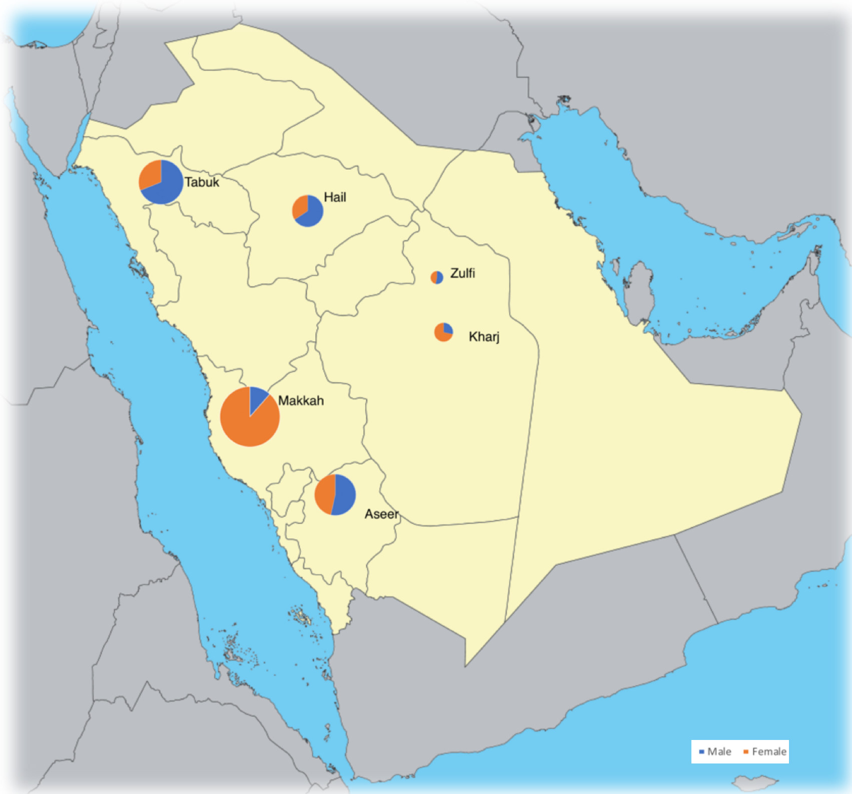


Figure 3.2: The Geographic distribution of science teachers

Participants and Sampling in the Qualitative Stage

In the qualitative case study, two regions were included in the case study. These are the regions of Makkah and Zulfi. They were selected due to the cooperation of the coordinators in these regions. The participants in each region were purposefully selected based on their degrees in subject area. The researcher interviewed eight male science teachers, while assigned female educational supervisors interviewed female science teachers in the two regions. The total number of teachers participating in the qualitative method was 20 certified science teachers as illustrated in table 4.28.

INSTRUMENT DEVELOPMENT

The Quantitative Questionnaire

Given that no scale existed in the field of STEM integration that focuses on investigating the challenges that may hinder high school science teachers from conducting integrative approaches, the researcher combined a group of surveys that aim to investigate each domain individually. The final entire questionnaire originally consisted of four scales in addition to the demographic questions (see Appendix 5). All these scales are comprised of closed-ended questions. Closed-ended questions are more efficient due to their ease of analysis (Seliger, Shohamy,1989).

The first modified scale that focuses on *science content and pedagogy integration* was adapted from the technological pedagogical content knowledge (TPACK) pathways. Eleven out of twelve items were adapted from (Koh, Chai, and Tasi, 2013), including Content Knowledge (3 items; $\alpha = 0.91$), Pedagogical Knowledge (5 items; $\alpha = 0.94$), and pedagogical content knowledge (3 items; $\alpha = 0.94$). The second scale, *Technology Integration,* consists of eight items. This scale was adapted from Teacher Efficacy and Attitudes Toward STEM Survey (T-STEM). The instrument was developed by the William and Ida Friday Institute for Educational Innovation located on the campus of North Carolina State University (8 items; $\alpha = 0.90$). The third scale, *Engineering Integration*, was newly generated in the study based on the finding of the literature that consider engineering design process the main component of engineering integration in STEM instruction. This scale consists of 12 items. These items focus on how science teachers evaluate themselves with regard to the implementation of engineering design process in science teaching.

The fourth scale, *Mathematics Integration*, was adapted and modified from several resources, such as Weisman (1981); and reviewing current Saudi science textbooks. Since the researcher did not find a reliable scale that evaluate science teachers STEM integration as a whole, the researcher included this domain in the qualitative method approach.

All the four domains' items asked participants to rate their level of agreement on 5-point Likert scale (1 = *strongly agree*, 2 = *agree*, 3 = *neither agree nor disagree*, 4 = *disagree*, and 5 = *strongly disagree)*. The majority of the questions were positively worded (e.g., I have sufficient knowledge about science). However, a few questions were negatively worded (e.g., I find it difficult to implement engineering design approach in my teaching). The questions negatively worded were assigned value in reverse order: 1 = *strongly disagree*, 2 = dis*agree*, 3 = *neither agree nor disagree*, 4 = *agree*, and 5 = *strongly agree*.

In addition to the closed-ended questions, and to gain further insight and a higher-level exploration (Gillham, 2000), participants had the opportunity to respond to five open-ended questions related to the professional development programs attended in each domain: science content and pedagogy, technology, and engineering integration (see Appendix 5). The objectives of all closed-ended and open-ended questions were to explore high school science teachers' perceived challenges with regard to the integration of science content and pedagogy, technology, engineering, and mathematics.

Qualitative Protocol

The interview protocol consisted of five domains. These domains are (1) science content and pedagogy integration, (2) technology integration, (3) engineering integration, (4) mathematics integration, and (5) STEM as a whole. The researcher included the fifth domain, STEM integration as a whole, due to the lack of finding a reliable quantitative scale that evaluates science teachers perceived challenges while conducting STEM instruction. Each domain consisted of three sub-questions. The overall total of the interview protocol questions was 20 questions. Each domain of the interview protocol corresponded to one of the research questions (see Appendix 6).

The questions were constructed to extract teachers' perception about how they integrate and conceptualize science content and pedagogy, technology, engineering, mathematics, and STEM as a whole in science teaching. Additionally, the subsequent questions elicited the challenges that teachers may encounter while conducting integrative approaches based on their conceptualized framework they viewed for each domain. This protocol does not just elicit teachers' challenges, but also elaborates on teachers' outcomes from the quantitative method. The qualitative interview helped the researcher comprehend the research results stemmed from the quantitative methods particularly in the areas of the integration of technology and engineering in science teaching.

These instruments, including the questionnaire and the interview protocol, went through rigorous procedures in order to obtain valid and reliable results. They were developed based on the literature review, the conceptual framework illustrated in Figures 2.11 and 2.12 , pilot participants, the feedback from experts in the United States and Saudi Arabia (see Appendix 7), statistical results, and the dissertation committee.

Having constructed the research questionnaire and the interview protocol in the English language, the researcher translated them into the Arabic language (see Appendix 8 and 9) since it is the main language of teachers, students, and curricula in the K-12 level. However, the translated instruments can produce several problems such as the loss of connation especially while dealing with new concepts, for instance integration, technology, and STEM. This problem may threaten validity and reliability of the research. This predicted problem was addressed through the following: 1) translation and back-translation procedures (Rode, 2005), and 2) committee approach (Harkness et el., 2010).

The back-translation procedure in this research refers to the processes of reconverting the questionnaire and the interview protocol from the Arabic language into the English language in order ensure the accuracy of the translation. The committee approach aims to ensure the accuracy of the translated version into the Arabic language. The committee consists of specialists in science and mathematics education in addition to a linguistic expert (See Appendix 7). The steps of constructing the instruments and implementation of the study are shown in figure 3.3.

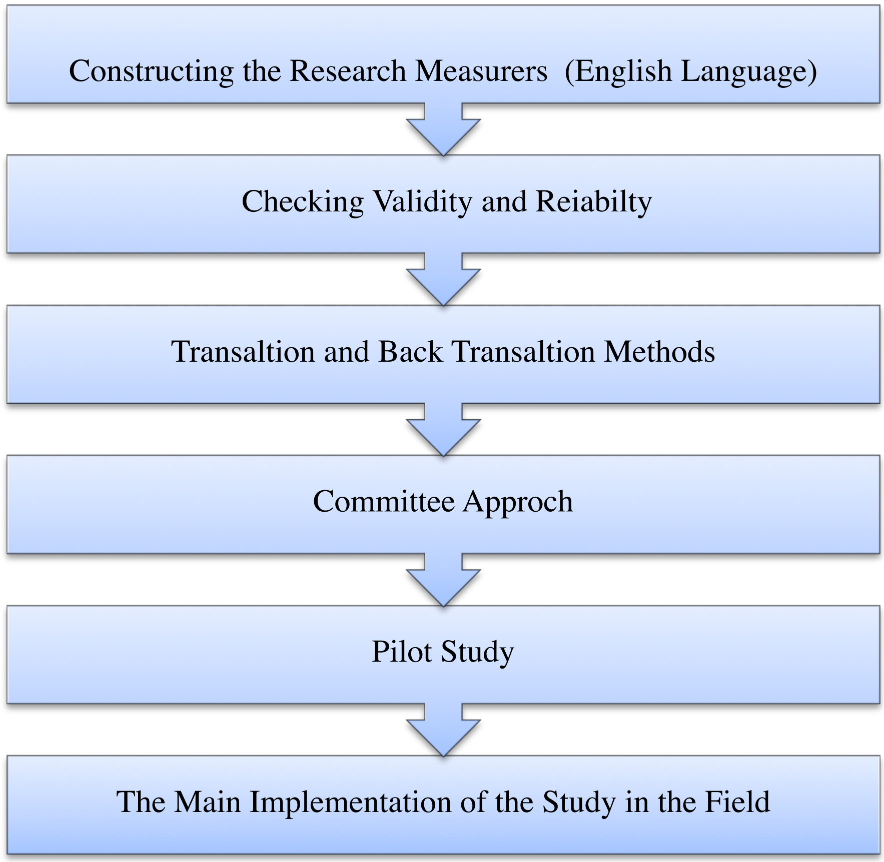


Figure 3.3: Procedures of the research tools construction

Pilot Study

A pilot study is a small-scale version of the large project. The aim of the pilot study is to examine research data collection instruments and iron out any problems or difficulties before the main implementation of the study in the field (Essays, 2013). This pilot study was conducted between September 15, 2017 to October 5, 2017. The total number of high school science teachers participating in the pilot study was 67 from untargeted regions in the main study. Those untargeted regions are Al Khat, Riyadh and Buridah, El Qassim. Those regions were selected because of the ease of contacting science teachers.

To ensure the degree to in which the questionnaire provides consistent and stable scores (Creswell, 2017), Cronbach's alpha coefficient was utilized to calculate the internal consistency coefficients of the surveys. Internal consistency describes the extent to which "all the items in a test measure the same concept or construct and hence it is connected to the inter-relatedness of the items within the test" (Tavakol, Dennick, 2011, p. 53). Cronbach's alpha coefficient is considered to be the best indicator of the quality of research instruments (Drost, 2011). Alpha Cronbach coefficient ranges from 0.00 to 1.00. The larger number indicates more internal consistency of the survey items. Table 3.1 demonstrates Alpha Cronbach coefficients of the four surveys in the pilot and after conducting the comprehensive studies.

Table 3.1: Reliability of the high school level STEM questionnaire

Construct	Number of items	Cronbach's alpha	
		Pilot study (n= 67)	Comprehensive Study (n= 1,207)
Science content and Pedagogy Integration	12	0.84	0.90
Technology Integration	8	0.85	0.91
Engineering Integration	12	0.85	0.94
Mathematics Integration	17	0.91	0.96

To ensure the reliability of the questionnaire, the researcher implemented internal consistency (item homogeneity). Internal consistency or item homogeneity is used for determining intra-scale reliability (Boyle, 1991). Cronbach's alpha coefficient was conducted to estimate internal consistency of the questionnaire (Cronbach, 1951) designed for investigating high school science teachers' challenges with regard to the implantation of STEM integrative approaches in science teaching. Table 3.1 demonstrate Cronbach's alpha coefficients for each domain: science content and pedagogy integration, technology integration, engineering integration, and mathematics integration. The outcomes Cronbach's alpha coefficient demonstrate high internal consistency of the four domains.

DATA COLLECTION

Data Collection in the Quantitative Stage

After building and translating the questionnaires into the Arabic language, the researcher submitted a letter to conduct the study in the six regions in Saudi Arabia. Letters of approval were obtained (see Appendix 10) through the Ministry of Education and ECSME (see Appendix 11). Then, the researcher coordinated with the supervisors assigned to each region. Then the online questionnaire link— through the administration of the web-based survey Qualtrics – was sent to each school, teacher, supervisor in each region (see Appendix 8). The supervisors assigned for each region contacted/visited each school individually to promote science teachers' participation and also report any concern about the implementation of the questionnaire to the researcher. The supervisors in all regions indicated that the language of the translated survey was clear, and they did not report any ambiguity about the survey items. The quantitative data using the questionnaire were collected from the six regions during the period from October 28, 2017 to December 10, 2017.

The overall response rate was 27.7%, 1,207 out of 4,350 science teachers. Participants were asked to express the most important challenges that they may encounter in relation to the integration of separate domains within the STEM, including science content and pedagogy, technology, engineering, and mathematics. Also, they were asked questions about their demographic information (e.g., gender, years of experience, major).

Data Collection in the Qualitative Stage

Having built the interview protocol and gotten science teachers' responses from the quantitative method, the researcher began to conduct the qualitative protocol in the regions of Makkah and Zulfi (See Appendix 9). These regions were selected due to the availability of trained science supervisors who can conduct the interview protocol with the female science teachers in the two regions. Among all regions participating in the study, Makkah represents the largest region while Zulfi represents the smallest. The researcher conducted the face to face interviews with the male science teachers in the Zulfi region. All the interview sessions were conducted in the Arabic language as it is considered the primary language of teachers and students at the K-12 level. The average duration of interviews ranged from 45-65 minutes. Teachers' experience ranged from 4 years to more than 22 years.

Besides the interviews with science teachers, multiple types of data were collected. The researcher was able to conduct interviews with the directors of educational training and scholarship for male and female departments. Also, the researcher was able to analyze the Educational Training Plan of the Zulfi region. Moreover, a selection of high school science teachers' daily plans was obtained. Finally, the researcher was able to interview a professional development provider and attend two science teachers' lessons and one session of a professional development program. All these several types of data helped the researcher fully comprehend teaching and learning in Saudi Arabia, especially in the region of Zulfi and Makkah with regard to the integration of science, technology, engineering, and mathematics in science teaching.

DATA ANALYSIS

Quantitative Data Analysis

The researcher conducted a quantitative research approach using a questionnaire developed for this purpose (Appendix 5). The questionnaire targeted the six different geographic regions in Saudi Arabia to collect data regarding Saudi Arabian high school science teachers' concerns (perceived challenges) related to the integration across different science disciplines as well as the integration of technology, engineering, and mathematics into their science instruction.

Data analysis includes separating data into component parts to determine participants' responses and then connecting this data together to generate constructive conclusion (Creswell, 2017). In this research, data were analyzed using descriptive statistics (mean, frequencies, percentage, and standard deviation). The most recent statistical package for the social science (SPSS) was utilized to determine high school science teachers' concerns related to the integration of science, technology, engineering, and mathematics. Preliminary analyses including missing data and outliers were conducted.

For data analysis, mean values of the teachers' responses have been calculated. Ranking of means was used to determine the greatest perceived challenges of Saudi Arabian high school science teachers related to the integration of science, technology, engineering, and mathematics in science instruction. All the five scales (science, technology, engineering, mathematics) asked respondents to rate their level of agreement on a 5-point Likert scale (1 = *strongly agree*, 2 = *agree*, 3 = *neither agree nor disagree*, 4 = *disagree*, and 5 = *strongly disagree*).

Two-way Multivariate Analysis of Variance (MANOVA), Analysis of Variance (ANOVA), and post-hoc tests were utilized to explore whether there was a statistically significant difference among the independent variables based on gender or geographical regions as shown in

Figure 3.4. MANOVA allows researchers to analyze more than one dependent variable, while Analysis of Variance allows to only analyze one dependent variable. Post-hoc tests were used to confirm where the difference occurred between the participants based on geographic region or gender (Meyers, Gamst, & Guarino, 2017). The Bonferroni correction was utilized to reduce type I error particularly when multiple pair wise tests are conducted on a single data set (Armstrong, 2014).

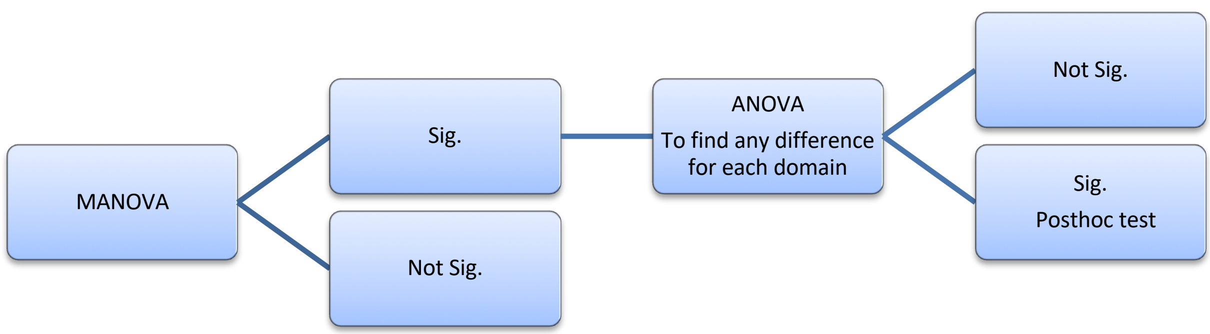


Figure 3.4: Data analysis using MANOVA and ANOVA

Additionally, Pearson correlation (Pearson Product-Moment Correlation) coefficient was conducted in order to measure the strength connections among the dependent variables—e.g., science content and pedagogy, technology, engineering, and mathematics integration (Benesty , Chen, Huang, Cohen , 2009).

Qualitative Data Analysis

For the qualitative method, the sample included 20 science teachers divided according to gender, region and discipline. The participants included eight male teachers and six female teachers from the region of Zulfi, and six females from Makkah. with regard to discipline, the sample included two teachers for each major: physics, chemistry, biology, and geology. This classification scheme proved especially productive for investigating Saudi Arabian high school science teachers' concerns (perceived challenges) related to the integration across different science disciplines as well as the integration of technology, engineering, mathematics, and STEM as a whole in science instruction.

This project conducted in depth interviews with science teaches in efforts to gain extensive knowledge that cannot be attained using survey-based methods (Merriam, 1998). The process of qualitative analysis can be described as a conceptual funnel (Marshall, & Rossman, 2001). The mouth of the funnel represents a general phenomenon that includes, in this research, the integration of STEM in science instruction (Figure 3.5). The narrow end of the funnel indicates the specific focus Saudi Arabian high school science teachers' perceived challenges related to the integration across different science disciplines as well as the integration of technology, engineering, mathematics, and STEM as a whole.

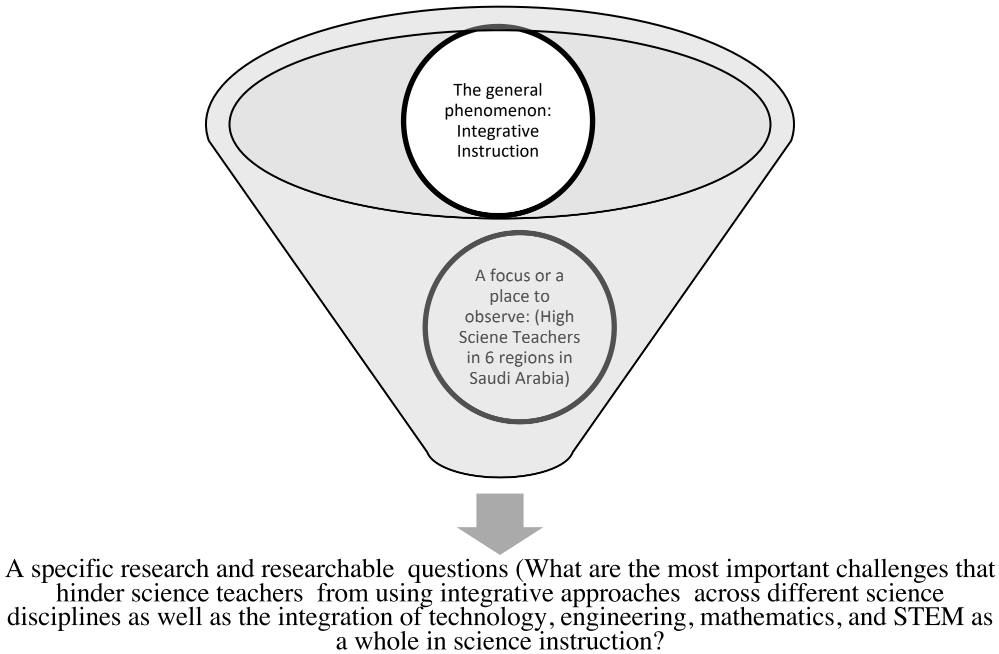


Figure 3.5: The conceptual funnel of a qualitative study

First, the researcher analyzed the quantitative questionnaire data and then analyzed the qualitative interview data. This approach strengthens the representation and legitimation of the research problem under investigation (Frels and Onwuegbuie, 2013). Data analysis of the qualitative interview went through five steps, which Creswell (2018) described as:

1. Organizing and preparing data for analysis. For this project, this step required audio, and written recording methods. The researcher used all methods based on the interviewees' preferences. Afterward, each interview was transcribed using Microsoft Word and saved in an organized folder protected with password.
2. Reading and looking at all the data. For the purposes of this dissertation, this involved thoroughly analyzing each part of an interview in order to build conceptual understandings

about the participants ideas and attitudes. This step proceeds hand-in-hand with other supportive procedures, such as writing notes or using mind maps.

3. Data coding. A code is defined as "a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data" (Saldana, 2009, p.3) Open coding is considered the first practical stage of qualitative data analysis. The main purpose of coding is to capture the significant ideas without losing their meaning, understand the phenomenon under investigation, develop constructs, and develop a theory.
4. Identifying a description, themes of patterns, and categories. The purpose of identifying patterns and categories is to categorize how each science teacher conceptualizes the integration of technology, engineering, and mathematics into science teaching, and determines the factors that might hinder them from conducting integrative approaches in science instruction.
5. Representing the description and themes. The purpose of this step is to present all participants' responses in order to find common themes and categories that can be discussed in the cross-case analysis (Figure 3.6).

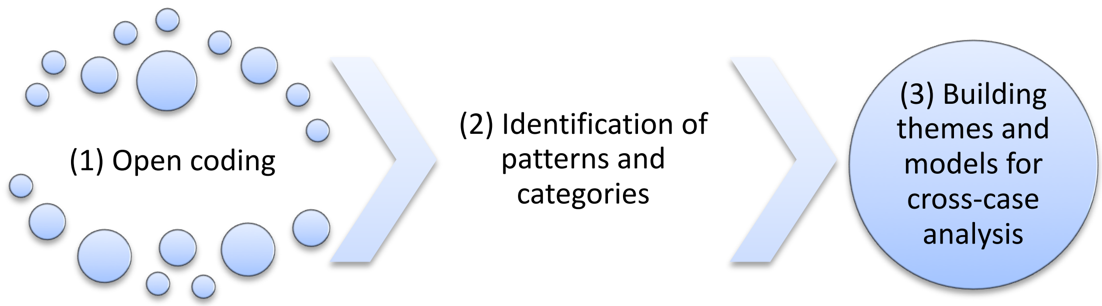


Figure 3.6: Qualitative analysis steps

VALIDITY AND RELIABILITY

Validity and reliability are the most important factors in the evaluation of research instruments and results (Patton, 1980; Tvakol & Dennik, 2011). Validity determines whether an instrument measures what is supposed to measure (Creswell, 2014). In other words, if the questionnaire, interview protocol, and the research results are meaningful, then they are considered valid measurements. According to (Creswell & Miller, 2008) validity is concerned with determining whether research findings are accurate from the stand point of the investigators, participants, and specialized readers. On the other hand, reliability refers to the degree to which an instrument generates stable and consistent test scores (Creswell, 2014). The researcher followed rigorous procedures to ensure the validity and reliability of the current study.

To determine the validity of the questionnaire and the interview protocol, the researcher conducted a content validity. Content validity process aims to assure the extent in which the questionnaire and the interview protocol measure the most important challenges that science teachers encounter while conducting STEM integrative approaches in science teaching. The research questionnaire and the interview protocol were extensively checked and evaluated by science and mathematics scholars in addition to linguistic experts (See Appendix 7) to ensure the scientific and the linguistic accuracy.

In addition to content validity, the researcher employed triangulation method. Triangulating different data resources yields full understanding of the phenomenon under investigation. In this research, data were triangulated by: 1) questionnaire; 2) interviews with science teachers; 3) interviews with professional development providers; 4) interviews with some students; 5) classroom observation; and 6) document analysis.

Besides content validity and triangulation, the researcher conducted member checking to enhance the accuracy of the findings. Peer debriefing was also implemented to enhance the accuracy and reduce subjectivity from the researcher.

ROLES OF EXTRA DATA

The fundamental data—including the questionnaire and the interview protocol— provided the researcher with extensive knowledge about the status quo of teaching science in K-12 level in Saudi Arabia. However, the other triangulated resources provided the researchers with a clear evidence that support the findings of the questionnaire and the interview protocol. These resources encompass classroom observation, professional development program directors and providers' interviews, lessons' plan analysis, and professional development programs' plan analysis.

Summary:

This chapter provides a snapshot of the research design (mixed methods), sample, research surveys, and data collection and analysis. The main purpose of this study was to explore Saudi Arabian high school science teachers’ perceived challenges and needs related to the integration of science content and pedagogy, technology, engineering, mathematics, and STEM in science teaching. Chapter 4 presents the results from the data analysis.

Chapter Four: Findings of the Study

Chapter four reports the results of the statistical analysis of the quantitative and qualitative data for the study. This chapter is organized into four sections. The first section summarizes the purpose of the study; the second section describes the population of the study; the third section demonstrates the research questions; the four section discusses the data analysis and results.

PURPOSE OF THE STUDY

The main purpose of this study was to investigate the most important perceived challenges and needs of high school science teachers in Saudi Arabia related to the integration of science content and pedagogy, technology, engineering, and mathematics into science teaching as measured by quantitative and qualitative methods. Also, the study aimed to investigate if there were differences of perceived challenges and needs in terms of gender and geographical regions. This study is beneficial in that it may provide teachers, school administrators, and policymakers with suggestions that enhance integration in science teaching.

POPULATION

The sample of population for the study consisted of 4,350 certified high school science teachers. The study included teachers in the six geographic regions of the Kingdom of Saudi Arabia (Makkah, Tabuk, Aseer, Hail, Kahrj, and Zulfi). These regions were carefully selected to comprehensively reflect the geographic and diverse views of teachers across the Kingdom of Saudi Arabia. To accomplish the study goals, data were collected using the mixed methods of quantitative and qualitative approaches in order to acquire an in-depth exploration of challenges and concerns that hinder teachers from using integrative approaches in science teaching (Creswell, 2008). In the study when using the quantitative method, data were collected from 1,208 certified science teachers while twenty science teachers from the regions of Makkah and Zulfi participated in the qualitative method.

TOTAL NUMBER OF SCIENCE TEACHERS IN THE RESEARCH COMMUNITY:

This section represents the total number of teachers employed in the six regions included in this research study in terms of location, gender, and subject taught: physics, chemistry, biology, and geology.

Table 4.1: *Total Number of High School Science Teachers in the Research Community*

Region	Gender	Physics	chemistry	Biology	Geology	Total	Percent of population
Makkah	Male	187	206	209	47	649	14.9%
	Female	197	207	209	0	613	14.1%
Aseer	Male	172	188	198	17	575	13.2%
	Female	208	206	172	0	586	13.5%
Hail	Female	124	125	121	18	388	8.9%
	Male	134	129	129	0	392	9%
Tabuk	Male	117	108	120	15	360	8.3%
	Female	117	129	134	0	380	8.7%
Kharj	Male	59	59	61	8	187	4.3%
	Female	50	46	52	0	148	3.4%
Zulfi	Male	13	10	10	4	37	0.9%
	Female	13	11	11	0	35	0.8%
Total	Male and Female	1391	1424	1426	109	4350	100%

Table 4.1 indicates that Makkah's region was the largest region among targeted regions accounting for 30% of the total participants, while the Zulfi's region included the lowest number of participants with almost 2% of the total participants. Also, this table indicates that female students are not required to take geology in high schools.

SCIENCE TEACHERS PARTICIPATING IN THE STUDY:

More than 25% of science teachers across the six geographic regions participated in this study using an online-based survey as illustrated in table 4.2.

Table 4.2: *Total Number of Teachers Participating in the Study*

Region	Gender	Physics	chemistry	Biology	Geology	Total	Percentage to population
Makkah	Male	14	13	11	2	40	3.31%
	Female	108	81	119	0	308	25.5%
Tabuk	Male	55	49	57	3	164	13.6%
	Female	22	32	20	0	74	6.13%
Aseer	Male	31	23	26	5	85	7%
	Female	41	53	43	0	137	11.4%
Hail	Male	27	42	47	11	127	10.5%
	Female	20	25	21	0	66	5.5%
Kharj	Male	12	14	14	1	41	3.4%
	Female	45	31	27	0	103	8.5%
Zulfi	Male	14	8	9	2	33	2.7%
	Female	10	7	12	0	29	2.4%
Total	Male and Female	399	378	406	24	1,207	100%

Table 4.2 and figure 4.1 indicate that the Makkah's region included the largest number of female participants accounting for 28.81% of the total participants, while the Zulfi's region included the lowest number of female participants accounting for only 5.1% of the total participants.

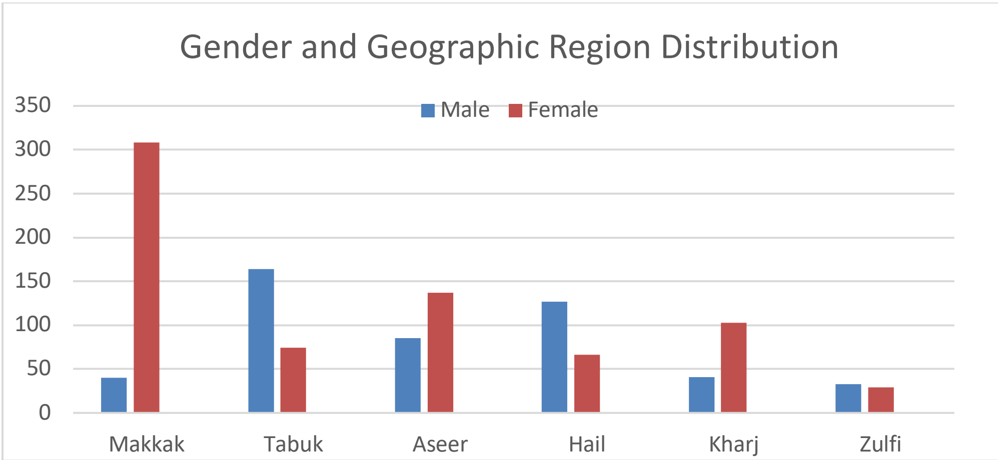


Figure 4.1: Gender and geographic region distribution of science teachers participated in the study

RESEARCH QUESTIONS

In this chapter, the researcher provides results focusing on the following research questions:

3. What are the most important challenges and needs perceived by Saudi Arabian high school science teachers in relation to the integration of:
   a. Separate domains within STEM, including Science content and pedagogy, technology, engineering and mathematics?
   b. STEM as a whole?
4. Are there differences of perceived challenges and needs in terms of gender and geographic region?

Question 1a will be addressed using both qualitative and quantitative data, while question 1b will be addressed via qualitative data only, and question 1b will addressed via quantitative data only.

Data Analysis and Results

First Research Question:

To examine the most important challenges and needs perceived by Saudi Arabian high school science teachers as measured by quantitative methods, the researcher used separate scales focusing on A) Science Content and Pedagogy Integration, B) Technology Integration, C) Engineering Integration, and D) Mathematics Integration.

The first research question was addressed through the analysis of data using descriptive statistics. Scores for teachers' self-competency were calculated based on the average score for each item and each scale. Teachers were asked to rate their level of agreement on a 5-point Likert scale (1 =strongly agree (competent), 2 = agree (fairly competent), 3 = neither agree nor disagree (undecided), 4 = disagree (fairly incompetent), and 5 = strongly disagree (incompetent)). Higher mean scores demonstrate incompetency, more challenges, and a more need for improvement, while lower scores demonstrate more competency, and less need for improvement as illustrated by figure 4.2. First, results within each scale will be discussed, before summarizing overall patterns.

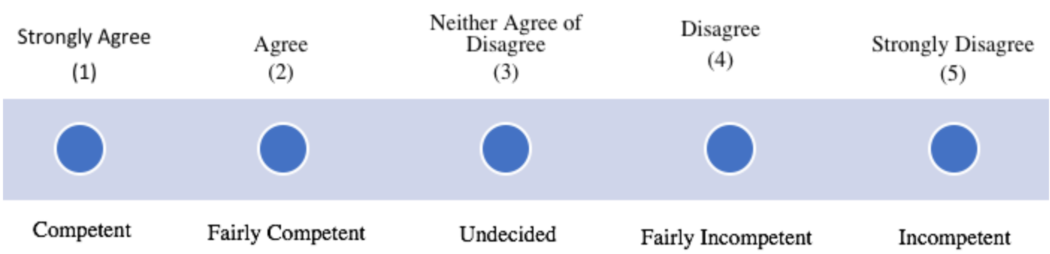


Figure 4.2: Scale of teachers' competency

Science Content and Pedagogy Integration (SSCI):

Science teachers in Saudi Arabia demonstrated need for improvement with regard to the implementation of science content and pedagogy integration. Scores of science teachers' responses ranged from 1 to 5 except for the items 1,6, and 9 that ranged from 1 to 4 as illustrated by table 3. They expressed the most need for improvement with regard to science content and pedagogy integration in the following areas: 1) integrating other science disciplines (physics, chemistry, biology, and geology) into science teaching practices *(Mean*= 3.43; SD= 1.15). The results indicated that more than 50% of science teachers expressed a pressing need for improvement in the area of integrating other disciplines such as physics, chemistry, biology and geology into science teaching as highlighted in figure 4.3; 2) helping students reflect on their learning strategies *(Mean= 2.00 ; SD= 0.817);* and 3) stimulating students' scientific thinking by engaging them in challenging tasks (Mean= 1.98; SD= 0.805) as illustrated by table 4.3.

Table 4.3: *Science Teachers Responses Regarding Science Content and Pedagogy Integration*.

Item	(N=1,208) Minimum	Maximum	Mean	Standard deviation
1) I have sufficient knowledge about science.	1	4	1.64	0.688
2) I can think about the content of science subjects like a subject matter expert.	1	5	1.92	0.797
3) I am able to develop deeper understanding about science.	1	5	1.89	0.793
4) I am able to stimulate my students' scientific thinking by engaging them in challenging tasks.	1	5	1.98	0.805
5) I am able to guide my students to adopt appropriate learning strategies for science.	1	5	1.90	0.797
6) I am able to help my students monitor their own science learning.	1	4	1.79	0.721
7) I am able to help my students reflect on their learning strategies	1	5	2.00	0.817
8) I am able to guide and motivate my students to share their thoughts during science group work.	1	5	1.88	0.783
9) I can address the common misconceptions my students have about science.	1	4	1.83	0.728
10) I know how to select effective teaching approaches to guide student thinking and learning in science.	1	5	1.88	0.749
11) I can help my students understand the content knowledge of science by using a variety of instructional technology tools.	1	5	1.87	0.777
12) I am able to integrate science disciplines (physics, chemistry, biology, and geology) into my teaching practices.	1	5	3.43	1.152

On the other hand, science teachers expressed the lowest concern with regard to: 1) the acquisition of content knowledge of each discipline individually such as physics, chemistry, or biology (*Mean* = 1.64, *SD*= 0.688), and 2) the capacity of helping students monitor their own science learning (*Mean* = 1.79, *SD*= 0.721).

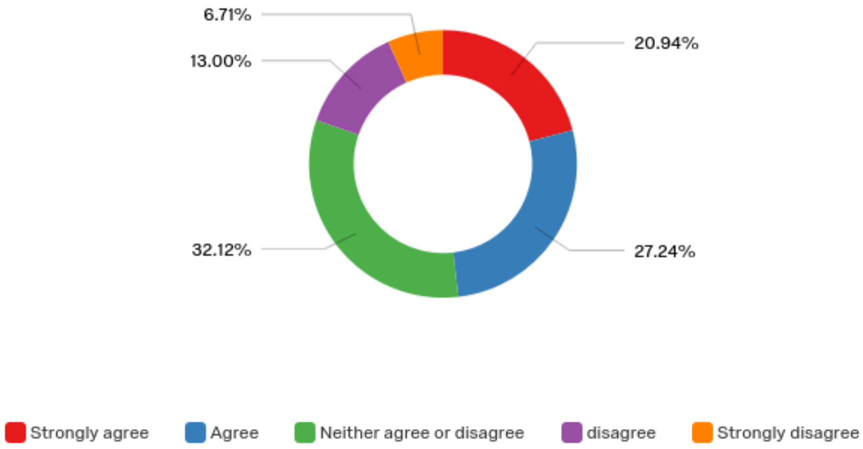


Figure 4.3: Science teachers' responses on integrating other disciplines into science teaching

Overall, high school science teachers in Saudi Arabia rated themselves as fairly competent (M=2, SD= 0.479, n= 1,207) in the area of science content and pedagogy integration as shown in table 4.4.

Table 4.4: *Means and Standard Deviation for Science Content and Pedagogy Integration*.

Gender	Mean	Std. Deviation	N	Alpha Cronbach
Male	1.9619	.45612	490	0.90
Female	2.0252	.49322	717	0.91
Total	1.9995	.47932	1,207	0.907

The results of the study indicate that science teachers across all regions of the kingdom of Saudi Arabia tend to evaluate themselves as fairly competent in the area of the integration of science content and pedagogy; however, they are highly concerned about how to effectively integrate other science disciplines (physics, chemistry, biology, and geology) into science teaching practices.

Technology Integration (TI):

Science teachers in Saudi Arabia demonstrated more need for improvement with regard to the implementation of technology integration. Scores of science teachers' responses ranged from 1 to 5. They expressed the most need for improvement with regard to technology integration in the following areas: 1) helping students use the same kinds of tools that professional researchers use such as databases, satellite imagery, and experimentation approaches *(Mean= 3.03; SD= 1.061)* ; 2)) helping students utilize a variety of technologies such as PhET interactive simulations (https://phet.colorado.edu/ar_SA/), data visualization, research and communication tools (Mean= 2.87; SD= 1.067) as illustrated on table 4.5.

Table 4.5: *Science Teachers Responses Regarding Technology Integration*.

Item	(N=1,207)			
	Minimum	Maximum	Mean	Standard deviation
1) I am able to help my students use a variety of technologies, e.g. PhET, data visualization, research and communication tools.	1	5	2.87	1.067
2) I am able to help my students use technology to communicate and collaborate with others, beyond the classroom.	1	5	2.41	1.041
3) I am able to help my students use online resources and information.	1	5	2.04	.865
4) I am able to help my students use the same kinds of tools that professional researchers use, e.g. databases, satellite imagery.	1	5	3.03	1.061
5) I am able to help my students work on technology-enhanced projects that emphasize real- world applications of technology.	1	5	2.69	1.011
6) I can help my students use technology to help solve problems.	1	5	2.32	.906
7) I wonder if I can help my students use technology to support higher-order thinking, e.g. analysis, synthesis, and evaluation of ideas and information.	1	5	2.34	.924
8) I am able to help my students use technology to create new ideas and representations of information.	1	5	2.38	.916

On the other hand, science teachers expressed the lowest concern with regard to the integration of technology in the area of helping students use online sources and information (*Mean* = 2.04, *SD*= 0.865) as they illustrated by table 4.5.

Overall, high school science teachers in Saudi Arabia rated themselves as “fairly low competent” (M=2.51, SD= 0.768, n= 1,207) in the area of technology integration in science teaching practices as illustrated by table 4.6 and figure 4.2.

Table 4.6: Mean and Standard Deviation for Science Technology Integration.

Gender	Mean	Std. Deviation	N	Alpha Cronbach
Male	2.4439	.77335	490	0.916
Female	2.5544	.76112	717	0.908
Total	2.5095	.76771	1207	0.912

Engineering Integration (EI):

Science teachers in Saudi Arabia demonstrated the greatest need for improvement with regard to the implementation of engineering integration. Scores of science teachers’ responses ranged from 1 to 5 as illustrated by table 4.7. They expressed their concern regarding the implementation of engineering design process in teaching science *(Mean= 3.35; SD= 1.465)* due to the fact that they may are not familiar with engineering design process integration in science teaching. They reported that their most important concerns were in the following areas: 1) acquiring the knowledge required for testing and evaluating students’ proposals *(Mean= 3.04; SD= 1.025)*; 2) acquiring the knowledge required for helping students design projects based on customers’ needs *(Mean= 3.00; SD= 1.041);* and 3) acquiring the knowledge required for helping students refine and improve student design solutions *(Mean= 2.93; SD= 1.041)*. However, science teachers expressed the lowest concern with regard to the integration of engineering in the areas of the acquisition of knowledge required for helping students brainstorm possible solutions of scientific problems (*Mean* = 2.30, *SD*= 1.035), and helping students generate new ideas (*Mean* = 2.30, *SD*= 0.918). Scores of science teachers' responses ranged from 1 to 5 as illustrated by tables 4.7.

Table 4.7: *Science Teachers Responses Regarding Engineering Integration*.

Item	(N=1,207)			
	Minimum	Maximum	Mean	Standard deviation
1) I am familiar with the engineering design process represented by the graphic attached.	1	5	2.62	1.173
2) I have sufficient knowledge to have my students define engineering problems clearly.	1	5	2.73	1.096
3) I have sufficient knowledge to have my students specify constraints and identify criteria of engineering problems.	1	5	2.87	1.034
4) I have sufficient knowledge to have my students brainstorm possible solutions of scientific problems.	1	5	2.30	1.035
5) I have sufficient strategies to teach my students how to generate ideas.	1	5	2.30	.918
6) I have sufficient knowledge to have my students explore solutions of scientific problems.	1	5	2.49	.932
7) I have sufficient knowledge to teach students how to select an approach to solve engineering problems.	1	5	2.63	.992
8) I have sufficient knowledge to have my students create a model or prototype of an engineering problem.	1	5	2.87	.997
9) I have sufficient knowledge to have my students refine and improve design solutions.	1	5	2.93	1.019
10) I can direct students' design projects based on customers' needs.	1	5	3.00	1.041
11) I have sufficient knowledge to have my students test and evaluate their proposal designs.	1	5	3.04	1.025
12) In general, I find it difficult to implement engineering design approach in my teaching.	1	5	2.68	1.023

Overall, high school science teachers in Saudi Arabia rated themselves as "undecided" in the area of engineering integration (M=2.75, SD= 0.804, n= 1,207) as shown in table 4.8 and Figure 4.2.

Table 4.8: *Mean and Standard Deviation for Engineering Integration*.

Gender	Mean	Std. Deviation	N	Alpha Cronbach
Male	2.6707	.81989	490	0.949
Female	2.7958	.78991	717	0.943
Total	2.7450	.80423	1,207	0.946

Mathematics Integration (MI):

Science teachers in Saudi Arabia demonstrated the need for improvement with regard to the implementation of mathematics integration. Scores of science teachers' responses ranged from 1 to 5 as illustrated by table 4.9. They expressed an important need for improvement with regard to the implementation of mathematics integration in the following areas: (1) helping students solve simple integration equations (Mean= 2.35; SD= 1.077); (2) helping students recognize patterns in data (Mean= 2.28; SD= 1.011); and (3) helping students solve multistep problems by: a) perceiving the problem to be solved (Mean= 2.22; SD= 1.064), b) identifying the mathematical principles involved (Mean= 2.26; SD= 1.068), and c) performing the appropriate mathematics (Mean= 2.26; SD= 1.062). However, science teachers expressed the lowest concern with regard to the integration of mathematics in the area of helping students distinguish between direct and inverse proportions. (Mean = 1.90, SD= 1.012), and help students convert word expressions into mathematical ones. (Mean = 1.99, SD= 0.982) as shown in table 4.9.

Table 4.9: *Science Teachers Responses Regarding Mathematics Integration*.

Item	(N= 1,207)			
	Minimum	Maximum	Mean	Standard Deviation
1) I can help my students perform mathematical computations when given algebraic expressions such as quadratic equations, negative exponents etc.	1	5	2.10	1.036
2) I can help my students convert word expressions into mathematical ones.	1	5	1.99	.982
3) I can help my students recognize equalities and inequalities.	1	5	2.19	1.085
4) I can help my students visualize the different types of solids shapes (spatial visualization).	1	5	2.18	1.025
5) I can help my students apply the concept of transformation (translation, rotation, and reflection) in science.	1	5	2.25	1.032
6) I can help my students interpret data in different layouts (e,g. in tables, graph, written)	1	5	2.03	.932
7) I can help my students distinguish between symmetric and non-symmetric groups.	1	5	2.03	.946
8) I can help my students solve simple integration equations.	1	5	2.35	1.077
9) I can help my students distinguish between direct and inverse proportions.	1	5	1.90	1.012
10) I can help my students identify various types of angles in given shapes such as prisms.	1	5	2.19	1.049
11) I can help my students use appropriate mathematical tools strategically.	1	5	1.94	1.010
12) I can help my students reason abstractly.	1	5	2.10	.955
13) I can help my students reason quantitatively.	1	5	2.09	.941
14) I can help my students recognize patterns in data	1	5	2.28	1.011
15) I can help my students solve multistep problems by:				
a) Perceiving the problem to be solved	1	5	2.22	1.064
b) Identifying the mathematical principles involved	1	5	2.26	1.068
c) Performing the appropriate mathematics	1	5	2.26	1.062

Overall, high school science teachers in Saudi Arabia rated themselves as fairly competent in the area of mathematics integration (M=2.14, SD= 0.831, n= 1207) as shown in table 4.10 and figure 4.2.

Table 4.10: *Mean and Standard Deviation for Mathematics Integration*

Gender	Mean	Std. Deviation	N	Alpha Cronbach
Male	2.2224	.88639	490	0.97
Female	2.0837	.78574	717	0.96
Total	2.1400	.83051	1207	0.967

The Correlation among the Dependent Variables

To investigate the association between perceived needs in the different fields, Pearson correlations were calculated. Table 4.11 indicates that there were positive correlations among all the dependent variables, meaning that as science teachers perceived challenges increase in one domain, the perceived challenges in another domain typically increase as well and vice versa. The highest correlation was found between technology integration and engineering integration (r= 0.644, n=1,208, p< 0.001), while the lowest correlation was found between science content & pedagogy integration and mathematics integration (r= 0.374, n= 1,207, p< 0.001). While these four dependent variables are positively correlated, they are at the same time distinct.

Table 4.11: *The Correlation Between the Dependent Variables*

Correlations

		Science Content & Pedagogy Integration	Technology Integration	Engineering Integration	Mathematics Integration
Science Content & Pedagogy Integration	Pearson Correlation	1	.567**	.478**	.374**
	Sig. (2-tailed)		.000	.000	.000
	N	1207	1207	1207	1207
Technology Integration	Pearson Correlation	.567**	1	.644**	.392**
	Sig. (2-tailed)	.000		.000	.000
	N	1207	1207	1207	1207
Engineering Integration	Pearson Correlation	.478**	.644**	1	.499**
	Sig. (2-tailed)	.000	.000		.000
	N	1207	1207	1207	1207
Mathematics Integration	Pearson Correlation	.374**	.392**	.499**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	1207	1207	1207	1207

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

Summary of the Results:

The results indicate that high school science teachers perceived challenges were positively correlated which support the idea that STEM disciplines are firmly associated “that we do not see how education in any one of them can be undertaken well in isolation from the others” (AAAS, 1993, pp. 321–322). Also, the results of the study indicate that science teachers in Saudi Arabia expressed more need for improvement in the area of engineering integration (M=2.75, SD= 0.804, n= 1,207) compared to the technology integration (M=2.51, SD= 0.768, n= 1207) and science content & pedagogy integration (M=2, SD= 0.479, n= 1207). However, the most pressing challenge faced by science teachers in the area of science content and pedagogy integration was the integration other science disciplines (physics, chemistry, biology, and geology) into science teaching practices and the implementation of engineering design and technology in science teaching.

In other words, science teachers in Saudi Arabia rated themselves as “fairly competent” in the areas of science content and pedagogy and mathematics integration. They expressed the greatest concern with regard to the integration of other science disciplines (physics, chemistry, biology, and geology) into science teaching practices. When it comes to areas of technology and engineering integration, they rated themselves as “fairly low competent “and “undecided” respectively.

Second Research Question:

To answer the second research question, "what are the differences of perceived challenges and needs in terms of gender and geographic region in science content and pedagogy integration, technology integration, engineering design integration, and mathematics integration?", the researcher conducted a two-way multivariate analysis of variance (two-way MANOVA) to find out if there is an interaction between the two independent variables: 1) gender and 2) geographic location on the other dependent variables: a. science content and pedagogy integration, b. technology integration, c. engineering design integration, and d. mathematics integration. The results indicate that there was at least one statistically significant interaction effect between gender and location among the dependent variables, $F(20, 3954.367) = 1.630$, $p = 0.038$; Wilks' $\Lambda = .973$. Furthermore, results from Two-way Multivariate Analysis of variance revealed significant main effects of both location $F(20, 3954.367) = 1.738$, $p = 0.022$; Wilks' $\Lambda = .971$ and gender $F(4, 1192) = 3.35$, $p = 0.01$; Wilks' $\Lambda = .989$

The results of two-way ANOVA conducted for each domain indicate that there was a significant interaction between gender and region for a) science content and pedagogy integration $F(5) = 2.832$, $p = .015$; b) technology integration $F(5) = 2.931$, $p = 0.012$; and for c) mathematics integration $F(5) = 2.462$, $p = 0.031$. The interaction was close to significant for the dependent variables for engineering design integration $F(5) = 2.124$, $p = 0.060$. Therefore, significance tests suggest that there is an interaction present between gender and geographic region across all domains as shown in table 4.12.

Table 4.12: *Two-way ANOVAs Outputs for the Questionnaires A, B, C, and D*

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Location	Science Content and Pedagogy Integration	2.155	5	.431	1.902	.091	0.008
	Technology integration	11.285	5	2.257	3.907	.002	0.016
	Engineering integration	14.000	5	2.800	4.427	.001	0.018
	Mathematics integration	8.679	5	1.736	2.560	.026	0.011
Gender	Science Content and Pedagogy Integration	.009	1	.009	.038	.845	0.000
	Technology integration	.001	1	.001	.002	.967	0.000
	Engineering integration	.020	1	.020	.031	.860	0.000
	Mathematics integration	6.074	1	6.074	8.958	.003	0.007
Location * Gender	Science Content and Pedagogy Integration	3.208	5	.642	2.832	.015	0.012
	Technology integration	8.466	5	1.693	2.931	.012	0.012
	Engineering integration	6.717	5	1.343	2.124	.060	0.009
	Mathematics integration	8.347	5	1.669	2.462	.031	0.010

Science Content and Pedagogy Integration (SCPI):

Since there was a significant interaction for Science Content and Pedagogy Integration (SCPI), the researcher examined simple main effects for female and male science teachers across regions separately. The researcher split the data file by gender, and then performed one-way ANOVAs between region and the outcome separately for each gender. The results revealed that for male science teachers, at least one region differs from other regions on science content and pedagogy integration teachers' average scores on Science Content and Pedagogy integration ($F(5, 1195) = 2.449$, $p= 0.032$). For female science teachers, there were no significant differences among regions on science integration average scores on science content and pedagogy integration (F (5, 1195) = 2. 061, p= 0.068) as shown in table 4.13.

Table 4.13: *One-way ANOVA for Each Level of Gender: Male and Female of Science Content and Pedagogy Integration*

Dependent Variable	Gender		Sum of Squares	df	Mean Square	F	Sig.
Science Content and Pedagogy Integration	Male	Contrast	2.775	5	.555	2.449	.032
		Error	270.799	1195	.227		
	Female	Contrast	2.335	5	.467	2.061	.068
		Error	270.799	1195	.227		

Even though there was a main effect of region for males, results indicated that there were no significant differences in post hoc analyses using Bonferroni correction; however, males science teachers average score in Zulfi (m= 2.184 , SD= 0.469, n= 33) and Tabuk (m=1.9212, SD= 0.4465, n= 164) was close to significant (t= 2.89, p= 0.058) as shown in table 4.14 and Figure 4.4.

Table 4.14: *Means and Standard Deviation for Science Teachers' Responses on Content and Pedagogy Integration*

Location	Gender	Mean	Std. Deviation	N
Makkah	Male	2.0500	.50911	40
	Female	2.0135	.49330	308
	Total	2.0177	.49453	348
Tabuk	Male	1.9212	.44655	164
	Female	1.9065	.47581	74
	Total	1.9167	.45489	238
Kharj	Male	2.0447	.46663	41
	Female	2.0170	.45529	103
	Total	2.0249	.45708	144
Aseer	Male	1.9186	.43358	85
	Female	2.1083	.51035	137
	Total	2.0357	.49017	222
Zulfi	Male	2.1843	.46945	33
	Female	1.9655	.50813	29
	Total	2.0820	.49623	62
Hail	Male	1.9311	.44359	127
	Female	2.0795	.50857	66
	Total	1.9819	.47082	193
Total	Male	1.9619	.45612	490
	Female	2.0252	.49322	717
	Total	1.9995	.47932	1207

To further follow-up on the statistically significant interaction between gender and region, the researcher split the data file by region, and then performed one-way ANOVAs between gender and the outcome within each geographic location. Results of Bonferroni post-hoc tests revealed that male science teachers have an average score in the Aseer region (m= 1.919 , SD=0.434, n= 85) that is significantly lower than female science teachers' average score (m=2.108 , SD= 0.510, n= 137), (t=2.879 , p= 0.004). Also, male science teachers in the Hail region (m=1.931 , SD= 0.444, n=127) have significantly lower average score than female science teachers (m= 2.080, SD=0.059, n=66), (t=2.509 , p= 0.04) as shown in figure 4.4. In other words, female science teachers in Aseer and Hail regions reported significantly higher average need for improvement in science content and pedagogy integration compared to male science teachers.

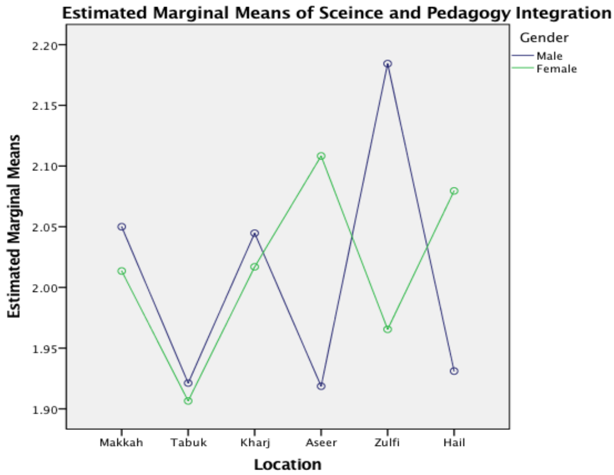


Figure 4.4: Estimated marginal means of science content and pedagogy integration

To examine gender differences across regions, results indicate that there were no significant differences across regions on science integration average scores on science content and pedagogy integration (F (1, 1195) = 0.038, p= 0.845). Table 4.15 below summarizes the significant differences among science teachers based on gender and geographic region.

Table 4.15: *Summary of Significant Differences among Science Teachers' Mean Responses in SCPI*

	Are There differences?	Region	Average Score Differences
Location differences within Gender	No		
Gender Differences Within the Same Location	Yes	Aseer Hail	Female > Male Female > Male
Gender Differences across all Regions	No		

Technology integration (TI):

Since there was a significant interaction for Technology Integration (TI), the researcher examined simple main effects for female and male science teachers across regions separately. The researcher split the data file by gender, and then performed one-way ANOVAs between region and the outcome separately for each gender. The results revealed that at least one of the regions differ from the others for male science teachers' average score in technology integration (F(5, 1195) = 3.859, p=0.002). For female science teachers, there was no significant difference on the average score on technology integration (F(5, 1195) = 1.977, p= 0.079) as illustrated by table 4.16. Using Levene's test, there were no significant differences in the variance between regions.

Table 4.16: *One-way ANOVA for Each Level of Gender (Male and Female) of Technology Integration*

Dependent Variable	Gender		Sum of Squares	df	Mean Square	F	Sig.
Technology integration	Male	Contrast	11.148	5	2.230	3.859	.002
		Error	690.383	1195	.578		
	Female	Contrast	5.711	5	1.142	1.977	.079
		Error	690.383	1195	.578		

Post hoc analyses using Bonferroni's correction indicated that there were significant differences among male science teachers' average scores in the technology integration questionnaire between Zulfi (m= 2.833 , SD=0.729, n= 33) and Tabuk (m=2.348, SD=0.755, n= 164), (t =3.35 , p= 0.013). Also, there were significant differences among male science teachers between Zulfi (m= 2.833 , SD=0.729, n=33) and Aseer (m=2.366, SD=0.700, n= 85), (t =2.99, p= 0.042). And between Zulfi (m=

2.833, SD=0.729, n=33) and Hail (m=2.396, SD=0.760, n= 127), (t =2.95, p= 0.048) as shown on table 4.17

Table 4.17: *Means and Standard Deviation for Science Teachers' Responses on Technology integration*

Location	Gender	Mean	Std. Deviation	N
Makkah	Male	2.7344	.71845	40
	Female	2.5743	.76732	308
	Total	2.5927	.76258	348
Tabuk	Male	2.3476	.75536	164
	Female	2.3176	.64810	74
	Total	2.3382	.72248	238
Kharj	Male	2.5457	.94941	41
	Female	2.5473	.78573	103
	Total	2.5469	.83217	144
Aseer	Male	2.3662	.70968	85
	Female	2.5940	.80280	137
	Total	2.5068	.77482	222
Zulfi	Male	2.8333	.72932	33
	Female	2.4914	.78129	29
	Total	2.6734	.76734	62
Hail	Male	2.3947	.76009	127
	Female	2.6837	.67874	66
	Total	2.4935	.74431	193
Total	Male	2.4439	.77335	490
	Female	2.5544	.76112	717
	Total	2.5095	.76771	1207

In other words, male science teachers in the Zulfi report significantly higher average need for improvement in technology integration compared to the science teachers in Tabuk, Hail, and Aseer regions as illustrated by table 4.18.

Table 4.18: Significant Differences based on Science Teachers' Mean Responses in Technology Integration

Number	Average Differences	P-value
1	Male average score in Zulfi > Male average score in Tabuk	0.013
2	Male average score in Zulfi > Male average score in Aseer	0.042
3	Male average score in Zulfi > Male average score in Hail	0.048

To further follow-up on the statistically significant interaction between gender and region, the researcher split the data file by region, and then performed one-way ANOVAs between gender and the outcome within each geographic location. Results of Bonferroni post-hoc tests revealed that male science teachers in the Aseer region have an average score (m=2.366, SD=0.700, n=85) that is significantly lower average score than female science teachers average score (m=2.594, SD=0.803, n= 137), (t=2.17, p= 0.03). Also, male science teachers in the Hail region (m=2.444, SD=0.773, 127) have significantly lower average score than female science teachers (m=2.554, SD=0.761, n= 66), (t=2.51, p= 0.012) as shown in figure 4.5 . In other words, female science teachers in Aseer and Hail regions report significantly higher average need for improvement in technology integration compared to male science teachers, but there are no significant gender differences in other regions.

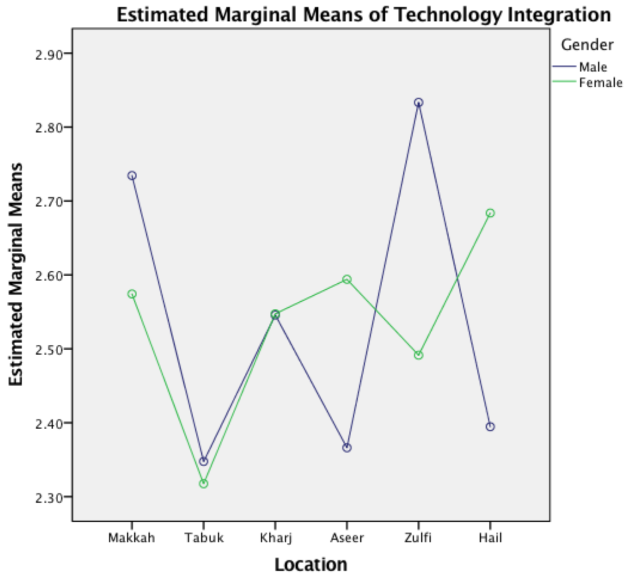


Figure 4.5: Estimated Marginal Means of Science Teachers' Responses on Technology Integration

To examine gender differences across regions, results indicated that there was no significant differences across regions on science integration average scores on technology integration ($F(5, 1195) = 0.002$, $p = 0.967$). Table 4.19 summarizes the significant differences among science teachers based on gender and geographic region on technology integration.

Table 4.19: Summary of Significant Differences Based on Science Teachers' Mean Responses in TI

	Are There differences?	Region	Average Score Differences
Location differences within Gender	Yes, Only for Male	Zulfi, Tabuk, Aseer, and Hail	Zulfi > Tabuk Zulfi > Aseer Zulfi > Hail
Gender Differences Within the Same Location	Yes	Aseer Hail	Female > Male Female > Male
Gender Differences across all Regions	No		

Engineering Integration (EI):

Since there was a borderline significant interaction for Engineering Integration (EI) between gender and location ($F(5,1195) = 4.764$, $p = 0.06$), the researcher examined simple main effects for female and male science teachers across regions separately. The researcher split the data file by gender, and then performed one-way ANOVAs between region and the outcome separately for each gender. The results revealed that at least one of the regions differ from the others for male science teachers' average score in engineering design integration ($F(5, 1195) = 4.764$, $p=0.001$). For female science teachers, there was no significant difference on the average score on engendering integration ($F(5, 1195) = 1.472$, $p= 0.196$) as illustrated by table 4.20.

Table 4.20: *One-way ANOVA for Each Level of Gender (Male and Female) of TI*

Dependent Variable	Gender		Sum of Squares	df	Mean Square	F	Sig.
Engineering integration	Male	Contrast	15.066	5	3.013	4.764	.000
		Error	755.748	1195	.632		
	Female	Contrast	4.653	5	.931	1.472	.196
		Error	755.748	1195	.632		

Post hoc analyses using Bonferroni's correction indicated that there were significant differences among male science teachers average scores in engineering integration questionnaire between Zulfi (m= 3.194, SD=0.890, n= 33) and Tabuk (m=2.557, SD=0.767, n= 164), (t =4.184 , p= 0.001). Also, there were significant differences among male science teachers between Zulfi (m= 3.194, SD=0.890, n= 33) and Aseer (m=2.679, SD=0.798, n= 85), (t =3.15, p= 0.025). And between Zulfi (m= 3.194, SD=0.890, n= 33) and Hail (m=2.586, SD=0.831, n= 127), (t =3.922, p= 0.001) as illustrated by table 4.21 and figure 4.6.

Table 4.21: *Means and Standard Deviation for Science Teachers' Responses on Engineering Integration*

Location	Gender	Mean	Std. Deviation	N
Makkah	Male	2.9447	.83196	40
	Female	2.8184	.80113	308
	Total	2.8329	.80452	348
Tabuk	Male	2.5571	.76658	164
	Female	2.5622	.68324	74
	Total	2.5587	.74024	238
Kharj	Male	2.6818	.79131	41
	Female	2.8344	.81929	103
	Total	2.7909	.81161	144
Aseer	Male	2.6794	.79776	85
	Female	2.8057	.80246	137
	Total	2.7573	.80122	222
Zulfi	Male	3.1935	.88962	33
	Female	2.8229	.92983	29
	Total	3.0202	.92021	62
Hail	Male	2.5858	.83113	127
	Female	2.8600	.68763	66
	Total	2.6795	.79398	193
Total	Male	2.6707	.81989	490
	Female	2.7958	.78991	717
	Total	2.7450	.80423	1207

To further follow-up on the statistically significant interaction between gender and region, the researcher split the data file by region, and then performed one-way ANOVAs between gender and the outcome within each geographic location. Results of Bonferroni post-hoc tests revealed that male science teachers have an average score (m=2.586, SD= 0.831, n= 127) in the Hail region that is significantly lower than female science teachers' average score (m=, 2.860, SD= 0.688, n= 66), (t= 2.27 p= 0.023) as illustrated by table 4.6, but there are no significant gender differences in other regions.

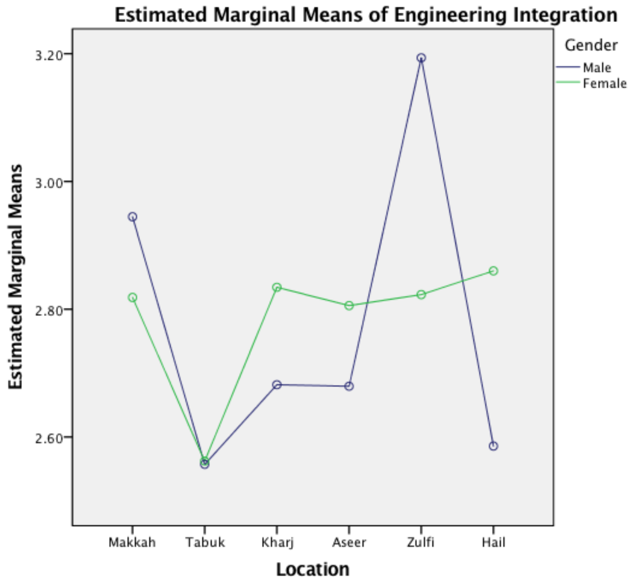


Figure 4.6: Estimated marginal means of science teachers' responses on engineering integration

To examine gender differences across regions, results indicated that there were no significant differences across regions on science integration average scores on engineering integration (F (5, 1195) = 0.031, p= 0.860). Table 4.22 below summarizes the significant differences among science teachers based on gender and geographic region on engineering integration.

Table 4.22: Summary of Significant Differences based on Science Teachers' Mean Responses in EI

	Are There differences?	Region	Average Score Differences
Location differences within Gender	Yes, Only for Male	Zulfi , Tabuk, Aseer, Hail	Zulfi > Tabuk Zulfi > Aseer Zulfi > Hail
Gender Differences Within the Same Location	Yes	Hail	Female > Male
Gender Differences across all Regions	No		

Mathematics integration (MI):

For the Mathematics integration, there were some outliers, but sensitivity analysis that excluded Z score in the outcome greater than 2.5 was no different than the original analysis, so the researcher used the full sample. Since there was a significant interaction for Mathematics Integration (MI), the researcher examined simple main effects for female and male science teachers across regions separately. The researcher split the data file by gender, and then performed one-way ANOVAs between region and the outcome separately for each gender. The results revealed that at least one of the regions differ from the others for female science teachers average score in mathematics integration ($F(5, 1195) = 3.624$, $p=0.003$). For male science teachers, the mathematics domain integration was not significant ($F(5, 1195) = 1.099$, $p=0.359$) as shown in table 4.23.

Table 4.23: One-way ANOVA for Each Level of Gender (Male and Female) of MI

Dependent Variable	Gender		Sum of Squares	df	Mean Square	F	Sig.
Mathematics integration	Male	Contrast	3.727	5	.745	1.099	.359
		Error	810.237	1195	.678		
	Female	Contrast	12.287	5	2.457	3.624	.003
		Error	810.237	1195	.678		

Post hoc analyses using Bonferroni's correction found significant differences among female science teachers average scores in mathematics integration questionnaire domain between Kharj (m= 2.207, SD= .828, n= 103) and Tabuk (m=1.770, SD= 0.563, n=74), (t=3.50, p= .008). Also between Aseer (m= 2.224, SD= 0.828, n= 137) and Tabuk (m=1.770, SD= 0.563, n=74), (t = 3.81, p=.002) as illustrated by table 4.24 and figure 4.7.

Table 4.24: Means and Standard Deviation for Science Teachers' Responses on MI

Location	Gender	Mean	Std. Deviation	N
Makkah	Male	2.3044	.80895	40
	Female	2.0450	.75712	308
	Total	2.0748	.76653	348
Tabuk	Male	2.1661	.88229	164
	Female	1.7703	.56339	74
	Total	2.0430	.81661	238
Kharj	Male	2.1306	.92556	41
	Female	2.2074	.82775	103
	Total	2.1855	.85414	144
Aseer	Male	2.1712	.83223	85
	Female	2.2236	.82781	137
	Total	2.2036	.82801	222
Zulfi	Male	2.4755	.61675	33
	Female	2.0507	.91166	29
	Total	2.2768	.79164	62
Hail	Male	2.2673	.98984	127
	Female	2.1471	.82510	66
	Total	2.2262	.93633	193
Total	Male	2.2224	.88639	490
	Female	2.0837	.78574	717
	Total	2.1400	.83051	1207

The study found a significant difference for Levene's test of equality of error variances ($F (11,1195) =2.756$, $p= 0.002$), so there is no bias in comparisons because the larger variances are associated with larger groups. This only would cause a lack of power not type I error[1].

[1] The ratio in sample sizes between Kharj (n=103, SD= 0.8277) and Tabuk (n=74, SD= 0.56339) is less than threshold (1.5), so the differences in sample is not a concern. Also, the ratio in sample sizes between Aseer (n=137. SD= 0.82787) and Tabuk (n=74, SD= 0.56339) is bigger than threshold (1.5), however, it is not a concern, because the larger variance is associated with the larger sample size.

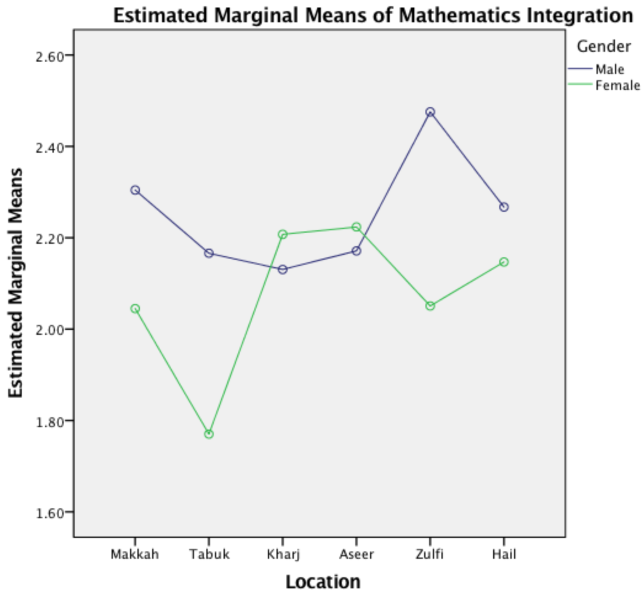


Figure 4.7: Estimated Marginal Means of Science Techers' responses on Mathematics Integration

In other words, female science teachers in the Kharj's region report significantly higher average need for improvement in mathematics integration compared to science teachers in Tabuk's region. Also, female science teachers in Aseer's region report significantly higher average need for improvement in mathematics integration compared to female science teachers in Tabuk's region as shown in table 4.25.

Table 4.25: Significant Differences based on Science Teachers' Mean Responses in Mathematics Questionnaire

Number	Average Differences	p-value
1	Female average score in Kharj > Female average score in Tabuk	0.008
2	Female average score in Aseer > Female average score in Tabuk	0.002

To further follow-up on the statistically significant interaction between gender and region, the researcher split the data file by region, and then performed one-way ANOVAs between gender and the outcome within each geographic location. Results of Bonferroni post-hoc tests revealed that male science teachers in the Tabuk region have an average score (m= 2.166, SD= 0.882, n=164) that is significantly higher average score than female science teachers (m= 1.770, SD= 0.563, n= 74), (t=3.44, p= 0.001). Also, male science teachers in Zulfi (m= 2.476, SD= 0.617, n=33) have significantly higher average score than female science teachers (m= 2. 051, SD=0.9112, n=29), (t= 2.024, p= 0.043), but there are no significant gender differences in other regions.

To examine gender differences across regions, results indicate that there were significant differences across regions on mathematics integration (F(5, 1195) = 8.958, p= 0.003). Male science teachers have significantly higher average score (m= 2.25, SD= 0.886, n=490) than female science teachers across all regions (m= 2.07, SD=0.786, n=717), (t= 2.97, p= 0.003).

Table 4.26 below summarizes the significant differences among science teachers based on gender and geographic region on mathematics integration.

Table 4.26: Summary of Significant Differences based on science teachers' mean responses in MI

	Are There differences?	Region	Average Score Differences
Location differences within Gender	Yes, Only for Female	Kharj, Tabuk, and Aseer	Kharj > Tabuk Aseer > Tabuk
Gender Differences Within the Same Location	Yes	Tabuk Zulfi	Female < Male Female < Male
Gender Differences across all Regions	Yes	Across all regions	Female < Male

Summary*:*

This study found that geographic location contributed to significant differences within gender in science teacher average scores in relation to their ability to integrate (1) science content and pedagogy, (2) technology, (3) engineering, and (4) mathematics into science teaching. Also, the results showed gender differences within the same geographic location in the four subjects. Finally, the results showed that there were significant differences across regions in favor of male science teachers average scores on mathematics integration.

Using Partial Eta Squared to measure the effect size of the Analysis of Variance (ANOVA), the significant gender by region interactions explain 1.2%, 1.2%, 0.9%, and 1.0% of the variance between subjects for science content & pedagogy integration, technology integration, engineering, integration , and mathematics integration respectively. Similarly, geographic regions explain 0.80%, 1.6%, 1.8%, and 1.1% of the variance between subjects for science content & pedagogy integration, technology integration, engineering, integration, and mathematics integration respectively. While gender did not explain any of the between-subject variance for science content and pedagogy integration, technology integration, and engineering, integration. Yet for mathematics integration, it explains only 0.7% of the variance between subjects. Finally, the effect sizes for the significant gender by region interactions explain as illustrated by table 4.12.

Conclusion*:*

Even though the study found significant differences in teachers' responses with regard to gender and geographic location in the four dependent variables, the effect sizes calculated using Partial Eta Squared are too small to be meaningful. Therefore, it is suggested that there are no meaningful differences among science teachers in Saudi Arabia in perceived challenges across the domains of science content and pedagogy, technology, engineering and mathematics integration into science teaching. To illustrate, examining the interaction plot for science content and pedagogy integration with full y-axis reflecting the full scale from one to five of the questionnaire demonstrates how the differences between gender and geographic region are negligible as shown by figure 4.8. This result is most evident in the discussion of the qualitative part of the research. These quantitative results support what is seen in the qualitative results in the next section.

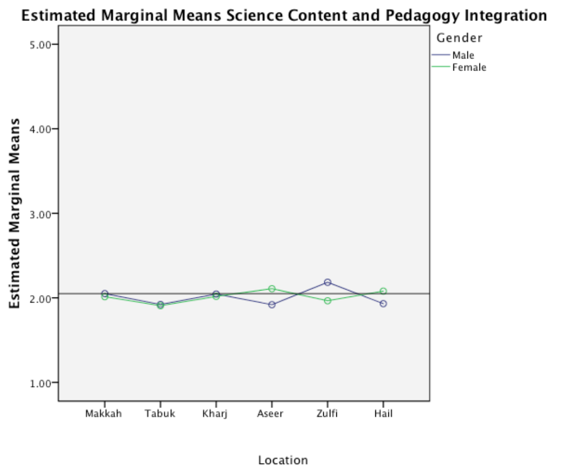


Figure 4.8: Interaction Plot for Science Content and Pedagogy Integration with Full Y-axis

The Results of the Qualitative Approach

The qualitative approach aims to answer the following question: what are the most important perceived challenges and needs of high school science teachers related to the integration of: 1) science content and pedagogy; 2) technology; 3) engineering;

4) mathematics; and 5) STEM as a whole into science teaching in the six geographic regions of the Kingdom of Saudi Arabia (Makkah, Tabuk, Aseer, Hail, Kahrj, and Zulfi)?.

The research qualitative approach consists of a questionnaire with 20 questions (see Appendix 6) that aims to investigate high school science teachers perceived challenges in terms of the integration science content and pedagogy, technology, engineering, mathematics, and STEM as a whole.

The sample consists of twenty science teachers; eight male science teachers (two each from physics, chemistry, biology, and geology), six female science teachers (two from each physics, chemistry, biology) from Zulfi's region, and six female science teachers (two from each physics, chemistry, biology) from Makkah's region as shown in table 4.27.

Table 4.27: *Science Teachers' Distribution Participated in the Qualitative Research*

Region	Major	Gender		Total
		Male	Female	
Makkah	Physics	0	2	2
	Chemistry	0	2	2
	Biology	0	2	2
	Geology	0	0	0
Zulfi	Physics	2	2	4
	Chemistry	2	2	4
	Biology	2	2	4
	Geology	2	0	2
Total		8	12	20

The researcher interviewed male science teachers, while female science teachers were interviewed by trained science educational supervisors working in each region. Teachers' responses were recorded and classified based on the most commonly reported perceived challenges across all science teachers. The steps of each case analysis follow: (1) open coding;(2) identifying patterns; and then (3) identifying categories (Appendix 12).

After completing the interviews with male and female science teachers in Saudi Arabia, data were coded based on every statement made by each teacher. The main ideas emerged as patterns that helped the researcher categorize high school science teachers' perceived challenges in terms of the integration of science content and pedagogy, technology, engineering, mathematics, and STEM. Three categories emerged:

1) Challenges related to teachers,

2) Challenges related to students, and

3) Challenges related to management and administration.

The challenges that relate to science teachers consist of a) science teachers' perception about integration, and b) lack of content and pedagogies required for integration. The challenges that related to students includes: a) students' skills and knowledge, and b) students' motivation. The challenges that relate to management and administration are as follows: a) lack of time requited for integration for each science subject, b) lack of instructional material and devices required for integration, c) lack of curricula that support integration such as textbooks and continuous professional development programs, d) lack of financial support, and e) lack of well-trained educational supervisors who promote effective and active learning.

Science Content and Pedagogy integration (SCPI):

The researcher investigated science teachers' perceived challenges regarding the integrations of science content and pedagogy. Five challenges emerged that hinder science teachers from applying an integrative approach to teaching science.

First, science teachers have negative attitudes and perceptions about science content integration. They consider content integration as a complicated process for both science teachers and students, a process that might lead to misunderstanding and distraction. A male physics teacher (PhyM1) stated:

> …. [students] want to know the summary of each lesson, they do not want to recognize details about each topic. Also, providing students with details from other disciplines might lead to misunderstanding and distraction. Therefore, I only focus on physics lessons.

Science teachers believe that science integration negatively affects student learning in terms of providing students with excessive knowledge that may lead to focus on specific areas and skip some important details.

In addition to considering integration as a complicated and distracting process, science teachers believe that no relationship exists between science disciplines and suggest that each science discipline should be taught as a subject of its own. A male biology teacher (BioM1) stated:

> It is impossible to integrate biology with chemistry! There is no space for integration. In biology, students learn plants and animals, while they study elements and chemical compounds in chemistry and acceleration in physics.

A male geology teacher (Geo 01) with four years of experience emphasized that teachers should focus on their discipline as students are assigned to study specific courses with specific purposes. He questioned how a geology teacher could integrate geology with physics. He stated, “I believe that there is no connection between geology and physics, so I cannot find any relationship between them”.

This geology teacher with limited experience was wondering how a geology teacher would be able to find connection between geology and other disciplines such as physics, chemistry, and biology. This explains how this teacher conceptualizes science integration.

Interestingly, another geology teacher (GeoM2) who is certified in geophysics and worked for several years at the King Abdul-Aziz City for Science and Technology (KACST) in geoscience department, expressed his ability to integrate geology with physics. He said, “As I am majoring in geophysics and studying many mathematics courses, I can integrate geology with physics and mathematics”. The researcher asked him for an example. He answered, “In lesson on volcanoes, I can discuss [with students] the potential and kinetic energy. Also, we can investigate the effects of volcanos on human beings, animals, plants, and soil.”

Another misconception about science content integration is that science teachers believe that bringing marginal information from one discipline to another is considered a full integration. A female biology teacher (BioF1) stated that she could use science integration in teaching biology. She said, “while teaching the phenomenon of photosynthesis, I write the chemical formulas of compounds such as water H_2O and glucose $C_6H_{12}O_6$”

Second: Science teachers lack the content and pedagogy required for science integration. All science teachers who participated in the study are prepared to teach one discipline such as physics, chemistry, biology or geology except one teacher who is certified in geophysics.

All teachers agree that they are underprepared to teach science using an integrative approach due to the lack of content knowledge in other science disciplines. A male chemistry teacher (ChemM1) stated:

> I am qualified to teach chemistry due to the fact that the teacher preparation programs prepare teachers to teach one subject matter of chemistry, but I could not integrate other disciplines with chemistry due to insufficient knowledge about other disciplines such as physics or biology. The main reason is that the current professional development programs do not focus on science integration.

In addition, science teachers lack the pedagogies required for integration such as project-based learning (PBL). A female chemistry teacher (ChemF1) stated,

> The majority of professional development programs focus on theoretical domains such as lessons planning, and classroom management. I have not the opportunity to participate in professional development programs that focus on pedagogies such as science integration using project-based learning.

Third: There is lack of instructional materials required for science integration. Even though the Ministry of Education improved and updated the science curricula in K-12 schools, many schools still do not have sufficient materials required for teaching science using an integrative approach. A female physics teacher (PhysF1) stated that:

> The current curricula and teachers' manuals do not focus on describing the relationship among several disciplines or how to integrate science subjects systematically. Therefore, it depends on each teacher's personal initiative to research and study how to integrate science disciplines in science classroom or laboratories. In fact, we are required to teach specific topics at a specified time of the academic year.

Another male physics teachers (physM2) complained about the language of the new curricula. He stated:

> Even though the new curricula were updated and translated from an American series, I still have difficulties in terms of the language of these curricula and applying them in an integrative approach due to the lack of materials and professional development programs. Therefore, I resort to using the old curricula in some topics as they are more obvious than the current curricula.

Also, schools lack the tools and devices required for science integration. A female physics teacher (physM1) stated,

> There is a lack of instructional tools needed for integration and experimentation approaches using project-based laboratories. The school sometimes has these tools, but they are not sufficient for all students to participate using project-based instruction.

Fourth: There is a lack of time required to promote effective integration in over-crowded classrooms. A male biology teacher (BioM2) expressed his concern about the duration of science periods assigned for each subject and number of students in each classroom. He said:

> The current curricula are too heavy and require time to complete the assigned topics in a specific time. Also, the number of students in my class is too high (38 students), a situation that hinders innovation using integrative approaches such as science integration.

Fifth: Students' proficiency in science knowledge and skills is not adequate for science integration. Science teachers encounter difficulties related to students' previous knowledge and skills. A male chemistry teacher (ChemM2) expressed concerns about students' knowledge and skills regarding chemical elements and balancing chemical equations. He said,

> I teach chemistry to 10th and 11th graders. I feel that students in the current grade level lack the adequate preparation and skills required for teachers to build on these pervious skills using integrative approaches. For example, many students do not recognize the symbols of chemical elements and are not able to balance chemical equations. Therefore, I am forced to spend more time reviewing these basic skills. Lack of required skills and knowledge negatively affect students' abilities and motivation to effectively integrate science subjects.

Technology Integration (TI):

The researcher investigated science teachers perceived challenges regarding the integration of technology and found three main challenges that hinder science teachers from applying an integrative approach using technology in science teaching.

First: Science teachers have negative perceptions about technology integration.

Science teachers in the two regions of Makkah and Zulfi believe that technology is just the use of digital resources such as computers and methods of presentation. A male biology teacher (BioM02) stated: "technology is very important in teaching science; hence I use technology to present the digital textbooks in my classroom and to present lessons using PowerPoint".

A female physics teacher (PhysF01) said: "even though schools do not have interactive software that helps students comprehend complicated processes in physics, I think technology means conducting experimentation such as computer simulation". A male chemistry teacher (chemM02) believes that "technology is associated with presenting science experiments using YouTube." He stated that "I use YouTube to present some complicated and processes in chemical reactions that are not possible to execute in science laboratories due to cost or safety reasons". Interestingly, a male physics teacher (PhyM003) said: "I do not use technology in my classroom as it is a waste of time in terms of preparation and application. I prefer to use pencil and paper activities".

Second: Lack of content and technological knowledge required for technology integration in science teaching.

Science teachers believe that they do not have sufficient technological knowledge to integrate technology into science teaching. A male physics teacher (Phys 001) said: "I do not have the technological knowledge that helps me design lessons or to effectively integrate technology in science teaching due to the lack of effective professional development programs". A professional development provider has been meeting to investigate the challenges that teachers encounter in implementing technology integration. He declared, "I provided a group of teachers with a professional development program focusing on applying Microsoft OneNote, but teachers do not use it in their daily practices! I do not know what the reasons are!".

In terms of conducting science experiments with students, a male biology teacher (BioM3) asserted that science teachers focus on theoretical practices rather than conducting the experimentation approach. He stated:

> In this term (Fall 2017), students must conduct seven experiments, we just conducted two out of seven experiments. The main reason is that I do not have sufficient knowledge and confidence that enable me to conduct these experiments. Therefore, I just skipped them. Also, professional development programs provided to science teachers do not focus on building teachers' content knowledge and confidence capacities.

Third: Lack of technological tools and devices required for technology integration and experimentation. Science teachers in both regions Makkah and Zulfi expressed their concerns about the lack of equipment required for integration. A female biology teacher (BioM1) stated:

> There is an inadequate number of devices/equipment that allow for maximum student participation. For example, my class consists of 37 students with only two microscopes. Therefore, I cannot engage my students in hands-on real-world experiences.

A male chemistry teacher (ChemM003) stated: "I do not have interactive software such as computer simulation programs that fit with the new curricula even though schools are equipped with computers and projectors in each classroom and laboratory." In comparison, a female biology teacher (BioM 2) from Makkah region complained about lack of devices required for integration in her school. She said: "in our school, we do not have sufficient computers or projectors. We have to make reservation for each device since our school is not well-equipped with technological tools".

Engineering Integration (EI):

Science teachers in the two regions articulated four challenges and concerns related to the integration of engineering into science teaching. In addition to teachers' misunderstanding of engineering integration, they have difficulties in relation to pedagogies, curricula, and time required for integration.

First: Science teachers' perception of engineering integration.

Science teachers articulated their understanding regarding the definition of engineering in science teaching. Teachers' definitions vary based on their conceptual understanding of engineering.

A male chemistry teacher (chemM002) said: "engineering design is defined as simple drawing". A male geophysics teacher (GeoM1) stated that "engineering is using AutoCAD software, a mechanical product design and drafting software". A male Chemistry teacher (ChemM4) said, "engineering means applying the scientific method in science teaching. The scientific method starts with exploring observations and ends with answering questions". Another female physics teacher (PhyF4) said, "engineering includes the study of mechanical, civil, and electrical engineering".

Second: Lack of pedagogies required for engineering design integration.

All science teachers who have been interviewed agree that they do not have sufficient pedagogical knowledge required for applying the engineering design process in science teaching. A male physics teacher (PhysM3) said, "to me, I am not quite sure how to implement engineering design in my physics classroom. I think engineering can be taught for engineering students in colleges and universities! I am not qualified to teach engineering". Another male biology teacher (BioM2) stated: "science teachers are not well-prepared to teach using engineering design process as they have not studied this approach and the current professional development programs also do not include this approach in the professional development plan”.

Third: the current curricula do not include engineering design process.

Science teachers stated that the current curricula, including textbooks, professional development programs, and educational supervision do not in reality focus on meaningful integration including engineering integration. A male chemistry teacher (ChemM5) said, “even though the textbooks have been updated, the engineering design process has not been included in these updated versions. Therefore, science teachers follow a specific plan based on the current science textbooks”. A female physics teacher (PhysF003) stated: “teachers do not have the choice to make modifications in science curricula, they must teach what they have in these curricula”.

Fourth: Lack of time required for promoting effective integration in over-crowded classrooms.

Regarding the introduction of the engineering design process into science teaching, teachers were concerned about time required for that introduction, especially in overcrowded classrooms. A male biology teacher (BioM2) said: “there are too many students in each class and I am teaching (38-40 students). This high number of students hinder teachers from applying active learning strategies such as the inclusion of engineering integration in science teaching”. A female physics teacher (PhysF 04) said, “engineering design integration requires ample amounts of time that will infringe on time allotted to teach the physics curriculum.”

Mathematics Integration (MI):

Science teachers in the two regions articulated three challenges and concerns related to the integration of mathematics into science teaching.

First: Lack of mathematical content and pedagogy knowledge required for integration: Science teachers especially physics and chemistry teachers believe that they need more mathematical and pedagogical knowledge in terms of the inclusion of mathematics in science teaching. A male physics teacher (PhysM5) stated:

> I have insufficient skills in the area of using mathematics and applying these skills strategically. Even though the curricula have been translated and updated, there is insufficient professional development programs that update teachers' content and pedagogical knowledge in term of applying mathematics integration.

A male chemistry teacher (ChemM04) said: "I have concerns regarding the best ways to present mathematical problems such as logarithms and quadratic equation in a meaningful way".

In comparison, biology teachers did not express any concern regarding the integration of mathematics into biology teaching due to the low level of mathematical skills in the biology curriculum.

Second: Lack of time required for promoting effective integration in over-crowded classrooms:

Science teachers in the two regions expressed their concern to time allotted for each science class especially for 11^{th} grade. A male physics teacher (PhysM 3) said, "allotted time for physics periods is not adequate to teach science in an integrative approach. Teacher have to race against time to complete the assigned curricula".

Another female chemistry teacher (ChemF3) said, “there are too many students in each classroom (38 students) which hinder conducting integrative approaches”.

Third: Lack of basic mathematical skills required for science integration:

Science teachers in the two regions expressed their concern related to the students’ skills in mathematics, which might affect their achievement and motivation toward studying science. A male physics teacher (PhysM2) said: “many students in my class are not able to solve basic mathematics problems such as simple equation and logarithms.” Another male physics teacher (PhysM01) said: “it is too difficult for students to relate physics concepts to a mathematical equation such as converting word expressions into mathematical ones”. A female chemistry teacher (ChemF3) was concerned about diagnosing students’ mathematical skills. She said: “students’ mathematical skills that need improvement have not been diagnosed. Therefore, science teachers discover these weaknesses and they have to spend time focusing on these mathematical skills instead of focusing on science integration”.

Another male physics teacher (PhysM2) noted that students have negative attitudes toward mathematics. He said, “students in general have negative attitudes toward mathematics due probably to their low mathematical skills”.

STEM Integration:

Science teachers in the two regions were not able to define STEM integration because they were not aware of this concept with the exception of a biology teacher who participated in a workshop focusing on STEM integration. All teachers except the biology teacher were not able to answer the interviewer's questions about the STEM integration domain.

The biology teacher classified the challenges that science teachers might encounter while conducting STEM approach into three categories:

First: Lack of content and pedagogical knowledge required for STEM integration:

The biology teacher (Bio001) was concerned about the content and pedagogical teachers' knowledge required for STEM integration. He said,

> I do not have a sufficient knowledge and teaching strategies about integrating STEM in science teaching because preservice and in-service professional development programs do not prepare teachers to integrate STEM into science teaching. Therefore, I do not have sufficient knowledge to design STEM lessons and also how to evaluate students' outcomes.

Second: Lack of curricula that support STEM integration

The current curricula do not focus on STEM integration. The teacher said: "the curricula do not support integration. Instead, they are designed to be taught theoretically and in isolation. Also, professional development programs do not emphasize practical programs such as using STEM. In summary, how can we teach using STEM framework with incompatible curricula?".

Third: Lack of time and financial support required to promote effective STEM integration.

The biology teacher was concerned about time, number of students in each class and financial support. He said: “There are too many students in each classroom (37-40 students) which hinders teachers’ ability to use the STEM approach. Also, STEM integration requires conducting student-centered learning, which is considered time-consuming in light of limited science periods. Moreover, there is a lack of financial support to help teachers and students conduct experimentation and science projects”.

CONCEPTUALIZING STEM INTEGRATION

There is no consensus among researchers in STEM education about the conceptualization of STEM integration (Breiner, Harkness, Johnson, & Koehler, 2012). The conceptualization of STEM integration is ill-defined and diverse (Breiner et al., 2012; Bybee, 2013; Moore et al., 2014; Roehrig et al., 2012). However, teachers – in this study— were asked to conceptualize the integration of science, technology, engineering, and mathematics. Based on the data emerged from the qualitative method, the following continuum (Figure 4.9) demonstrates science teachers' conceptualization about STEM integration. Figure 4.9 indicates that 50% of science teachers conceive STEM integration as an acronym or fragmented. Research findings indicate that teacher conceptions affect their daily practices (Gow & Kember, 1993; Trigwell, Prosser, & Waterhouse, 1999)

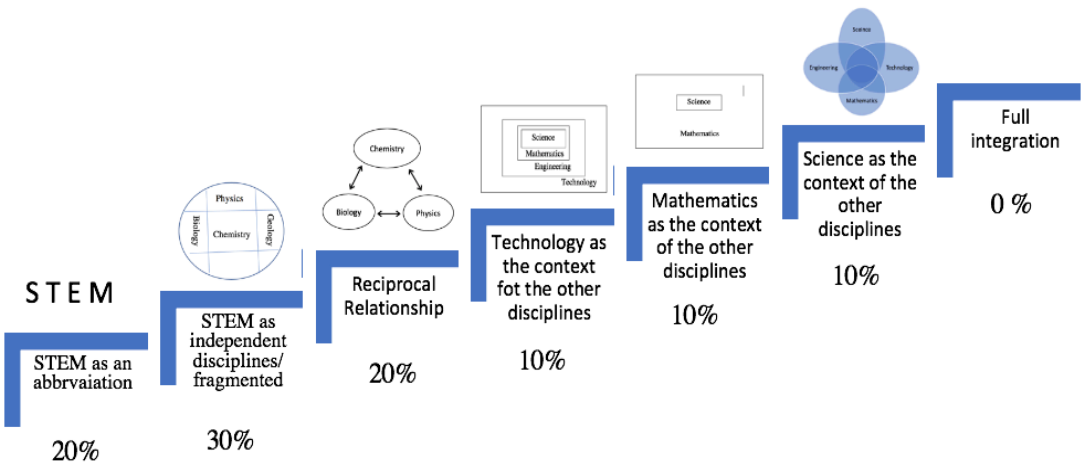


Figure 4.9: Science teachers' perception continuum about integration

Summary

This study investigated the perceived challenges and needs of high school science teachers in Saudi Arabia related to the integration of science content and pedagogy, technology, engineering, and mathematics into science teaching in the six geographic regions of the Kingdom of Saudi Arabia (Makkah, Tabuk, Aseer, Hail, Kahrj, and Zulfi). Also, the researcher determined if differences exist among perceived challenges and needs in terms of gender and geographic regions on the dependent variables.

The most important perceived challenge for science teachers across all regions in terms of science content and pedagogy integration is the lack of knowledge and skills required for integrating all science disciplines (physics, chemistry, biology, and geology) into science teaching practices (Male/Mean= 2.61, Female/Mean= 2.62). In terms of technology integration, the most pressing challenge cited by science teachers across all regions was related to helping students use the same kinds of tools that professional researchers use, e.g. databases, satellite imagery (Male/Mean= 2.87, Female/Mean= 3.14). When it comes to engineering integration, the most important challenge for science teachers across all regions was the lack of knowledge required for implementing engineering design approaches in science teaching (Male/Mean= 3.5, Female/Mean= 3.5). It seems that science teachers are not aware of engineering design integration in science teaching. The most important challenge for science teachers across all regions in terms of mathematics integration is helping students solve simple integration equations (Male/Mean= 2.43, Female/Mean= 2.30).

The qualitative methods provided the researcher with in-depth information about the nature of challenges that encounter science teachers while using integration in science teaching. These challenges can be categorized into three levels:

1) Challenges related to teachers,

2) Challenges related to students, and

3) Challenges related to management and administration.

Overall, even though there is a main effect of region and gender on the dependent variables, the actual differences on science teachers average scores on the dependent variables are statistically minimal. This suggests that science teachers across the nation have the same concerns related to the integration of science content & pedagogy, technology, engineering, and mathematics into science teaching. The next chapter will discuss the results and present recommendations for conducting integrative approaches in science teaching.

Chapter Five: Summary, Conclusions, and Implications

This final chapter summarizes and discusses the overall findings of this study as they pertain to identifying the most important challenges and needs that high school science teachers in Saudi Arabia experience as they pursue integrative approaches in science teaching. This chapter begins with a summary of the study, the results, and discussion of these findings. Study implications, limitations, and recommendations for future research are then presented.

This study has used mixed qualitative and quantitative methods to investigate the most important perceived challenges and needs of high school science teachers in Saudi Arabia related to the integration of (1) science content and pedagogy, (2) technology, (3) engineering, (4) mathematics, and (5) STEM as whole in science teaching. The study also investigated how these perceived challenges and needs differ based on gender and geographic region.

The Ministry of Education in Saudi Arabia has played a critical role in improving science and mathematics textbooks to achieve a student-centered constructivist approach to science teaching (Almannie, 2015). However, studies still demonstrate that many science teachers continue to use traditional methods when teaching science (Abouammoh, 2009; Almazroa, Al-Shamrani, 2015). These teachers also tend to view discipline-specific scientific knowledge as a set of isolated facts unrelated to other disciplines, and they fail to integrate the results of research on STEM integration into their teaching. Therefore, there is an urgent need to investigate and improve science teachers' practices of STEM integration in science teaching in Saudi

Arabia. Preparing science teachers with sufficient knowledge and skills in science content and pedagogy, technology, engineering, and mathematics helps improve student learning and understanding (Moore & Smith, 2014; J. A. Morrison et al., 2008).

If we want to improve high school science teachers' knowledge and skills in regard to the implementation of integration in science teaching, it is crucial to explore their views and beliefs about the challenges they might encounter while using an integrative approach to teaching science. Studies have proven that teachers' beliefs have strong effects on their teaching practices (Mansour, 2009; Kagan, 1992). Therefore, there is an urgent need to explore science teachers' beliefs about challenges that affect the pursuit of integrated STEM instruction in Saudi Arabia. By exploring teachers' challenges, concerns, and needs, this study seeks to aid policymakers and professional development experts in designing programs that equip teachers with sufficient STEM knowledge and pedagogical skills; this professional support for teachers, in turn, will eventually lead to improving students' learning and understanding (Moore & Smith, 2014; J. A. Morrison et al., 2008; NRC, 2012; NGSS lead states, 2013).

The main purpose of this study was to explore the most important challenges that high school science teachers may encounter when conducting integrative approaches in science teaching. The study was guided by the following questions:

1. What are the most important challenges and needs perceived by Saudi Arabian high school science teachers in relation to the integration of:

   a. Separate domains within STEM, including Science content and pedagogy, technology, engineering and mathematics?

   b. STEM as a whole?

2. Are there differences of perceived challenges and needs in terms of gender and geographic region?

The current study was administered to 1,207 certified science teachers in six geographic regions in Saudi Arabia (Makkah, Tabuk, Aseer, Hail, Khahrj, and Zulfi) using a questionnaire that consisted of five domains: demographic information, science content and pedagogy integration, technology integration, engineering integration, and mathematics integration. These domains consisted of 49 Likert-type questions designed to measure high school science teachers' challenges regarding the integration of science, technology, engineering, and mathematics in science teaching. Four open-ended questions were included to gain further information about professional development programs attended in each subject matter domain.

Data were collected through the administration of a web-based survey Qualtrics survey and then imported into SPSS for analysis. Descriptive statistics including mean and standard deviation were utilized to rank science teachers perceived challenges and needs. Then the researcher conducted Two Way MANOVA, and One-Way ANOVA to explore the potential differences in teachers' responses on the questionnaires.

Finally, the researcher conducted a qualitative data analysis in order to identify themes and categories among the factors that science teachers may encounter while conducting science, technology, engineering, and mathematics integration, as well as STEM as a whole in science teaching.

DISCUSSION OF FINDINGS

Data analysis generated the following results:

Discussion of the quantitative method:

1) Discussion of the first research question:

This section identifies and discusses the most important perceived challenges and needs of high school science teachers in Saudi Arabia related to the integration of science content and pedagogy, technology, engineering, and mathematics into science teaching as measured by the results of the questionnaires.

Research Question 1 was addressed through data analysis using descriptive statistics. Scores for teachers' self-competency (perceived challenges) were calculated based on the average score for each item and each scale. Teachers were asked to rate their level of agreement on a 5-point Likert scale (1 =strongly agree, 2 = agree, 3 = neither agree nor disagree, 4 = disagree, and 5 = strongly disagree). Higher mean scores demonstrate more challenges and a more need for improvement, whereas lower mean scores indicate fewer challenges and a higher sense of competence.

The quantitative analysis indicated that science teachers in all regions rated themselves as "fairly competent" in the area of *science and content integration (Mean= 1.99; SD= 0.479, n=1,207)*. However, they expressed the greatest need for improvement with regard to the integration of scientific subjects (physics, chemistry, biology, and geology) into their science teaching practices *(Mean= 3.43; SD= 1.15, n=1,207)* in all the targeted regions as shown in previously outlined in Table 4.3 and Figure 4.4 and 5.1.

In the area of *technology integration*, science teachers demonstrated more need for improvement compared to the area of science content and pedagogy integration. They rated themselves as "fairly low competent" (M=2.51, SD= 0.768, n= 1,207) in technology integration. They believe that they need the greatest improvement with regard to engaging students in conducting scientific research with the same approaches that researchers employ, such as using databases and experimentation. Also, science teachers demonstrated a great need for improvement in helping students use a variety of technologies, e.g. PhET, data visualization, and communication tools, as shown in Table 4.6 and 5.1.

Concerning engineering integration, science teachers across all regions demonstrated the greatest need for improvement with regard to the implementation of engineering design process in science teaching compared to the other domains. As indicated in Table 4.8, teachers tend to rate themselves as "undecided" (M = 2.8, SD = 0.804, n = 1,207) in the acquisition of knowledge and skills required for engineering integration since they lack the awareness of such integration in science teaching as shown in table 4.7 and 5.1.

For mathematics integration, study participants generally rated themselves as "fairly competent" in the area of mathematics integration (M = 2.14, SD = 0.831, n = 1,207) as illustrated in Table 4.10. They expressed more need for improvement in helping students solve simple integrating equations; recognize patterns in data; and solve multistep problems by: a) perceiving the problem to be solved, b) identifying the mathematical principles involved, and c) performing the appropriate mathematics.

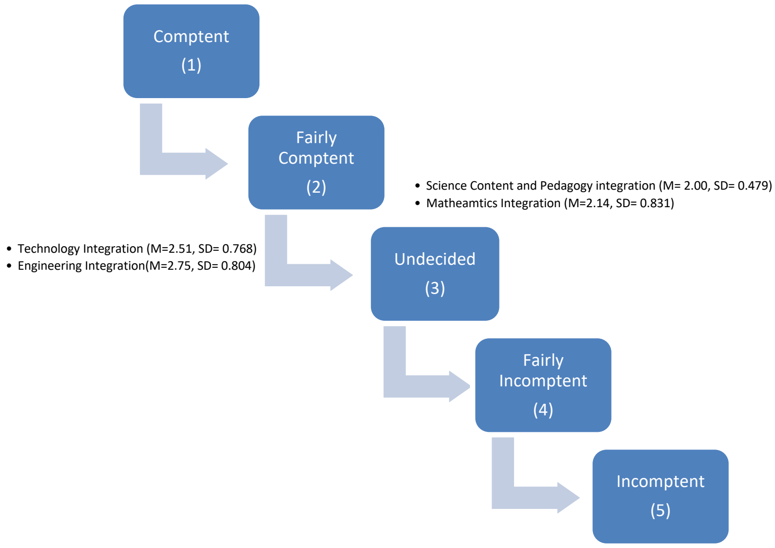


Figure 5.1: Science teachers' competency scale on each Domain

These results indicate that science teachers in Saudi Arabia need improvement in the four domains: science content and pedagogy, technology, engineering, and mathematics integration. However, they expressed the greatest need for improvement with regard to the integration of science disciplines subjects (physics, chemistry, biology, and geology) into their teaching practices, engineering integration, and technology integration.

These results coincide with previous research (Berlin, 1994; Pang & Good, 2000; Venville, Wallace, Rennie, & Malone, 2002) with regard to teachers' capacity to integrate other science disciplines into science teaching. The results also reinforce the findings of Ma (1999), who stated that ‘‘Limited subject matter knowledge restricts a teacher’s capacity to promote conceptual learning among students’’ (p. 36). Overall, high school science teachers rate themselves as experts in their own scientific discipline, but often believe they are underprepared to incorporate other disciplines into science teaching. Teachers majoring in one discipline tend not to conduct integrative approaches that focus on project-based learning; rather, they follow a prescribed curriculum (Roehrig, 2004).

Data collected from the research sample indicated that the percentages of male and female science teachers attending professional development programs in technology integration were only 39.2% and 52% respectively, whereas the percentages of teachers attending professional development programs in engineering integration were only 8.7% and 8.1% respectively, as shown in Figure 5.2. These low percentages of teachers attending professional development programs in technology and engineering integration may explain why science teachers expressed the greatest need for improvement with regard to the implementation of technology and engineering integration.

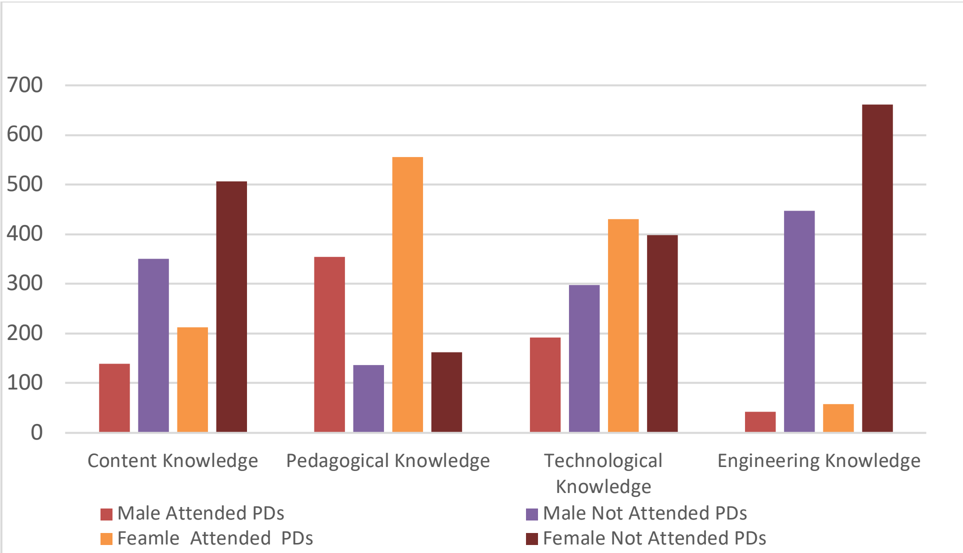


Figure 5.2: Teachers' Participation in PDs Based on Each Domain

Studies have found that teachers' competency is considered a major factor for successful teaching and student learning (Tschannen-Moran & Hoy, 2001). Teachers with high levels of competency tend to adopt new strategies that fulfill students' needs and concerns (Guskey, 1988; Stein & Wang, 1988) and provide struggling students with adequate time to accomplish projects and assignments (Gibson & Dembo, 1984), whereas teachers with low level of competency tend to rely on teacher-directed instruction and avoid innovative approaches such as hands-on activities, experimentation, and real-world applications (Powell-Moman & Brown Schild, 2011).

The current study also found positive correlations among the four dimensions of scale: science content and pedagogy, technology, engineering, and mathematics integration as illustrated in Table 4.1. This result concurs with the finding of Suprapto (2016). This study found significant correlation among the dimensions of the scale utilized to explore students' attitudes toward science, mathematics, technology and engineering, and STEM as a whole. Foster (2005) ensured this interrelationship among STEM components when he stated, "Science and technology education share more content than do most pairs of subjects …. science and technology should be easily correlated, or even fully integrated, in K-12 education" (p.50)

In summary, the quantitative method results indicate that high school science teachers have difficulties in the area of science content and pedagogy, technology, engineering, and mathematics integration. Also, the study found a positive correlation among the four dependent variables, which ensure the fact that science, technology, engineering, and mathematics are intertwined subjects (AAAS, 1993).

2) Discussion of the second research question:

The second question aimed to explore the potential differences in high school science teachers' perceived challenges and needs in terms of gender and geographical region. The study found significant differences in high school science teachers' average scores of perceived challenges and needs in relation to gender and geographic region as illustrated in Tables 4.15, 4.18, 4.23, and 4.26. However, the effect sizes calculated using Partial Eta Squared are too small to be meaningful, as shown in Table 4.12 and Figure 4.8.

In other words, high school teachers in the six regions had similar mean scores for science content & pedagogy, technology, engineering, and mathematics integration. This is not a surprising result since the educational system in Saudi Arabia is centralized (El-Deghaidy, Mansour, 2015) and administered by the Ministry of Education, which assign the same curricula and professional development programs needed for teachers. This result concurs with the finding of Mansour, Alshamarani, Al Dahmash, and Al quadah (2013). The results of the study indicated that there were no statistically significant differences that can be attributed to dependent variables such as gender. On the other hand, the current study findings disagree with Lin, Tsai, Chai, and Lee (2013). This study found that female science teachers perceive higher self-confidence in pedagogical knowledge but lower self-confidence in technological knowledge than male teachers. The reason of this disagreement may be attributed to the differences in science teachers' preparation programs.

Discussion of the qualitative method:

The qualitative method indicated that the challenges and factors that hinder science teachers from using integrative approaches in science teaching were fairly consistent across subjects. There were five main challenges and concerns that hinder teachers from the implementation of the STEM integration in science teaching.

First, science teachers have *negative attitudes and misconceptions* about integration. For example, some teachers believe that integration might lead to students' misunderstanding or distraction. Other teachers believe that technology integration involves merely using digital resources, such as computers or PowerPoint. Others look at engineering integration as simply drawing or using computer software such as AutoCAD.

Second, science teachers *lack sufficient content, pedagogical, and technological knowledge* in teaching science using an integrative approach. For example, science teachers expressed difficulties with regard to the integration of science discipline topics due to the fact that each teacher is only qualified to teach one specific discipline. Teachers also expressed their concerns regarding the acquisition of pedagogical knowledge required for integration, such as knowledge of how to implement project-based learning (PBL). Moreover, they were highly concerned about employing technology in science teaching and experimentation.

Third, the *current curricula are not compatible with integrative approaches* since the educational system at all levels in Saudi Arabia focuses on teaching science curricula as isolated subjects in separate classrooms within schools. Aa a result, science teachers tend to deliver each science topic in isolation from other disciplines.

Fourth, *teachers lack adequate time and resources* for integrative approaches. Teachers believe that integrated approaches require more time and resources compared to traditional approaches. For example, two periods with 45-50 minutes long per week is not enough for teaching science using an integrative approach.

Fifth, *lack of students' knowledge and skills in science and mathematics* is a strong barrier that prevents teachers from conducting an integrative approach to science teaching. For example, students lack subject matter content and skills required for integration, such as solving simple mathematics problems and balancing chemical equations.

The findings of the qualitative methods are in agreement with previous research (Roehrig, 2004; Minshew and Anderson, 2015; Al-Alwani, 2005; Almohaissin, 2006; Bingimals , 2009; Bingimals, 2009; Ayyash & Black , 2014; Siew, Goh, & Sulaiman, 2016; Katehi, Pearson, & Feder , 2009; Huntley ,1998; Watanabe & Huntley, 1998; Stohlmann, Moore, & Roehrig , 2012; Asghar, Ellington, Rice, Johnson & Prime, 2012;

El-Deghaidy & Mansour, 2015; Mansour, Alshamarani, Al Dahmash, & Al quadah, 2013; Mansour, El-Deghaidy, Al shamrani, & Aldahmash, 2014; Park, Cramer, & Ertmer, 2004; Park & Ertmer, 2008; Maxwell, Bellisimo, & Mergendoller, 2001; Meier, Hovde, & Meier, 1996; Nadelson, Seifert, & Hendricks, 2015). These studies indicate that science teachers expressed concerns related to the integration of STEM in science instruction.

The researcher noticed that high school science teachers rated themselves as fairly competent in the areas of science content and pedagogy integration and mathematics integration. On the other hand, they rated themselves as having fairly low competence in technology integration, and "undecided" in the area of engineering integration. However, the findings of the qualitative method indicated that science teachers are underprepared for STEM integration due to internal and external reasons. The reason for this conflict is that science teachers misconceive integrative approaches or conceive them at the lowest level of integration. For example, some science teachers believe that bringing in theoretical and marginal information from other disciplines qualifies as full integration. Also, they believe that technology integration is defined as using PowerPoint or Microsoft Word processing. Others confuse the engineering design process with the use of scientific theory. In fact, the research design conducted in this study is useful for exploring science teachers' challenges while conducting integrative approaches, particularly when unanticipated results emerge from the quantitative study (Morse, 1991).

Consequently, the results of explanatory sequential design indicate an urgent need for a systemic reform of science education in Saudi Arabia. Drawing on the Concerns-Based Adoption Model (see Appendix 15), science teachers' concerns center on self and management concerns. One of the most important factors that will lead to improving teachers' practices and raising their concerns to the "impact" level is providing them with professional development programs that enhance their knowledge of content, pedagogy, technology, engineering design, and STEM as a whole.

Providing science teachers with high-quality, ongoing, content-focused, data-driven professional development programs that focus on integration will promote science teachers' practices, students' learning (Yoon et al., 2008; Loucks-Horsley et al., 2009; Darling-Hammond, 2000), and teachers' awareness of integration conceptions in science education. This increased awareness might in turn change teachers' perceptions about science, technology, engineering, and mathematics integration.

Studies indicate that one of the greatest challenges that hinder teachers from improving their knowledge and skills is the lack of continuous professional development programs (CPDs) that focus on teachers' needs and new trends in science education (Long & Long, 2012; Nadelson et al., 2013; Stohlmann, Micah; Moore & Roehrig, 2012; Day & Sachs, 2004) within the context of the content that will be taught (Gonzales et al., 2004) and that achieve a balance between philosophic and pragmatic approaches. It is critical to take into consideration that real change in teachers' practices requires over 80 hours of professional development in each skill needed for improvement (Banilower, Heck, & Weiss, 2007; Fullan, 1993; Guskey, 1994). The Professional Development Programs Design Framework (Loucks-Horsley et al., 1998) illustrated in Figure 5.3 demonstrates the dynamic process of conducting professional development programs. According to this framework, professional development is an ongoing process that begins with setting goals based on teachers' needs and contemporary trends. This step is followed by planning and ongoing reflection. Professional development providers should take into consideration the contextual factors that shape teachers' knowledge and beliefs.

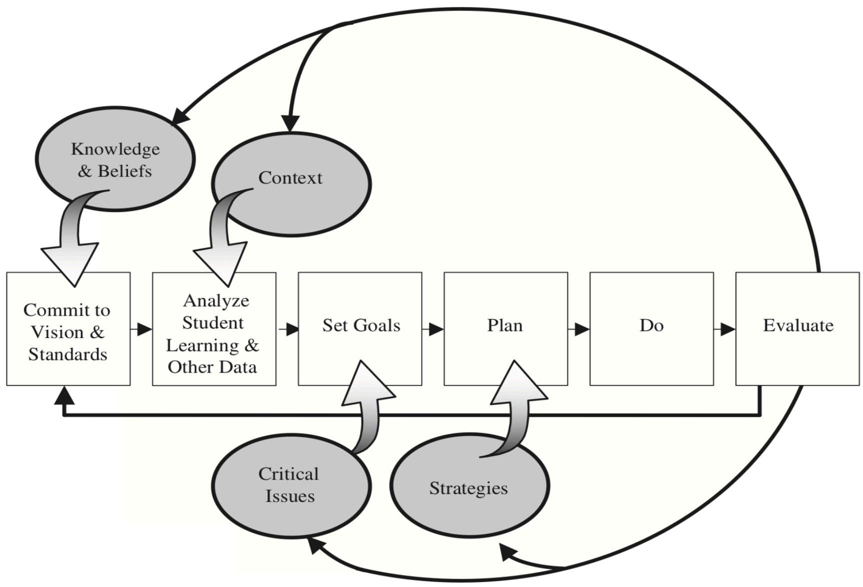


Figure 5.3: Design framework for professional development in science and mathematics. Form Loucks-Horsley et al., 1998, p. 34.

In addition to providing science teachers with ongoing professional development programs that enhance integration, there is a critical need to explicitly include STEM integration in the current curricula, since "the ideas and practice of science, mathematics, and technology are so closely intertwined that we do not see how education in any one of them can be undertaken well in isolation from the others" (AAAS, 1993, pp. 321–322). The current U.S. standards-based documents guiding science education (National Research Council, 1996), mathematics education (National Council of Teachers of Mathematics, 2000), technology education (International

Technology Education Association, 2003), and Standards for K-12 Engineering Education (National Research Council, 2010) have all called for building explicit connection among STEM disciplines to enhance student achievement and improve students' attitudes in these subjects.

Finally, implications of this study indicate that in order to enhance science, technology, engineering, and mathematics integration in Saudi Arabia, there is an implied urgent need to (1) providing teachers with educational strategies that help them manage their science classrooms, especially with a large number of students, (2) provide schools with devices and equipment, (3) diagnose students' knowledge and skills, and (4) provide students with relevant intervention programs, such as AVID (https://www.austinisd.org/avid). Studies showed that lack of space, resources, maintenance, and skills such as technological knowledge are considered important challenges that hinder science teachers from conducting effective integrative approaches and constructive teaching methods in science teaching (Bingimlas, 2009; Albugami, 2015; Qablan, Mansour, Alshamrani, and Aldahmash, 2015).

The results of this study are summarized by the following conclusions:

- Science teachers rate themselves as fairly competent with regard to the integration of science content and pedagogy in science instruction.
- Science teachers rate themselves as fairly competent with regard to the integration of mathematics in science instruction.
- Science teachers rate themselves as fairly low incompetence with regard to the integration of other science disciplines (physics, chemistry, biology, and geology) into science teaching practices.
- Science teachers rate themselves as fairly low incompetence with regard to the integration pf technology in science instruction.
- Science teachers rate themselves as "undecided" with regard to the integration of engineering in science instruction because they may not be familiar or may be confused about the term "Engineering Design".
- There are positive correlations among all science teachers' perceived challenges in the dependent variables of the STEM components.
- The professional development programs currently available to these teachers are mainly oriented toward addressing pedagogical issues such as classroom management.
- Professional development programs focusing on STEM integration were very limited or negligible.
- The qualitative method indicates additional challenges that hinder science teachers from conducting integrative approaches in science teaching. These challenges are:
    - Science teachers have negative attitudes and misconceptions about integration.
    - Science teachers lack sufficient content, pedagogical, and technological knowledge and skills.

- The current curricula are not compatible with the contemporary integrative approaches.
- Time and resources are not sufficient for conducting effective integrative approaches.
- Students lack sufficient fundamental knowledge and skills in STEM domains.

IMPLICATIONS FOR PRACTICE

The evaluative research (2015) conducted by The Excellence Research Center of Science and Mathematics Education at King Saud University to evaluate the project "Upgrading Mathematics and Science Curriculum of the Public School in Saudi Arabia" emphasized studying the quality of the project's implementation in the educational field. The study found that science teachers in Saudi Arabia expressed concerns about professional development programs. Based on their perceptions, science teachers indicated that all professional development standards have been achieved at only a medium level. Therefore, there is a sense of urgency to study science teachers' challenges and concerns regarding the use of integrated approaches in science teaching. The results of the current study support other studies related to the challenges and factors that hinder science teachers from implementing integrated approaches to STEM instruction.

This study can serve as an initial step toward ascertaining and addressing science teachers' challenges and concerns regarding integrative approaches to science teaching. Moreover, the results of this study can have essential implications for teachers, principals, educational supervisors, leaders, and policymakers in terms of helping teachers improve their knowledge and practices with regard to STEM integration.

For school administrators, the results of this study may provide leverage to encourage teachers to participate in professional development programs that focus on integration. For professional development providers and supervisors, the findings may aid in designing professional development programs that enhance STEM integration, as well as prioritizing such programs based on the intensity of need identified by the results of this study.

Finally, the Ministry of Education in Saudi Arabia may find the results helpful in terms of building and designing curricula that focus on integration and real-world practices.

RECOMMENDATIONS FOR FUTURE RESEARCH

The present study explored Saudi Arabian high school science teachers' challenges and concerns related to the integration of science content and pedagogy, technology, engineering, and mathematics in science teaching. The following recommendations may serve to further advance knowledge relevant to the challenges that many science teachers encounter while using an integrative approach:

To support the current study design, it might be beneficial for researchers to analyze documents such as professional development plans or teacher lesson plans in order to gain more detailed information about science teachers' challenges and concerns, especially in terms of professional development programs.

Another important direction for further study is to investigate elementary and middle school science and mathematics teachers' challenges related to integrated STEM instruction. Cotabish et al. (2013) pointed out that elementary school is considered the primary stage for directing students' talents towards integrative learning.

Furthermore, it would be valuable to compare science teachers' anticipated challenges and concerns before and after conducting professional development programs that focus on STEM integration and to study teachers' challenges and concerns before and after putting new integration strategies into practice with their students. It would also be valuable to provide science teachers with science experiments and activities that enhance STEM integration, then study the effects of these teaching strategies on teachers' practice as well as students' learning and attitudes toward STEM.

Finally, it is important to study current curricula and conduct content analyses across different educational stages in order to explore the potential of cross-cutting activities and themes that enhance integration in science education and then study the effects of these activities on teachers' practices, students' achievements, and students' attitudes toward science.

LAST THOUGHT

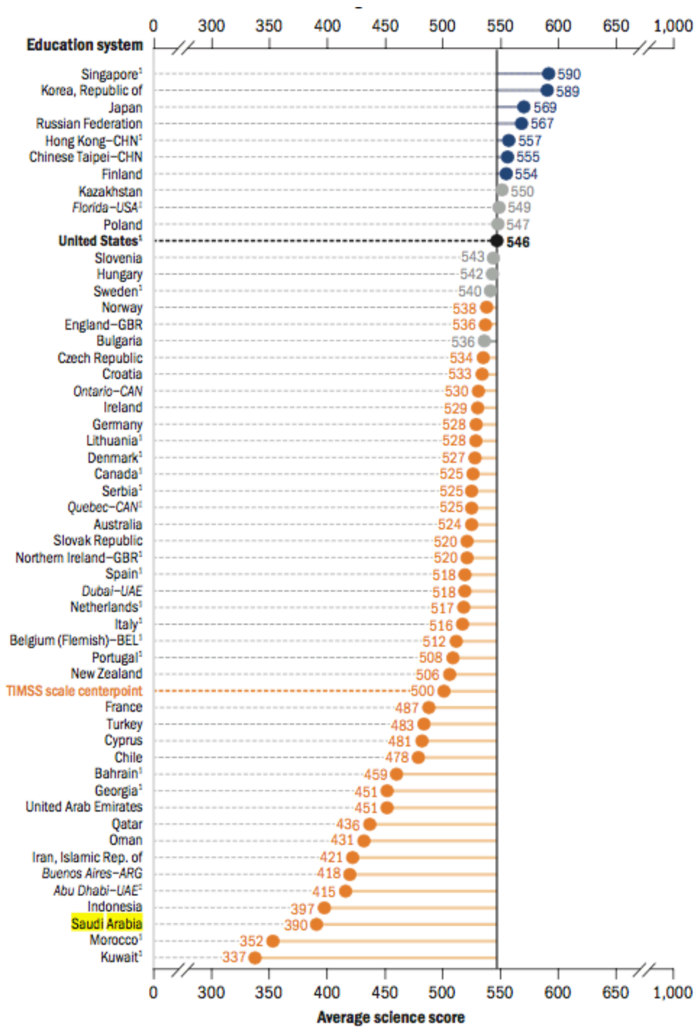
This study investigated high school science teachers' perceived challenges with regard to the implementation of STEM integrative approaches in science teaching. The study found that science teachers expressed needs for improvement across all domains of the study: science content and pedagogy integration, technology integration, engineering integration, and mathematics integration. Also, the study concludes that science teachers in Saudi Arabia are unfamiliar with STEM integrative approaches. Thus, systemic reform requires improving science teachers' skills in all domains since "we do not see how education in any one of them can be undertaken well in isolation from the others" (AAAS, 1993, pp. 321–322). STEM integration activities are not impossible to implement; they have strengths and limitations. A comprehensive, continuous, and systemic educational reform is crucial for improving STEM education in Saudi Arabia and thereby for supporting the nation's economic prosperity in accordance with Saudi Vision 2030.

Appendices

Appendix (1)

Average Mathematics Scores of 4TH -Grade Students, by Education System: 2015

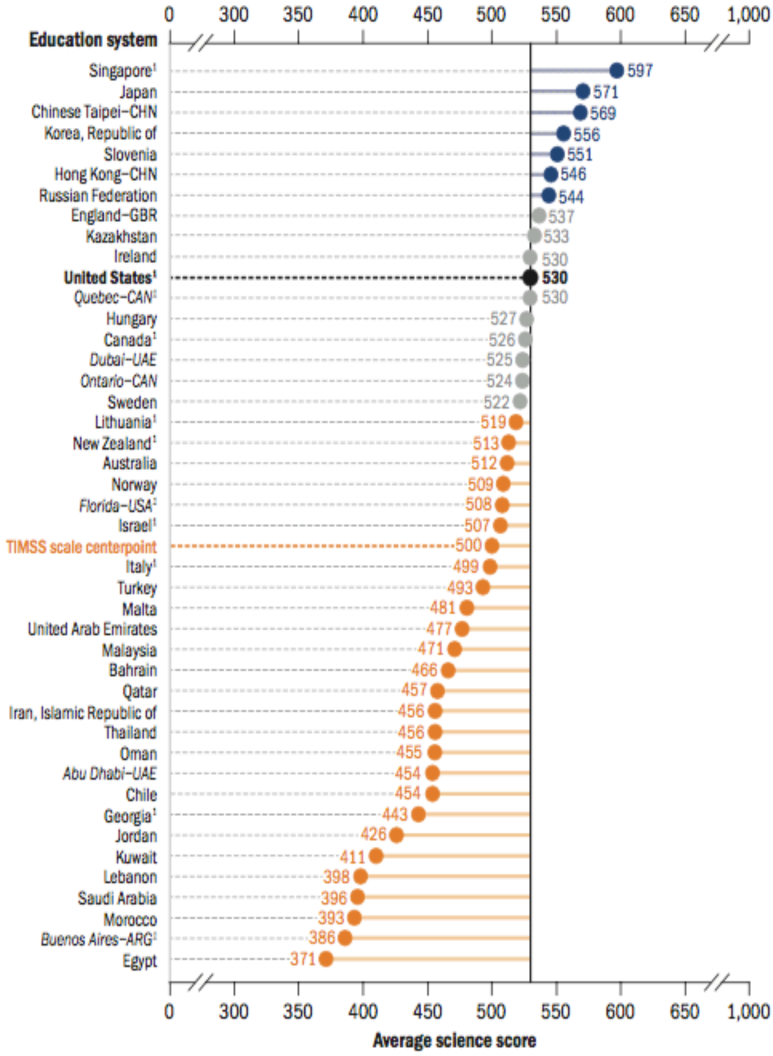
(Stephens, Landeros, Perkins, & Tang, 2016)



Appendix (2)

Average Science Scores of 8th-grade Students, by Education System: 2015

(Stephens, Landeros, Perkins, & Tang, 2016)



Appendix (3)

High School Course Plan (Courses' System)

Core Academic Requirement for all Majors:

Domain	hours	Number of courses	Courses' Details
Islamic Culture	25	5	5 Islamic culture courses
Arabic Language	20	4	Arabic1, Arabic2, Arabic3, Arabic4,
Mathematics	10	2	Math 1, Math 2
Science	20	4	Physics 1, Chemistry 1, Biology 1, and Ecosystem
English Language	20	4	English 1, English 2, English 3, English 4
Social Studies	5	1	Social Studies
Vocational Education	5	1	Vocational Education
Life and Family Education	5	1	Life and Family Education
Health and Physical Education (Boys)	5	1	Health and Physical Education
Health and Physical Education (Girls)			Health and Feminine Education
Total	125	25	

Core Academic Requirement for the Scientific Pathway:

Domain	hours	Number of courses	Courses' Details
Mathematics	20	4	Math 3, Math 4, Math 5, Math 6
Science	40	8	Physics 2, Physics 3, Physics 4, Chemistry 2, Chemistry 3, Chemistry 4, Biology 2, and Biology 3
English Language	5	1	English 5
Total	65	13	

Elective Courses: (10 Credits)

Practical Training	English 6	Arts
Quran 2	English 7 TOEFL	Geoscience
Islamic Culture 3	English 8 IELTS	Astronomy
Computer Science	Research and Information Sources	
Accounting		

Appendix (4)

The Diagram of the Explanatory Sequential Design

	Procedures	**Product**
Developing the Questionnaire and the Interview Protocol	Developing the Research instruments	Questionnaire and Interview Protocol
Phase One		
Quantitative Method Data Collection	Cross-sectional Survey N= 1,207 teachers	Numeric and Textual Data
↓		
Quantitative Method Data Analysis	SPSS Qualtrics	Descriptive and analytic statistics
↓		
Phase Two		
Qualitative Method Data Collection	Case study Individual interviews (N=20)	Transcript Documents N= 20 teachers
↓		
Qualitative Method Data Analysis	Content Analyses	Theme and Categories
↓		
Integration of the quantitative and qualitative Results	Discussion the results of both quantitative and qualitative methods	- Interpretation of the challenges that hinder science teachers from the implementation of STEM integrative approaches. - Implications - Future research

Appendix (5)

The Quantitative Questionnaire

Saudi Arabian High School Science Teachers Concerns Related to Integrating Mathematics, Technology, and Engineering into Science Teaching Questionnaire

Dear Science Teacher,

I am a graduate student at The University of Texas at Austin pursuing a study of your needs and concerns about using integrative educational approach to teaching science (Physics, chemistry, biology, geology).

Please take some time from your busy schedule to complete the enclosed questionnaire. The data and information collected from the questionnaire will be shared among science teachers and educators in Saudi Arabia for the purpose of designing targeted teacher professional development to improve the quality of Science Education in the areas of integrating technology, mathematics, and engineering into science teaching.

Your assistance is greatly appreciated

Yousef Aljuwayr

Purpose of the Study:

The purpose of this study is to investigate the high-priority concerns of high school science teachers in Saudi Arabia in regard to integrate technology, engineering, and mathematics into science teaching.

Research Questions

This study aims to answer the following research questions:

RQ: What are the needs and concerns (challenges) of Saudi Arabian high school science teachers related to the integration of:

1) Science disciplines (physics, chemistry, biology and geosciences);
2) Technology into science teaching;
3) Engineering into science teaching; and
4) Mathematics into science teaching?

Please answer the following questions:

Demographic Information:

1) LOCATION OF SCHOOL (check only one)
   a. ( ) Riyadh
   b. ( ) Makkah
   c. ( ) Zulfi
   d. ( ) Aseer
   e. ( ) East
   f. ( ) North
   g. ( ) Other

2) TEACHER GENDER
   a. ( ) Male
   b. ( ) Female

3) YOUR NATIONALITY: (check only one)
   a. ( ) Saudi
   b. ( ) Non Saudi. (please specify) ……………

4) HIGHEST DEGREE ATTAINED
   a. ( ) Bachelor's Degree
   b. ( ) Master's Degree
   c. ( ) Doctoral Degree
   d. ( ) Ed.D
   e. ( ) Other (please specify) ………………

5) STUDENT GRADE LEVEL
   a. ( ) 10th grade
   b. ( ) 11th grade
   c. ( ) 12th grade
   d. ( ) Other (please specify) ……………

6) TEACHING EXPERINCE (Total)
   a. ( ) Less than one year
   b. ( ) 1-5 years
   c. ( ) 6-10 years
   d. ( ) 11-15 years
   e. ( ) More than 15 years

7) NUMBER OF HOURS YOU ARE TEACHING EVERY WEEK
    a. (   ) Less than 10 Hours
    b. (   ) 10-15 Hours
    c. (   ) 16-20 Hours
    d. (   ) 21-24 Hours

8) WHAT SUBJECT (S) DO YOU TEACH?
    a. (   ) Physics
    b. (   ) Chemistry
    c. (   ) Biology
    d. (   ) Geology
    e. (   ) More than one discipline

9) WHAT SUBJECT HAVE YOU TAUGHT IN THE PAST?
    a. (   ) Physics
    b. (   ) Chemistry
    c. (   ) Biology
    d. (   ) Geology
    e. (   ) Other (please specify) ……………

10) HAVE YOU ATTENDED PROFESSIONAL DEVELOPMENT PROGRAMS (IN THE LAST FIVE YEARS) FOCUSING ON: (CHOOSE ALL THAT APPLY)
    a. (   ) Content Knowledge. Please specify? ……….
    b. (   ) Pedagogy Knowledge. Please specify? ……….
    c. (   ) Technology. Please specify? ……….
    d. (   ) Engineering. Please specify? ……….
    e. (   ) Other (please specify) ……………

Part one:

Please answer the following questions in regards to your own subject matter content knowledge (Physics, Chemistry, Biology, Geology, etc.)

Science (content and pedagogy): science is the study of natural world, including physics, chemistry, biology, and geology.					
Item	Strongly agree (1)	agree (2)	Neither Agree or Disagree (3)	Disagreed (4)	Strongly Disagree (5)
1) I have sufficient knowledge about science.					
2) I can think about the content of science subjects like a subject matter expert.					
3) I am able to develop deeper understanding about science.					
4) I am able to stimulate my students' scientific thinking by engaging them in challenging tasks.					
5) I am able to guide my students to adopt appropriate learning strategies for science.					
6) I am able to help my students monitor their own science learning.					
7) I am able to help my students reflect on their learning strategies					
8) I am able to guide and motivate my students to share their thoughts during science group work.					
9) I can address the common misconceptions my students have about science.					
10) I know how to select effective teaching approaches to guide student thinking and learning in science.					
11) I can help my students understand the content knowledge of science by using a variety of instructional technology tools.					
12) I am able to integrate science disciplines (physics, chemistry, biology, and geology) into my teaching practices.					

Note: science means your major; physics, chemistry, biology or geology.

Q: Any additional comments, notes, suggestions, or concerns related to science integration?

....

Part Two:
Please answer the following questions about Instructional Technology Knowledge and Skills.

Technology: Technology is defined as any innovation or device created by people for the purpose of meeting human need or want.					
Items	Strongly agree (1)	Agree (2)	Neither Agree or Disagree (3)	Disagreed (4)	Strongly Disagree (5)
1) I am able to help my students use a variety of technologies, e.g. PhET, data visualization, research, and communication tools.					
2) I am able to help my students use technology to communicate and collaborate with others, beyond the classroom.					
3) I am able to help my students use online resources and information.					
4) I am able to help my students use the same kinds of tools that professional researchers use, e.g. databases, satellite imagery.					
5) I am able to help my students work on technology-enhanced projects that emphasize real- world applications of technology.					
6) I can help my students use technology to help solve problems.					
7) I wonder if I can help my students use technology to support higher-order thinking, e.g. analysis, synthesis, and evaluation of ideas and information.					
8) I am able to help my students use technology to create new ideas and representations of information.					

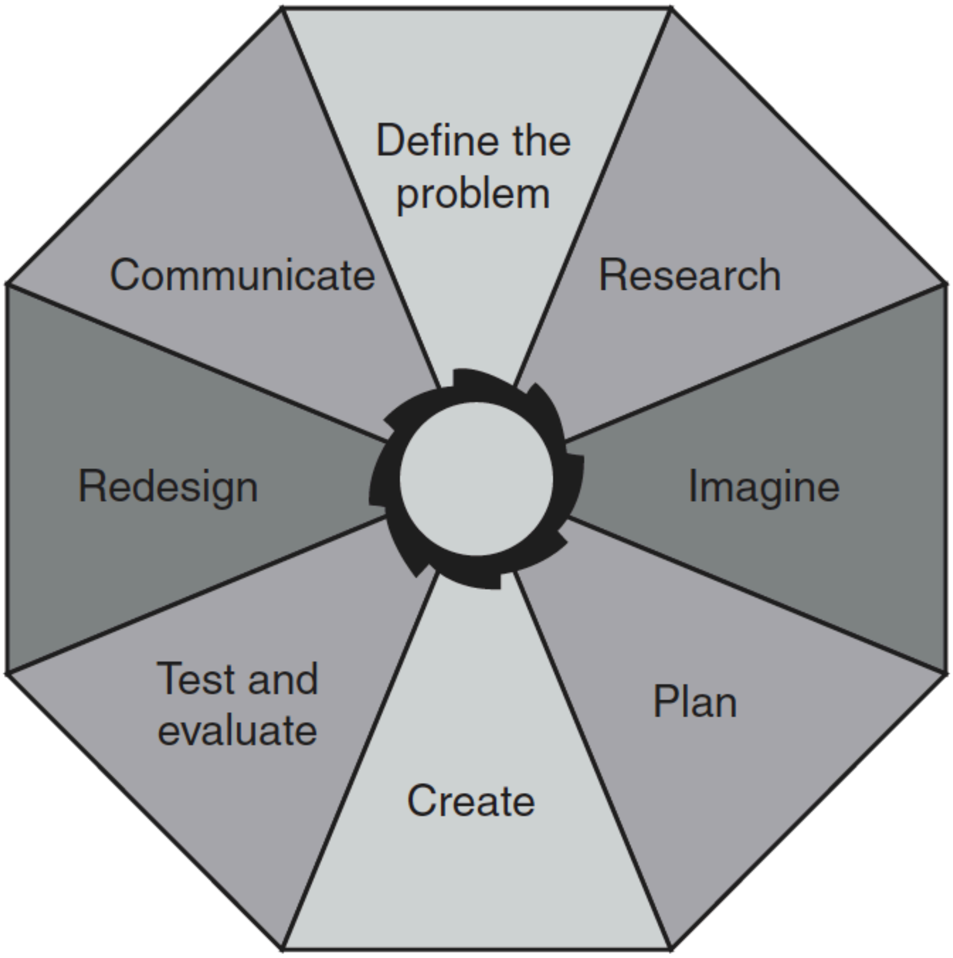
Q: Any additional comments, notes, suggestions, or concerns related to integrating technology into science teaching?

....

Part Three:
Please answer the following questions regarding Engineering:

Engineering: Engineering is the natural conduit for integrating and applying science, math, and technology. It is the "glue" that integrates those subjects and forces them toward a workable solution using the Engineering Design Process.					
Item	Strongly agree (1)	agree (2)	Neither Agree or Disagree (3)	Disagreed (4)	Strongly Disagree (5)
1) I am familiar with the engineering design process represented by the graphic attached.					
2) I have sufficient knowledge to have my students define engineering problems clearly.					
3) I have sufficient knowledge to have my students specify constraints and identify criteria of engineering problems.					
4) I have sufficient knowledge to have my students brainstorm possible solutions of scientific problems.					
5) I have sufficient strategies to teach my students how to generate ideas.					
6) I have sufficient knowledge to have my students explore solutions of scientific problems.					
7) I have sufficient knowledge to teach students how to select an approach to solve engineering problems.					
8) I have sufficient knowledge to have my students create a model or prototype of an engineering problem.					
9) I have sufficient knowledge to have my students refine and improve design solutions.					
10) I can direct students' design projects based on customers' needs.					
11) I have sufficient knowledge to have my students test and evaluate their proposal designs.					
12) In general, I find it difficult to implement engineering design approach in my teaching.					

Q: Any additional comments, notes, suggestions, or concerns related to integrating engineering into science teaching?



Engineering Design Process, adapted from Jolly, 2017, p. 18

Part Four:

Please answer the following questions regarding Mathematics:

Mathematics: students use their mathematical abilities and understanding to analyze, reason, and interpret solutions to problems in variety of real-world scenarios.					
Item	Strongly agree (1)	agree (2)	Neither Agree or Disagree (3)	Disagreed (4)	Strongly Disagree (5)
1) I can help my students perform mathematical computations when given algebraic expressions such as quadratic equations, negative exponents etc.					
2) I can help my students convert word expressions into mathematical ones.					
3) I can help my students recognize equalities and inequalities.					
4) I can help my students visualize the different types of solids shapes (spatial visualization).					
5) I can help my students apply the concept of transformation (translation, rotation, and reflection) in science.					
6) I can help my students interpret data in different layouts (e,g. in tables, graph, written)					
7) I can help my students distinguish between symmetric and non-symmetric groups.					
8) I can help my students solve simple integration equations.					
9) I can help my students distinguish between direct and inverse proportions.					
10) I can help my students identify various types of angles in given shapes such as prisms.					
11) I can help my students use appropriate mathematical tools strategically.					
12) I can help my students reason abstractly.					
13) I can help my students reason quantitatively.					
14) I can help my students recognize patterns in data					
15) I can help my students solve multistep problems by:					
a) Perceiving the problem to be solved					
b) Identifying the mathematical principles involved					
c) Performing the appropriate mathematics					

Q: Any additional comments, notes, suggestions, or concerns related to integrating Mathematics into science teaching

Appendix (6)

Open-ended Interview Protocol

Number : ………………………………………………………

Location of the school: ……………………………………………………….

Gender: ………………………………………………………..

Nationality: ……………………………………………………

Highest degree attained: ……………………………………………………..

Student grade level: ……………………………………………………..

Teaching experience: ……………………………………………………..

Subjects you are teaching: ……………………………………………………..

Teaching Experience ………………………………………………

1) What are your thoughts about **science** integration?
    a. How do you integrate science disciplines in your teaching? Draw a framework.
    b. Give examples from your teaching.
    c. What are the most important **challenges** that hinder you from implementing science integration (physics, chemistry, biology, geosciences) in your teaching practices?
2) What are your thoughts about integrating **math into your science** integration?
    a. Do you integrate mathematics into science teaching practices? If so, how? Draw a framework.
    b. Give examples from your teaching.
    c. What are the most important challenges that hinder you from integrating mathematics into science teaching?
3) What are your thoughts about integrating **technology into your science instruction**?
    a. Do you integrate technology into science teaching practices? If so, how? Draw a framework.

b. Give examples from your teaching practices.
c. What are the most important challenges that hinder you from integrating technology into science teaching?

4) What are your thoughts about integrating **engineering into your science instruction**?
    a. Do you integrate engineering into science teaching practices? If so, how? Draw a framework.
    b. Give examples your teaching practices.
    c. What are the most important challenges that hinder you from integrating engineering into science teaching?
5) What are your thoughts about the integration **science, technology, engineering, and mathematics** in your teaching?
    a. Do you integrate science, technology, engineering, and mathematics in your teaching practices? If so, how? Draw a framework.
    b. Give examples from your teaching practices.
    c. What are the most important challenges that hinder you from integrating science, technology, engineering, and mathematics in your teaching practices?

Appendix (7)

Scholars Reviewed the Questionnaire and the Interview Protocol

N.	Name	Degree	Major
1	James P. Barufaldi	Associate Professor, STEM Education	Professor Emeritus, STEM Consultant, The University of Texas at Austin
2	Catherine Riegle-Crumb	Associate Professor, STEM Education	Department of Curriculum and Instruction, The University of Texas at Austin, United States
3	Jill A Marshall	Associate Professor, STEM Education	Department of Curriculum and Instruction, The University of Texas at Austin, United States
4	Maura Borrego	Professor	Mechanical Engineering, The University of Texas at Austin, United States
5	Carol Flecher	PhD, Mathematics Education	Deputy Director, The Center for STEM Education at The University of Texas at Austin
6	Mary E. Hobbs	PhD, Science Education	Coordinator for Science Initiatives, The Center for STEM Education at The University of Texas at Austin
7	Yi Kong	Assistant Professor, Science Education	Science education, Fujian Normal University, China
8	Jair Aguilar	Assistant Professor, STEM Education	The University of Texas Rio Grande Valley, United States
9	Fahad Al Shaya	Professor, Science Education	Dean of the Education School, King Saud University, Saudi Arabia
10	Kamil Jbeily	Professor, Science Education	Professor in the Chemistry department at Austin Community College, Austin, TX
11	Saeed Al Shamrani	Professor, Science Education	Department of Curriculum and Instruction, King Saud University, Saudi Arabia
12	Mohammed Al Natheer	Professor, Mathematics Education	Department of Curriculum and Instruction, King Saud University, Saudi Arabia
13	Saleh A. Al Abdulkareem	Professor, Science Education	Department of Curriculum and Instruction, King Saud University, Saudi Arabia
14	Sulaiman M. Al-Balushi	Assistant Professor, Science Education	Dean - College of Education, Sultan Qaboos University, Oman
15	Noelle Luccioni	PhD Candidate, Science Education	Temple University, College of Education, TU, United States
16	Abdul Rahman Al Romi	PhD Candidate, Linguistic Department	Imam Mohammad Bin Saud University, Riyadh, Saudi Arabia

Appendix (8)

The Arabic Version of the Questionnaire

جامعة الملك سعود
King Saud University
المملكة العربية السعودية
ص.ب 2458 الرياض 11451
www.ksu.edu.sa
جامعة الملك سعود (034)
هاتف 4674819 11 966+
فاكس 4674815 11 966+
كلية التربية
مكتب العميد

سعادة مدير عام المركز الوطني لبحوث سياسات التعليم بوزارة التعليم حفظه الله

السلام عليكم ورحمة الله وبركاته، وبعد

أفيد سعادتكم أن الأستاذ/ يوسف بن فراج الجوير (المحاضر بقسم المناهج وطرق التدريس والمبتعث لدراسة مرحلة الدكتوراه) يقوم بإعداد دراسة علمية بعنوان (دراسة المعوقات التي تواجه معلمي العلوم الطبيعية اثناء دمج الرياضيات، والتقنية، والهندسة في تدريس العلوم الطبيعية في المرحلة الثانوية بالمملكة العربية السعودية) واستكمالاً لمتطلبات الحصول على درجة الدكتوراه من جامعة أوستن تكساس بالولايات المتحدة الأمريكية. كما تعد الدراسة من الدراسات التي يدعمها مركز التميز البحثي في تطوير تعليم العلوم والرياضات، وحيث يرغب تطبيق الأداة المرفقه (الاستبانة والمقابلة) على عينة من المعلمين والمعلمات في مدارس المرحلة الثانوية في عدد من مناطق المملكة، لذا نأمل التكرم بمكاتبة إدارات التعليم التالية :

- الإدارة العامة للتعليم بمنطقة عسير.
- الإدارة العامة للتعليم بمنطقة مكة المكرمة.
- الإدارة العامة للتعليم بمنطقة تبوك.
- الإدارة العامة للتعليم بالمنطقة الشرقية.
- الإدارة العامة للتعليم بمنطقة حائل.
- إدارة التعليم بمحافظة الزلفي.
- إدارة التعليم بمحافظة الخرج.

عليه آمل تكرم سعادتكم الموافقة وتسهيل مهمته، متمنين له التوفيق.

وتقبلوا فائق تقديري،،

عميد كلية التربية

أ.د. فهد بن سليمان الشايع

رابط الاستبانة الالكتروني (https://utexas.qualtrics.com/jfe/form/SV_bNoBQ9mzOjSXroN)

٣/٨/١١٠١٢٦

١٤٣٩/٣/١٠هـ

إجراءات التطبيق:

أولا: المستهدفون بالدراسة:

معلمو ومعلمات العلوم الطبيعية (الفيزياء، الكيمياء، الأحياء، علم الأرض) للمرحلة الثانوية فقط في المناطق التالية: عسير، مكة المكرمة، تبوك، حائل، الزلفي، الخرج، المنطقة الشرقية.

ثانيا : أدوات البحث:

١) أداة كمية: استبيان إلكتروني (مرفق ١)

٢) أداة نوعية: أسئلة مقابلة (مرفق ٢)

ثالثا: طريقة المشاركة الدراسة:

يتم المشاركة في الدراسة من خلال الإجابة على أسئلة الاستبيان الإلكتروني بإحدى الطرق التالية:

١) الدخول على الرابط التالي:

https://utexas.qualtrics.com/jfe/form/SV_bNoBQ9mzOjSXroN

أو

٢) استخدام رمز الاستجابة السريعة أو ما يعرف QR Code :

أو

٣) استخدام الرابط التالي:

المعوقات التي تواجه معلمي العلوم الطبيعية أثناء دمج الرياضيات، والتقنية، والهندسة في تدريس العلوم الطبيعية في المرحلة الثانوية بالمملكة العربية السعودية

الاستبيان الإلكتروني

مرفق (٢)

بسم الله الرحمن الرحيم

دراسة المعوقات التي تواجه معلمي العلوم الطبيعية أثناء دمج الرياضيات، والتقنية، والهندسة في تدريس العلوم الطبيعية في المرحلة الثانوية بالمملكة العربية السعودية

المكرم معلم العلوم الطبيعية (الفيزياء، الكيمياء، الأحياء، علم الأرض) حفظه الله

المكرمة معلمة العلوم الطبيعية (الفيزياء، الكيمياء، الأحياء، علم الأرض) حفظها الله

السلام عليكم ورحمة الله وبركاته،

تسعدني مشاركتكم معي في هذا البحث العلمي والذي يهدف إلى دراسة المعوقات التي يمكن أن تواجهكم بصفتكم أحد معلمي العلوم في المملكة العربية السعودية أثناء دمج المهارات الرياضية (الرياضيات) والتقنية والهندسة في تدريس العلوم الطبيعية (الفيزياء، الكيميا، الأحياء، وعلم الأرض).

أرجو منكم التكرم بالإجابة عن الاستبانة المرفقة والتي تتكون من ٤٧ فقرة، موزعة كالتالي:

١) البيانات الأساسية للمعلم (المؤهل ، سنوات الخبرة.....)

٢) معوقات تتعلق بالمحتوى العلمي والتربوي والتكامل بين العلوم الطبيعية (فيزياء، كيمياء، أحياء، علم الأرض).

٣) معوقات دمج التقنية (التكنولوجيا) في تعليم العلوم الطبيعية.

٤) معوقات دمج الهندسة (التصميم الهندسي) في تعليم العلوم.

٥) معوقات دمج المهارات الرياضية في تعليم العلوم.

أرجو أن تجد وقتا كافياً للإجابة عن هذه الاستبانة، علما بأن البيانات لن تستخدم إلا لأغراض بحثية، كتحديد الاحتياجات التدريبية لمعلمي العلوم الطبيعية في المملكة العربية السعودية حول دمج العلوم، والهندسة، والتقنية، والمهارات الرياضية أثناء تدريس العلوم الطبيعية والذي يعد أحد التوجهات الحديثة في تعليم العلوم الطبيعية.

لمزيد من المعلومات أو لأي استفسار حول هذه الأداة، يرجى التواصل مع الباحث عن طريق:

يوسف الجوير

جامعة الملك سعود King Saud University كلية التربية College of Education قسم المناهج وطرق التدريس Curriculum and Instruction Department

yusff@hotmail.com
٥١٢٥٧٦٩٨٠٤
٠٥٠٤٤٢١٧٠٠ (واتس أب)

أولاً: البيانات الأساسية:

- الموقع الجغرافي للمدرسة:
  - مكة المكرمة
  - الشرقية
  - عسير
  - تبوك
  - الزلفي
  - الخرج
  - حائل
  - أخرى (حددها: ....)
- الجنس:
  - ذكر
  - أنثى
- الجنسية
  - سعودي
  - غير سعودي
- المؤهل العلمي
  - بكالوريوس
  - ماجستير
  - دكتوراه
  - أخرى (حددها : ....)
- الصفوف التي تدرسها خلال السنة الحالية

- الأول الثانوي
- الثاني الثانوي
- الثالث الثانوي
- أخرى (حددها: ....)

• الخبرة التدريسية
- أقل من سنة
- من ١–٥ سنوات
- من ٦–١٠ سنوات
- من ١١–١٥ سنة
- ١٦ سنة فأكثر

• النصاب التدريسي الأسبوعي من الحصص
- أقل من ١٠ حصص
- من ١٠–١٥ حصة
- من ١٦–٢٠ حصة
- من ٢١–٢٤ حصة
-

• المادة العلمية التي تدرسها حاليا

- الفيزياء
- الكيمياء
- الأحياء
- علم الأرض
- أخرى (حددها : ....)

- هل سبق لك المشاركة في حضور برامج تدريبية – خلال السنوات الخمس السابقة– تركز على:
  - **المحتوى العلمي للمادة**، مثل: الهندسة الوراثية.
    - ( ) نعم، أرجو ذكر أمثلة :

....

    - ( ) لا، أرجو التعليل لعدم حضورها:..............................
  - المحتوى التربوي، مثل استخدام الاستقصاء في تدريس العلوم.
    - ( ) نعم، أرجو ذكر أمثلة :

....

    - ( ) لا، أرجو التعليل لعدم حضورها:..............................
  - المحتوى التقني كاستخدام التعلم الافتراضي، برامج المحاكاة.
    - ( ) نعم، أرجو ذكر أمثلة :

....

    - ( ) لا، أرجو التعليل لعدم حضورها:..............................
  - دمج الهندسة في تعليم العلوم، مثل تصميم جسر أو طريق، تصميم الروبوت .
    - ( ) نعم، أرجو ذكر أمثلة :

....

    - ( ) لا، أرجو التعليل لعدم حضورها:..............................

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ثانيا: معوقات تتعلق بالمحتوى العلمي والتربوي :

آمل الإجابة عن الأسئلة التالية، والتي تُعنى بمدى استيعاب المعلم للمحتوى العلمي والتربوي في تدريس العلوم الطبيعية .

ملحوظة: يقصد بمواد العلوم الطبيعية المادة العلمية (الفيزياء، أو الكيمياء، أو الأحياء، أو علم الأرض) التي يدرسها المعلم.

الفقرة	الاستجابة				
	موافق تماما	موافق	محايد	غير موافق	غير موافق تماما
١) أمتلك المعرفة العلمية الكافية في تخصصي العلمي الذي أدرسه.					
٢) أستطيع التفكير في المحتوى العلمي للمادة التي أدرسها بنفس مستوى تفكير المتخصصين.					
٣) أمتلك القدرة على تطوير طرائق تعليمية تساعد الطلاب على فهم عميق للمادة العلمية.					
٤) أمتلك القدرة على تحفيز التفكير العلمي للطلاب من خلال إشراكهم في أنشطة تتسم بالتحدي.					
٥) أمتلك القدرة على توجيه وقيادة طلابي لتبني استراتيجيات تعلم مناسبة.					
٦) أمتلك القدرة على مساعدة طلابي ملاحظة ومتابعة مستوى تعلمهم.					
٧) أمتلك القدرة على مساعدة طلابي في التفكير والتأمل باستراتيجيات التعلم التي يمارسونها.					
٨) أمتلك القدرة على توجيه وتحفيز طلابي لتبادل أفكارهم من خلال مجموعات التعلم المتنوعة					
٩) أستطيع علاج التصورات الخاطئة (البديلة) الشائعة لدى الطلاب.					
١٠) لدي القدرة الكافية لاختيار أساليب تدريسية فعالة توجه تعلم وتفكير الطالب.					
١١) أستطيع مساعدة طلابي على فهم المحتوى العلمي باستخدام تقنيات تعليم متنوعة.					
١٢) أمتلك القدرة الكافية على تدريس موضوعات المواد العلمية (الفيزياء، الكيمياء، الأحياء، علم الأرض) بشكل تكاملي؛ مما يؤدي إلى تقليص الحواجز بين تلك التخصصات.					

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س: هل يوجد لديكم تعليقات أو ملاحظات أو اقتراحات تتعلق بالمعوقات التي تواجه المعلم من حيث المحتوى العلمي، أو التربوي، أو تكامل تدريس المواد العلمية ؟

ثالثا: معوقات تتعلق بالتقنية (التكنولوجيا):

آمل الإجابة عن الأسئلة التالية والتي تعني باستخدام التقنية في تدريس العلوم الطبيعية.

ملحوظة: يقصد بالتقنية هي أي ابتكار أو جهاز اخترعه الإنسان تحقيقا لاحتياجاته ورغباته. وتشمل التقنية المواد والأدوات اللازمة لإجراء التجارب العلمية إضافة إلى التقنيات الحديثة كالحاسب الآلي والإنترنت ووسائل التواصل الحديثة.

الفقرة	الاستجابة				
	موافق تماما	موافق	محايد	غير موافق	غير موافق تماما
١) أستطيع مساعدة طلابي على استخدام تقنيات وبرامج متنوعة مثل PhET , Net Logo ، التمثيل التصويري للبيانات، المحاكاة ... إلخ					
٢) أستطيع مساعدة طلابي على استخدام التقنية الحديثة للتواصل والتعاون مع بعضهم خارج الفصول الدراسية.					
٣) أستطيع مساعدة طلابي على استخدام المصادر الإلكترونية ومصادر المعلومات المتنوعة.					
٤) أستطيع مساعدة طلابي على استخدام الأدوات التي يستخدمها المتخصصون في بحوثهم العلمية، مثل استخدام قواعد البيانات، صور الأقمار الصناعية .... إلخ					
٥) أستطيع مساعدة طلابي على إنجاز مشاريع باستخدام التقنية والتي تؤكد على استخدام تطبيقات العالم الواقعي (الحقيقي).					
٦) يمكنني مساعدة طلابي على استخدام التقنية في حل المشكلات التعليمية التي تواجههم.					
٧) أستطيع مساعدة طلابي على استخدام التقنية لدعم ممارستهم لمهارات التفكير العليا كالتحليل، التركيب، تقويم الأفكار ... إلخ.					
٨) أستطيع مساعدة طلابي على استخدام التقنية لإنتاج أفكار وتفسيرات جديدة.					

س: هل يوجد لديكم تعليقات أو ملاحظات أو اقتراحات تتعلق بالمعوقات التي تواجه المعلم من حيث استخدام التقنية في تدريس العلوم الطبيعية؟

المحور الرابع : معوقات تتعلق باستخدام الهندسة في تدريس العلوم الطبيعية :

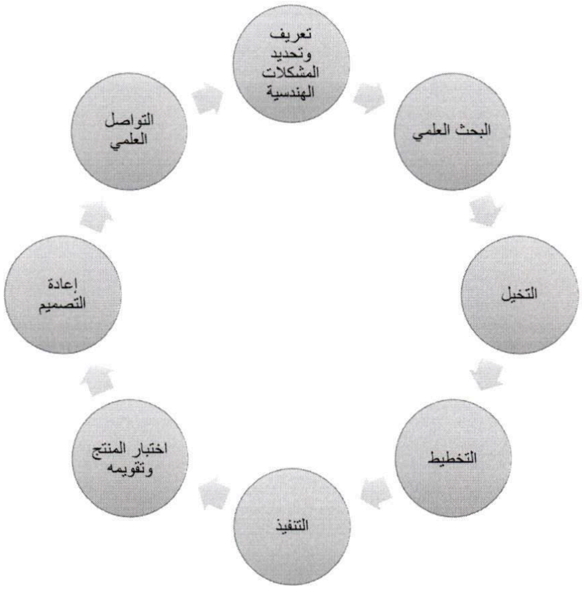
آمل الإجابة عن الأسئلة التالية والتي تعنى بمدى قدرة معلم العلوم الطبيعية على استخدام عملية التصميم الهندسي في تدريس العلوم الطبيعية.

ملحوظة: يقصد باستخدام الهندسة: القدرة على استخدم عملية التصميم الهندسي كحلقة وصل لتكامل العلوم والرياضيات والتقنية وتطبيقاتها والتي تهدف إلى حل المشكلات العلمية التي يواجهها المجتمع.

الفقرة	الاستجابة				
	موافق تماما	موافق	محايد	غير موافق	غير موافق تماما
١) أنا على اطلاع بعملية التصميم الهندسي Engineering Design Process المرفق في الصفحة التالية.					
٢) أستطيع مساعدة طلابي على تعريف وتحديد المشكلات الهندسية بوضوح.					
٣) أستطيع مساعدة طلابي على تعيين المعوقات وتحديد المعايير للمشكلات الهندسية.					
٤) أمتلك القدرة الكافية على استخدام استراتيجية العصف الذهني مع طلابي لاكتشاف الحلول الممكنة للمشكلات الهندسية.					
٥) امتلك القدرة على استخدام استراتيجيات كافية لتدريب طلابي كيفية توليد الأفكار واقتراح أفكار متنوعة.					
٦) أمتلك مهارات تساعد طلابي على استكشاف حلول ممكنة للمشكلات العلمية والهندسية.					
٧) أمتلك المعرفة الكافية لتشجيع طلابي لاستخدام طرق متنوعة تهدف لحل المشكلات الهندسية.					
٨) أمتلك المعرفة الكافية لمساعدة طلابي على إعداد نماذج أوليه ونهائية لمشكلة هندسية مقترحة.					
٩) أمتلك المعرفة الكافية لتوجيه طلابي لكيفية صقل وتحسين التصميم الهندسي المقترح.					
١٠) أمتلك القدرة الكافية لتوجيه مشاريع الطلاب الهندسية طبقاً لاحتياجات السوق المحلي (المستفيد من المشروع).					

١١) أمتلك الاستراتيجيات اللازمة لتمكين طلابي من اختبار وتقويم تصاميمهم الهندسية المقترحة.					
١٢) أجد صعوبة -بشكل عام- في تطبيق عمليات التصميم الهندسي في تدريس العلوم الطبيعية.					

س: هل يوجد لديكم تعليقات أو ملاحظات أو اقتراحات تتعلق بالمعوقات التي تواجه المعلم من حيث استخدام التصميم الهندسي في تدريس العلوم الطبيعية؟



عملية التصميم الهندسي

خامساً : معوقات تتعلق باستخدام المهارات الرياضية في تدريس العلوم الطبيعية :

آمل الإجابة عن الأسئلة التالية والتي تعنى بمدى قدرة معلم العلوم على استخدام العمليات الرياضية في تدريس العلوم الطبيعية.

ملحوظة: يقصد باستخدام الرياضيات: قدرة الطلاب علي استخدام مهاراتهم الرياضية المختلفة لتفسير وتحليل المشكلات العلمية التي تواجه الطالب في العالم الواقعي.

الفقرة	الاستجابة				
	موافق تماما	موافق	محايد	غير موافق	غير موافق تماما
١) أستطيع مساعدة طلابي على إجراء عمليات حسابية حينما يعطون تعبيرات جبرية مثل المعادلات التربيعية، الأسس السالبة .... إلخ					
٢) أستطيع مساعدة طلابي على تحويل العبارات اللفظية إلى صيغ رياضية رقمية.					
٣) أستطيع مساعدة طلابي على حل المعادلات والمتراجحات.					
٤) أستطيع مساعدة طلابي على تصور أنواع مختلفة من الأشكال والمجسمات الهندسية (التصور البصري /المكاني)، مثل تصور بعض الجزيئات والمركبات الكيميائية.					
٥) أستطيع مساعدة طلابي على تطبيق مفاهيم التحول الرياضي (النقل، الدوران، الانعكاس) أثناء تدريس العلوم الطبيعية.					
٦) أستطيع مساعدة طلابي على تفسير البيانات باستخدام تخطيطيات مختلفة كالجداول والرسوم البيانية و التقارير الكتابية.					
٧) أستطيع مساعدة طلابي على التمييز بين المجموعات المتماثلة وغير المتماثلة.					
٨) أستطيع مساعدة طلابي على حل المعادلات التكاملية البسيطة.					
٩) أستطيع مساعدة طلابي على التمييز بين المسائل الرياضية التي تحتوي تناسبا طرديا أو عكسياً.					

١٠) أستطيع مساعدة طلابي على تحديد أنواع الأشكال الرياضية بحسب أنواع الزوايا في كل شكل، مثل تحديد زوايا المنشور.					
١١) أستطيع مساعدة طلابي عمليا على استخدام الأدوات الرياضية المناسبة ، مثل استخدام الفرجار، المنقلة...إلخ.					
١٢) أستطيع مساعدة طلابي على تنمية مهارات التفكير بطرق مجردة (بيانات لفظية).					
١٣) أستطيع مساعدة طلابي على تنمية مهارات التفكير بطرق كمية (بيانات عددية).					
١٤) يمكنني مساعدة طلابي في التعرف على الأنماط الرياضية (المتكررة) في البيانات الرياضية.					
١٥) أستطيع مساعدة طلابي في حل المسائل الرياضية متعددة الخطوات من خلال:					
أ- التصور العام للمسألة الرياضية.					
ب – تحديد المبادئ الرياضية المستخدمة لحل المشكلة.					
ج – تنفيذ العمليات الرياضية المناسبة للمشكلة.					

س: هل يوجد لديكم تعليقات أو ملاحظات أو اقتراحات تتعلق بالمعوقات التي تواجه المعلم من حيث دمج المهارات الرياضية في تدريس العلوم الطبيعية؟

....

....

أسئلة المقابلة

مرفق (٢)

الرقم :

موقع المدرسة:

الجنس:

الجنسية:

المؤهل الدراسي:

الصف الدراسي الذي يدرسه المعلم:

المادة العلمية التي تدرسها:

---

١) كم عدد سنوات خبرتك التدريسية؟

٢) ما نظرتك الشخصية حول التكامل في تدريس العلوم (دمج العلوم الطبيعية)؟

- كيف يمكنك استخدام منحى التكامل في تدريس التخصصات العلمية (فيزياء، كيمياء، أحياء، علم الأرض) ؟ ارسم مخططا!
- أعط أمثلة من واقع تدريسك اليومي.
- ما أهم التحديات التي تعيقك أثناء تنفيذ التكامل العلمي (دمج موضوعات الفيزياء والكيمياء والأحياء وعلم الأرض) في ممارساتك التدريسية؟

٣) ما أفكارك (تصوراتك) حول دمج المهارات الرياضية (مادة الرياضيات) في تدريس العلوم الطبيعية؟ ارسم مخططا.

- كيف يمكنك استخدام الرياضيات (المهارات الرياضية) في تدريس التخصصات العلمية (فيزياء، كيمياء، أحياء، علم الأرض) ؟ ارسم مخططا!
- أعط أمثلة من واقع تدريسك اليومي.
- ما أهم التحديات التي تعيقك أثناء دمج المهارات الرياضية (مادة الرياضيات) في ممارساتك التعليمية في تدريس العلوم الطبيعية بصفة تكاملية؟

Appendix (10)

Approval Letter from the Ministry of Education

المملكة العربية السعودية
وزارة التعـليم
(٢٨٠)
وكـالة التخطيط والمعلومات
المركز الوطني لبحوث سياسات التعليم

وزارة التعــليم
Ministry of Education

الرقم : ٣٩١٠٢١٤٨٧٧٤
التاريخ : ١٢/٣/١٤٣٩هـ
المشفوعات : ....

الموضوع : تسهيل مهمة الباحث/ يوسف بن فراج الجوير

سعادة مدير التعليم بمحافظة الزلفي وفقه الله

السلام عليكم ورحمة الله وبركاته ، ،

تجدون سعادتكم برفقه أداتي بحث "استبانة ومقابلة" لطالب الدكتوراه بجامعة (أوستن تكساس) بالولايات المتحدة الأمريكية/ يوسف بن فراج الجوير بعنوان "دراسة المعوقات التي تواجه معلمي العلوم الطبيعية أثناء دمج الرياضيات، والتقنية، والهندسة في تدريس العلوم الطبيعية في المرحلة الثانوية بالمملكة العربية السعودية".
حيث يرغب الباحث تطبيق الأداة المرفقة على عينة من المعلمين والمعلمات في مدارس المرحلة الثانوية.

آمل من سعادتكم التكرم بالتوجيه بتسهيل مهمته.

والسلام عليكم ورحمة الله وبركاته ، ،

مدير عام
المركز الوطني لبحوث سياسات التعليم

د. عبدالله بن محمد الحميد

ص. لمركز البحوث.

Appendix (10)

Approval Letter from the Ministry of Education

المملكة العربية السعودية
وزارة التعليم
(٢٨٠)
وكالة التخطيط والمعلومات
المركز الوطني لبحوث سياسات التعليم

وزارة التعليم
Ministry of Education

الرقم : ٣٩١٠٢١٤٨٧٧٤
التاريخ : ١٤٣٩/٣/١٢هـ
المشفوعات : ....

الموضوع : تسهيل مهمة الباحث/ يوسف بن فراج الجوير

سعادة مدير التعليم بمحافظة الزلفي وفقه الله
السلام عليكم ورحمة الله وبركاته، ،

تجدون سعادتكم برفقه أداتي بحث "استبانة ومقابلة" لطالب الدكتوراه بجامعة (أوستن تكساس) بالولايات المتحدة الأمريكية/ يوسف بن فراج الجوير بعنوان "دراسة المعوقات التي تواجه معلمي العلوم الطبيعية أثناء دمج الرياضيات، والتقنية، والهندسة في تدريس العلوم الطبيعية في المرحلة الثانوية بالمملكة العربية السعودية".
حيث يرغب الباحث تطبيق الأداة المرفقة على عينة من المعلمين والمعلمات في مدارس المرحلة الثانوية.

آمل من سعادتكم التكرم بالتوجيه بتسهيل مهمته.

والسلام عليكم ورحمة الله وبركاته، ،

مدير عام
المركز الوطني لبحوث سياسات التعليم

د. عبدالله بن محمد الحميد

ص. لمركز البحوث.

Appendix (11)

Approval from The Excellence Center for Science and Mathematics Education

جامعة الملك سعود
King Saud University
مركز التميز البحثي في تطوير تعليم العلوم والرياضيات

المملكة العربية السعودية
ص.ب 2458 الرياض 11451
ecsme.ksu.edu.sa

جامعة الملك سعود
هاتف +966 11 467 8022
فاكس +966 11 467 8263

سعادة مدير التعليم بمحافظة الزلفي   سلمه الله

السلام عليكم ورحمة الله وبركاته، وبعد:

نحيطكم علماً بأن مركز التميز البحثي في تطوير تعليم العلوم والرياضيات يسعى في الفترة الحالية إلى إنجاز مجموعة من البحوث الوطنية التي تهدف إلى التعرف على واقع تعليم العلوم والرياضيات وتطويره في المملكة العربية السعودية، وامتداداً لبرنامج الصداقة الذي يعقده المركز مع مجموعة من إدارات التعليم في المملكة، وحيث إن إدارتكم ضمن الإدارات الصديقة للمركز، فقد تم اختيار معلميها ومعلماتها لمادة العلوم ضمن عينة الدراسة التالية **"دراسة المعوقات التي تواجه معلمي العلوم الطبيعية أثناء دمج الرياضيات، والتقنية، والهندسة في تدريس العلوم الطبيعية في المرحلة الثانوية بالمملكة العربية السعودية"**. عليه نأمل منكم التكرم بتسهيل مهمة منسق إدارتكم (المنسق المكلف في إدارة تعليم الزلفي سعادة الأستاذ عبد العزيز بن أحمد الجبر) للتعاون مع الباحث في تطبيق أدوات البحث (مرفق إجراءات تنفيذ الدراسة)، علماً أن المركز سيوافيكم بنتائج الدراسة المرتبطة بإدارتكم حال إتمامها.

تقبلوا وافر التحية والتقدير،

مدير المركز

أ. د. سعيد بن محمد الشمراني

الرقم ٥/٩/٧٢٢٧٥
التاريخ ١٦/٢/١٤٣٩هـ
المرفقات

Appendix (11)

Approval from The Excellence Center for Science and Mathematics Education

قسم التخطيط والتطوير

VISION رؤيـــة 2030
المملكة العربية السعودية
KINGDOM OF SAUDI ARABIA

الموضوع / تسهيل مهمة باحث

(تعميم لجميع المدارس الثانوية / بنين ـ بنات)

المكرمـ ـة / قائد ـ ة مدرسة / الثانوية ، يحفظهـ ـها الله

السلام عليكم ورحمة الله وبركاته وبعد :

بناء على خطاب سعادة مدير عام المركز الوطني لبحوث سياسات التعليم رقم ٣٩١٠٢١٤٨٧٧٤ بتاريخ ١٤٣٩/٠٣/١٢هـ .

بشأن الموافقة على تطبيق أداتي بحث " استبانة ومقابلة " طالب الدكتوراه بجامعة (أوستن تكساس) بالولايات المتحدة الأمريكية يوسف بن فراج الجوير ، بعنوان : (دراسة المعوقات التي تواجه معلمي العلوم الطبيعية أثناء دمج الرياضيات ، والتقنية ، والهندسة في تدريس العلوم الطبيعية في المرحلة الثانوية بالمملكة العربية السعودية) ، والمستهدف بها معلمو ومعلمات العلوم في المرحلة الثانوية (كيمياء ، فيزياء ، أحياء ، علم الأرض) ، وذلك من خلال تعبئتهم الاستبانة على الرابط
https://utexas.qualtrics.com/jfe/form/SV_bNoBQ9mzOjSXroN
وكذلك في الإجابة عن بيانات المقابلة . وذلك بالتعاون مع المنسقين :

١) الأستاذ / عبدالعريز بن أحمد الجبر (للبنين ، ج : ٠٥٥٤٢٥٥٥٢٥) .
٢) الأستاذة / إيمان بنت عبدالله الزنيدي (للبنات ، ج : ٠٥٠٦٢٤٣٣١٨) .

عليه فإننا نأمل تسهيل مهمة الباحث ومنسقيه أثناء زيارتهم للمدرسة .

ولكم تحياتي ، ، ،

مدير التعليم

محمد بن عبدالله الطريقي

ص / للإشراف التربوي (بنين / بنات) .
ص / منسق مركز التميز البحثي / الأستاذ : عبدالعزيز بن أحمد الجبر ، بوحدة تطوير المدارس (بنين) .
ص / منسقة مركز التميز البحثي / الأستاذة : إيمان بنت عبدالله الزنيدي ، في الإشراف التربوي (بنات) .
ص / للتخطيط والتطوير
ص / للصادر

Appendix (12)

The Arabic Version of the Questionnaire

Open Coding for participants' factors that hinder teachers from applying integrating technology, engineering, and mathematics into science teaching.

(Example)

Participants	Quotes	Open coding	Patterns	Category
Jim	• I do not have enough skills to implement integrative instruction in teaching chemistry. • I just know how to teach chemistry. I do not know other subjects. • I do not know how to teach using integrative framework. • Integration requires undersigning the content knowledge of several disciplines. • We, as teachers, do not have time for PD	Skills, other content knowledge, integrative skills, several disciplines, professional development programs	Lack of skills needed for integrative approaches. Lack of content knowledge required for integrative instruction.	Lack of professional development programs that focus on pedagogical and content knowledge required for integrative instruction

Appendix (13)

Stages of Concern About the Innovation

Adapted from Hall (1979)

Impact	6	Refocusing	The individual focuses on exploring ways to reap more universal benefits from the innovation, including the possibility of making major changes to it or replacing it with a more powerful alternative.
	5	Collaboration	The individual focuses on coordination and cooperation with others regarding use of innovation.
	4	Consequence	The individual focuses on the innovation's impact on students in his or her immediate sphere of influence
Task	3	Management	The individual focuses on the processes and tasks of using the innovation and the best use of information and resources.
Self	2	Personal	The individual is uncertain about the demands of the innovation, his/her inadequacy to meet those demands, and the role of the innovation.
	1	Informational	The individual indicates a general awareness of the innovation and interest in learning more about it.
	0	Awareness	The individual indicates little concern about or involvement with the innovation is indicated.

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