

**A PATHWAY TO STEM EDUCATION:
INVESTIGATING PRE-SERVICE MATHEMATICS AND SCIENCE
TEACHERS AT TURKISH UNIVERSITIES IN TERMS OF THEIR
UNDERSTANDING OF MATHEMATICS USED IN SCIENCE**

A Dissertation

by

MEHMET SENCER CORLU

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2012

Major Subject: Curriculum and Instruction

A Pathway to STEM Education: Investigating Pre-service Mathematics and Science
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ABSTRACT

A Pathway to STEM Education: Investigating Pre-Service Mathematics and Science Teachers at Turkish Universities in Terms of Their Understanding of Mathematics Used in Science. (May 2012)

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Reforms in education of Science, Technology, Engineering, and Mathematics (STEM) disciplines have been particularly critical for the economic competitiveness of Turkey. STEM education includes the set of knowledge, skills, and beliefs which are collaboratively constructed by students and teachers at the intersection of more than one STEM subject area. The overall purpose for all three studies comprising this dissertation was to investigate whether prospective Turkish mathematics and science teachers were ready to implement STEM education in terms of their integrated teaching knowledge (ITK), teaching self-efficacy beliefs, and attitudes toward mathematics and science integration. The dissertation employed a quantitative research methodology to investigate ITK and attitudes whereas teaching self-efficacy beliefs were investigated with an explanatory mixed methods study.

Results from the first study suggested that the pre-service mathematics and science teachers, who were educated in an integrated teaching education program,

outperformed peers in the departmentalized teacher education program in terms of their ITK. There was evidence in the second study that practical teaching experiences helped pre-service mathematics and science teachers develop high self-efficacy beliefs for mathematics and science integration. The findings of the third study indicated that the integrated teacher education program provided noteworthy benefits for pre-service mathematics and science teachers' attitudes toward mathematics and science integration when compared to pre-service mathematics teachers in the departmentalized program.

The unique attributes of integrated mathematics and science teacher education programs, such as balanced coursework of content, pedagogy, and pedagogical content knowledge, integrated teaching courses, and the increased peer stimulation in classrooms were discussed as possible factors that explain the results.

Overall, the three studies demonstrated that the pre-service mathematics and science teachers in the integrated teacher education program were ready to implement STEM education aligned with the reforms enacted by the K-12 policy-making organization while the departmentalized teacher education program, which was recommended by the higher education policy making organization, was preparing pre-service teachers as content experts of individual STEM subjects. Policy coordination in K-12 and higher education emerged as a critical factor for the success of Turkish education reforms.

DEDICATION

To the Owner of All Knowledge

&

To All Men of Understanding Who Believe in Education from the Cradle to the Grave

ACKNOWLEDGEMENTS

I would like to express profound gratitude to my advisor, Dr. Robert M. Capraro for his invaluable support, encouragement, mentoring, and supervision at Aggie-STEM Center and throughout my doctorate. His moral support and continuous guidance enabled me to complete my work successfully. Being his *Padawan* has been an precious experience in many ways.

I am also highly thankful to my committee members, Dr. Lynn M. Burlbaw, Dr. Elsa Gonzalez y Gonzalez, and Dr. Victor L. Willson, as well as Dr. Mary M. Capraro for their teaching, invaluable suggestions, and moral support.

I am as ever, especially indebted to my parents, Dr. M. Ali Corlu and Mrs. Vildan Corlu for their love, support, prayers, and pushing me forward throughout my life. I wish to thank my sister, Ms. BilgeNur Corlu for her endless love and for her suggestions and my uncle, Ekrem Corlu, who provided his *house in the woods* so I could work intensively on my dissertation during the summer of 2011. Moreover, my sincere gratitude goes to my friends, who shared their love, friendship, and experiences with me.

Finally, I dedicate this work to all the students I taught in Turkey, Morocco, and Switzerland. At the end of the day, I found the courage to start a doctorate because of my nickname, *The Doctor*.

NOMENCLATURE

AtMuS	Attitudes towards Mathematics Used in Science
CoHE	The Council of Higher Education (Yüksek Öğretim Kurumu)
CK	Content Knowledge
DAS	Dogan (1999) Attitude Survey
EU	European Union
ITK	Integrated Teaching Knowledge
MoNE	Ministry of National Education (Milli Eğitim Bakanlığı)
MTEBI	Mathematics Teaching Efficacy Beliefs Instrument
MTOE	Mathematics Teaching Outcome Expectancy
MuS	Mathematics used in Science
MuSITK	Mathematics Used in Science Integrated Teaching Knowledge
MuSTEB	Mathematics Used in Science Teaching Self-Efficacy Beliefs
OECD	Organisation for Economic Cooperation and Development
PCK	Pedagogical Content Knowledge
PISA	Programme for International Student Assessment
PMTE	Personal Mathematics Teaching Efficacy
PPSE	Public Personnel Selection Examination
PSTE	Personal Science Teaching Efficacy
SSPE	Student Selection and Placement Examination
STEBI	Science Teaching Efficacy Beliefs Instrument

STEM	Science, Technology, Engineering, and Mathematics
TALIS	Teaching and Learning International Survey
TEB	Teaching Self-Efficacy Beliefs
TIMSS	Trends in International Mathematics and Science Study

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CHAPTER I

INTRODUCTION

Overview

Nations invest in innovation to promote sustainable economic growth. While many countries are suffering from the effects of global economic difficulties, such as rising unemployment and soaring public debt, the role of labor input is decreasing in the 21st century economy. Only innovation-driven growth has the potential to create value-added jobs and industries (Organisation for Economic Co-operation and Development [OECD], 2010a). Because innovation is largely derived from advances in the science, technology, engineering, and mathematics (STEM) disciplines (National Academy of Sciences, National Academy of Engineering, & Institute of Medicine, 2011) an increasing number of jobs at all levels require STEM knowledge (Lacey & Wright, 2009). Nations need an innovative STEM workforce to be competitive in the 21st century.

This dissertation follows the style of *School Science and Mathematics*.

Innovation involves the integration of diverse STEM skills and transcends disciplines. Innovation is a highly interactive and multidisciplinary process that rarely occurs in isolation and is tightly connected to life (OECD, 2010a). Today, there is a clear consensus among stakeholders on the importance STEM education to economic innovation (Kuenzi, 2008; OECD, 2010b). STEM education in K-12 settings, fosters interdisciplinary knowledge and skills that are relevant to life and prepare students for a knowledge-based economy (National Research Council, 2011). The overarching goal of STEM education is to raise the current generation with innovative mindsets.

Curriculum integration provides the theoretical framework for STEM education. Integrative learning and curriculum integration theories reflect the progressive tradition of Dewey, in which subject matter is connected to real-life and made more meaningful to students through curriculum integration (Beane, 1997). John Dewey's elegant statement, "Relate the school to life, and all studies are of necessity correlated" (Dewey, 1910, p. 32) serves as an inspiration to many educators who intuitively believe that curriculum integration produces greater learning outcomes in school subjects despite the lack of empirical evidence (Czerniak, Weber, Sandman, & Ahern, 1999; Frykholm & Glasson, 2005; McBride & Silverman, 1991). A major obstacle to conducting empirical research on curriculum integration is the different definitions of curriculum integration among scholars (Berlin & White, 1994, 1995). In this regard, some propose curriculum integration models that are too general and lack rigor in domain-specific knowledge while other models of curriculum integration posit radical changes in the K-12 school curriculum through interdisciplinary approaches (Hartzler, 2000). "The rigidity and

resilience of the school curriculum structure should not be underestimated when proposing reform” (Williams, 2011, p. 27), likewise many researchers ignore the power of status quo practices and teachers’ lack of readiness to adopt integrated approaches in their teaching (Schleigh, Bossé, & Lee, 2011). Nevertheless, curriculum integration helps educators understand four STEM disciplines as an interconnected entity with a strong collaborative connection to life.

STEM education builds upon curriculum integration theories in two perspectives. One perspective is that STEM education enables teachers to integrate correlated subjects to increase students’ innovation capacities without ignoring the unique characteristics, depth, and rigor of each discipline (National Research Council, 2011). However, there is a gap between how STEM subjects are taught in schools and the knowledge, skills, and beliefs required for innovation (Cuadra & Moreno, 2005). Reducing the gap between current STEM instruction and the actual skills needed for innovation is contingent upon the expertise of STEM teachers to successfully transition from the departmentalized model of teaching to an integrated model that promotes innovation (Furner & Kumar, 2007). In this model, teachers are not only the expert of a single subject, but also have the additional responsibility of guiding their students in at least one other STEM subject (Sanders, 2009), which necessitates an investment in professional development of in-service teachers, as well as reorganizing the teacher education programs at universities (Kline, 2005). The second perspective is in regard to the STEM education curriculum that guides the teachers. A highly structured curriculum with rigid boundaries among STEM disciplines is likely to weaken the effectiveness of the teachers (Pinar, Reynolds,

Slattery, & Taubman, 2000) whereas an integrated curriculum enables teachers to teach STEM subjects in their natural contexts in contrast to disparate curricular disciplines (Jardine, 2006). STEM education requires teachers to excel in utilizing natural and active exchanges of knowledge, skills, and beliefs among STEM disciplines.

In an increasingly knowledge-based economy, the future prosperity of countries lies in their capacity to educate workers with innovative mindsets. While innovation serves as the objective of STEM education, curriculum integration provides a foundation for STEM education. The integration of STEM disciplines helps teachers enhance students' innovation capacities without ignoring the unique characteristics of each STEM discipline. In order to achieve successful STEM education, there is a need to provide in-service teachers with quality professional development opportunities and to restructure current teacher preparation programs. The pathway to the prosperity of societies in the 21st century is teacher education that prepares current and future teachers to teach STEM subjects with an integrated approach.

Background of the Problem

Many countries around the world, including global economic powers such as the United States and the European Union (EU) are transforming their educational systems to be competitive in the age of innovation (Fensham, 2008). STEM education is at the core of both American (Department of Education, 2010; National Economic Council, Council of Economic Advisers, & Office of Science and Technology Policy, 2011; National Science Board, 2010; President's Council of Advisors on Science and Technology, 2010) and EU (Commission of the European Communities, 2008, 2010)

research-based innovation strategies. Innovation strategies provide a vision for policymakers and a motivation for public and private STEM initiatives to raise interest in STEM and STEM teaching (e.g., Partnership for 21st century skills, STEM education coalition and UTeach in the United States and Scientix, InGenious and European Schoolnet in the EU). The immediate goal of STEM initiatives is to increase the number and quality of STEM teachers so that well-educated teachers can help more students develop 21st century skills and a capacity to innovate (Partnership for 21st Century Skills, 2009). In many countries, educational reforms focus on increasing interest in STEM and STEM teaching.

Turkey, a founding member of OECD, is going through major reforms to meet standards (*acquis*) as a candidate country for EU membership. Reforms in education of STEM disciplines are particularly critical for the economic competitiveness of Turkey because the innovation productivity of human capital in Turkey falls behind other developed countries (Turkish Academy of Sciences, 2010). Despite significant improvements in the last decade, the number of research development workforce per population is still among the lowest of OECD countries (OECD, 2010a). In response to the unsatisfactory innovation performance of the country, the administration is enacting regulations similar to American and European innovation strategies and educational policies (Grossman, Onkol, & Sands, 2007; Lonnqvist, Horn, & Berktaç, 2006). In fact, *Vision 2023 project* (Serbest, 2005) and *2010-2014 Strategic Plans* (MoNE, 2009d, 2009e) are foresight exercises with an agenda to improve quality of and access to STEM education (Uzun, 2006). Although there is a clear consensus on the necessity of

educational reforms, several stakeholders have criticized current reforms for not considering the political, social, and technological history of the country (Aksit, 2007; Argun, Arikan, Bulut, & Sriraman, 2010; Tuzcu, 2006). Criticisms have also been leveled at the rapid introduction of reforms at the macro level with minimal consideration to the difficulties at the micro level (Yagci, 2010). Turkish educational reforms are in accordance with EU and OECD innovation strategies but reforms also need to recognize the specific challenges and working practices in the country (Argun et al., 2010; Scientific and Technological Research Council of Turkey, 2010).

The Ministry of National Education (MoNE) in Turkey manages one of the largest educational systems in Europe with the continent's most centralized and selective system (Fretwell & Wheeler, 2001). The non-political rationale that supports the current centralized and selective system is the massive size of the youthful citizenry in the country (Baki & Gokcek, 2005). Indeed, out of the 75 million people in the country, more than 15 million are students at the formal primary (11 million students in grades 1 to 8) and secondary (5 million students in grades 9 to 12) education levels, who are educated by over 650,000 active teachers on duty (MoNE, 2011). In order to allocate the limited resources to the large student population on merit—rather than equality, the educational system relies on the success of centrally administered standardized and multiple-choice tests. MoNE not only imposes the curriculum and the textbooks used in the classroom, but also implicitly uses tests to have power over the teaching practices in the classroom. Tests select the ablest out of masses for an elite education at secondary and higher education institutions (Turkish Education Association, 2008, 2010). The

student selection process begins in grade 6 and aims to channel the ablest to specialized education after the compulsory eight years of primary education. The system works to provide a limited number of selected students, who encompass approximately 6% of the entire student body, with the best available education in specialized secondary schools (e.g., Anatolian schools, science schools, social science schools, teacher schools, police and military academies, etc.) (MoNE, 2011; cf. Ozel, Yetkiner, Capraro, & Kupçu, 2009). The centralized and elitist system of MoNE results in an early labeling of the large student body in terms of their performances on tests (Republican People's Party, 2011; Turkish Education Association, 2010).

Only a small percentage of Turkish students, who are educated in specialized schools meet the international standards in STEM disciplines. School type is a major predictive factor of Turkish students' success in STEM subjects (Alacaci & Erbas, 2010). Students from specialized schools perform consistently well at International Mathematical and Physics Olympiads, placing Turkey within the top 10 countries (Gorzowski & Tichy-Racs, 2010; Webb, 2011). However, randomly selected Turkish students rank below the sixtieth percentile in international comparison studies in mathematics and science (Provasnik, Gonzales, & Miller, 2009). When the performance of specialized and general public schools is analyzed separately, the results vary significantly in favor of specialized schools with up to two standard deviation difference in mathematics and science performance (Berberoglu, 2007). Thus, the majority of the students in Turkey are not receiving a quality education in STEM subjects (Sarier, 2010).

The implementation of education in STEM disciplines in Turkey varies according to the school level (primary or secondary), school type (specialized or general public), and teacher characteristics, respective to each school level and type. The first discrepancy in education of STEM subjects occurs at the school level with increasing departmentalization after grade 6. Primary school mathematics teachers are responsible to teach the integrated mathematics course (including arithmetic, geometry, and pre-algebra) according to the set of standards for grades 6, 7, and 8 (MoNE, 2009a, 2009b). The integrated science and technology course (including earth, life, and physical science contents with technology literacy emphasis) begins in grade 4. Primary school science teachers also use two separate sets of standards; one for 4th and 5th grades (MoNE, 2005) and another for grades 6 through 8 (MoNE, 2006). Although MoNE's intended curriculum encourages primary school teachers of mathematics and science to collaborate and integrate their coursework (MoNE, 2006, 2009b), the enacted curriculum is particularly departmentalized and focuses on standardized tests (Ozden, 2007). At the secondary school level, departmentalization in STEM subjects increases as mathematics teachers teach high school geometry and mathematics in two separate courses, while physics, chemistry and biology cover the high school science content. The second discrepancy in education of STEM subjects is based on school type as specialized schools offer more advanced mathematics and science courses and a greater number of instructional hours in these subjects (MoNE, 2010a). The third discrepancy is the age and experience of teachers at different school levels and types. The majority of the STEM teachers at the primary school level are below the age of 30 and on average have

less than five years of teaching experience (MoNE, 2009c). In contrast, the majority of the STEM teachers in secondary schools have more than 15 years of teaching experience and are above the age of 30 (MoNE, 2010b). Furthermore, for specialized schools, MoNE recruits only teachers with substantial experience and who perform well at a content-based standardized selection test (Gur & Celik, 2009; Ozoglu, 2010). The implementation of education in STEM disciplines in Turkey depends on school level and type, as well as the characteristics of STEM teachers.

Three major institutional organizations are involved in the STEM teacher education system in Turkey: universities, Council of Higher Education (CoHE), and MoNE. Universities educate prospective STEM teachers in the faculties of education with a five-year program for secondary school level teaching positions and four-year program for primary school level teaching positions. While CoHE holds the responsibility of organizing the curriculum for the teacher education programs, MoNE's duty is to select the new teachers to employ at public schools. Each institution has its own interests and concerns. First, the faculties of education produce more STEM teachers than the actual recruitment capacity (in terms of budget and need) of MoNE (Ozoglu, 2010). As a result, there are over 350,000 teacher candidates actively seeking employment (Ozoglu, 2010), yet the universities still organize teacher certification programs for the graduates of other faculties, such as engineering and pure sciences. In addition, teacher education programs at universities are struggling to be accredited at European Union standards for instructional quality, research, and academic freedom (Turkish Academy of Sciences, 2010). Second, CoHE changes the standard teacher

education curriculum frequently with little research support and without consulting subject-matter specialists at universities (Aslan, 2003). In particular, teacher educators criticize the STEM teacher education curriculum for ignoring the teaching practice and pedagogical content knowledge in the program (Corlu & Corlu, 2010). Third, Public Personnel Selection Examination (PPSE) is the only criterion that MoNE considers for teacher employment. The PPSE is a uniform pedagogy test, which is administered to all teacher candidates, thus it tests neither the content nor the pedagogical content knowledge (CoHE, 2007). Teacher candidates believe the current teacher employment system is damaging the credibility of teacher education programs at the universities because teacher candidates prefer studying for the PPSE rather than actually learning to teach (Ozoglu, 2010). Further, MoNE recruits experienced teachers to teach at specialized schools based on their scores on a content-based examination with no reference to pedagogical content knowledge (Ozoglu, 2010). Given the OECD's Teaching and Learning International Survey (TALIS) finding that the need for well-educated teachers in Turkey is twice the international average (Buyukozturk, Akbaba Altun, & Yildirim, 2010; OECD, 2009a), it is evident that the teacher education system of Turkey is not functioning well (Kartal, 2011). The problems within the universities, CoHE, and MoNE, in addition to the lack of coordination among them (Gur & Celik, 2009) are limiting the success of STEM education in the country.

As a candidate country for EU, Turkey is implementing educational reforms at the macro level, which are similar to the American and European innovation strategies. However, because of the size of the Turkish educational system and the top-down

management style, policy makers are unaware of the difficulties and good practices at the micro level (Yagci, 2010). There are also several structural problems, one of which is the elitist selective system, and thus the unequal distribution of the resources to schools and students. While the education at the primary school level works as a preparation for standardized tests, only the highest-performing students on these tests receive a departmentalized education of STEM subjects at the secondary level. As a result, students in specialized schools perform above the OECD average, but the majority of the students lack a solid knowledge of STEM. Investment to increase the quality of teacher education programs can be a step forward to overcome the historically elitist nature of the Turkish educational system so that every child receives a quality STEM education and is given the opportunity to be an innovator. Otherwise, despite the best intentions and efforts of the Turkish administration, policy makers, researchers, and teachers, the risk of wasting allocated educational funds is high (Dulger, 2003), and so is the risk to the future of the country.

Purpose

The overall purpose for all three articles comprising this dissertation is to investigate whether prospective Turkish teachers are ready to implement STEM education. The model in Figure 1 delineates the specific focus of the research. The model shows the continuum starting from the innovation policies that advocate an integrated STEM teaching at the K-12 level. At the bottom of the model are the three proposed variables of teaching integrated STEM: Teachers' Integrated Teaching Knowledge (ITK), Teaching self-Efficacy Beliefs (TEB), and attitude.

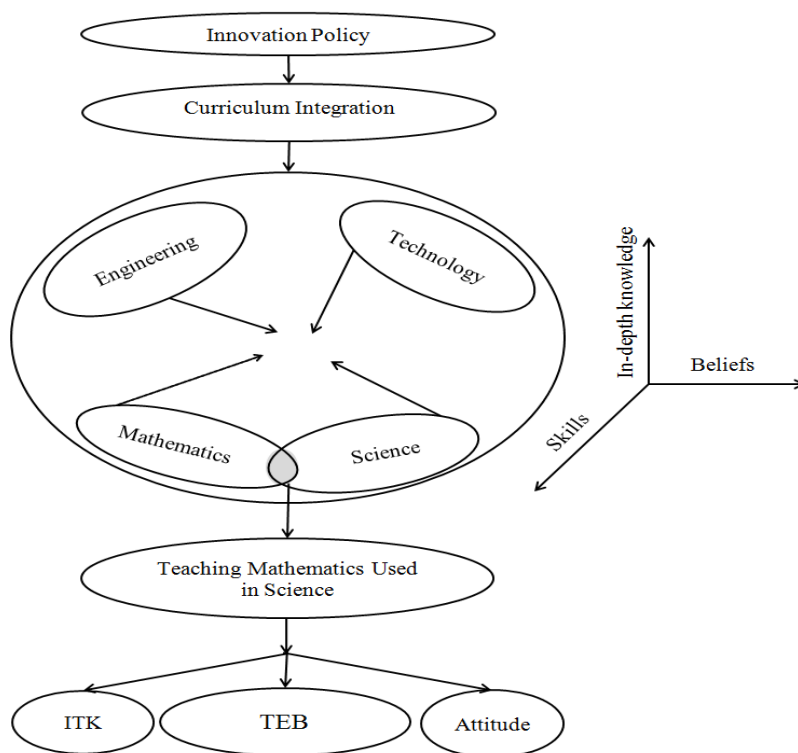


Figure 1. A research model in STEM education.

The model guides the studies in this dissertation. While the oval STEM shapes indicate the preservation of unique characteristics within each STEM discipline, such as in-depth knowledge, skills, and beliefs, the arrows from the shapes represent the teacher and student-driven interactions. The interactions exist because they are often integral parts of the STEM disciplines, rather than optional. The model hypothesizes that it takes a well-educated teacher with a strong integrated teaching knowledge, teaching self-efficacy, and attitude to such interactions actually occur in the classroom settings.

The dissertation investigates one particular interaction between mathematics and science and defines it as *mathematics used in science* (MuS). This MuS construct is not new; it is an integral part of both disciplines (Garavaso, 2005). The construct of MuS

also plays an important role in the teaching and learning of mathematics and science (Blum & Niss, 1991). In fact, MuS appears in science textbooks as a preliminary chapter, or it exists in the problem solving exercises in mathematics, although often skipped or taken granted by the teachers (Taft, 2007). The dissertation, in lay terms, asks whether prospective teachers know MuS to teach it, believe in their ability to teach MuS, and like to teach MuS.

Thus, the main research principle that guides this study is to critically analyze prospective mathematics and science teachers' readiness to facilitate STEM education.

The following questions guide these investigations:

- 1) Are prospective mathematics and science teachers foundationally prepared to implement STEM education in terms of their ITK in MuS?
- 2) How confident are prospective mathematics and science teachers to teach MuS to facilitate STEM education?
- 3) How can the attitudes of prospective mathematics and science teachers towards MuS be described?

Intellectual Merit and Broader Impact

The dissertation, with all three articles taken as a whole, advances the knowledge about STEM education in three strands. Firstly, the study reveals the ITK of Turkish prospective teachers who are responsible of teaching MuS. Secondly, the study investigates the teaching self-efficacy beliefs of Turkish prospective teachers for MuS. Thirdly, the study explores the attitudes of Turkish prospective teachers towards MuS. The dissertation seeks empirical evidence to the proposition that without integrated

teaching knowledge, a high self-efficacy, and a positive attitude, it is unlikely that teachers will be able to facilitate STEM education (Battista, 1986; Stevens & Wenner, 1996; Tosun, 2000).

The dissertation will have a broader impact on STEM teacher education programs by investigating STEM teacher education programs in Turkey. By conducting research through concrete variables to compare teacher education programs, the dissertation will help policy makers decide whether STEM teacher education programs foster STEM education, and speculate why the impact of Turkish reforms were limited in increasing student performances. It is hoped that the dissertation will be the starting point of the pathway to STEM education that provides every Turkish student with an equal opportunity to be an innovator.

Definitions of Terms

Curriculum integration: It builds the theoretical framework of STEM education, which guides students to understand and learn how innovators think, solve problems, and construct a new product or process.

Innovation: It is the utilization of new knowledge that transcends STEM disciplines. It involves a multidisciplinary approach with a tight connection to life (OECD, 2010a).

Mathematics used in science: The knowledge, skills, and beliefs related to mathematics that are used in and necessary to solve the problems of science. The MuS construct differs from applied mathematics, as it is not a separate discipline but a set of skills and practices. It provides a well-defined definition of the interaction between

mathematics and science in the STEM education research model. Examples presented to the participants in the dissertation studies are given in Appendix A. Tasks included arithmetic used in chemistry and physics (atomic weight calculations), exponentials in physics (dimension analysis and large numbers), reading graphs in physics (velocity-time graphs), plotting graphs in physics (relationship between two inversely proportional variables), probability in biology (Punnett squares), algebra in chemistry (balancing equations), and trigonometry in physics (vector components).

Science education in Turkey: The official name of the middle school science course is integrated science and technology education.

STEM education: STEM education includes the set of knowledge, skills, and beliefs, which are collaboratively constructed by students and teachers at the intersection of more than one STEM subject area (Breiner, Harkness, Johnson, & Koehler, 2012).

CHAPTER II

**STEM EDUCATION FROM A TURKISH PERSPECTIVE:
INTEGRATED TEACHING KNOWLEDGE OF PRE-SERVICE
MATHEMATICS AND SCIENCE TEACHERS**

Overview

There have been some criticisms of the standard mathematics and science teacher education program in Turkey, suggesting that the majority of pre-service teachers might not be equipped with adequate knowledge to facilitate STEM education. The present study explored possible relationships between gender, department (mathematics or science), and program (departmentalized or integrated teacher education) and integrated teaching knowledge of pre-service teachers. Data were collected from middle grades pre-service teachers in Turkey ($N = 226$) during the last semester of their teacher education programs. In this exploratory study, an instrument was designed to quantitatively measure integrated teaching knowledge. Data provided support for the usage of the instrument (Cronbach's $\alpha = .64$). Data were analyzed with a three-way factorial analysis of variance model. The results indicated that the pre-service teachers in integrated programs had statistically significantly higher scores on a measure of integrated teaching knowledge compared to pre-service teachers in departmentalized programs. The study showed that an integrated program might be an effective alternative to the standard teacher education program.

Introduction

Countries are investing in innovation to create value-added jobs and industries in the 21st century economy. Innovation, utilization of new knowledge that transcends science, technology, engineering, and mathematics (STEM), involves a multidisciplinary approach with a tight connection to life (Organisation for Economic Co-operation and Development [OECD], 2010a). Likewise, STEM education, which transcends K-12 STEM subjects, particularly mathematics, science, and technology, establishes the missing link between life and axiomatic disciplines (National Science Board, 2010). While the overarching goal of STEM education is to raise the current generation with innovative mindsets, specific goals of STEM education include “to increase advanced training and careers in STEM fields, to expand the STEM-capable workforce, and to increase scientific literacy among the general public” (National Research Council [NRC], 2011, p. 4). Countries that invest in STEM education can create a nation of innovative minds and hence, achieve a sustainable economical growth in the 21st century.

Educational organizations in various countries called for wider access to STEM education. In the United States, School Science and Mathematics Association (SSMA), National Council of Teachers of Mathematics (NCTM), American Association for the Advancement of Science (AAAS), and NRC provided leadership to in-service and pre-service mathematics and science teachers so that more students would have access to STEM education (Schleigh, Bossé, & Lee, 2011). In the European Union (EU), the Lisbon objectives emphasized the importance of reform-oriented mathematics and

science teacher education programs for providing more students with STEM education opportunities (Tuzcu, 2006). Influential organizations in Turkey, such as Scientific and Technological Research Council of Turkey (2010) and Turkish Academy of Sciences (2010) have tangled with Council of Higher Education (CoHE) about the reorganization of teacher education programs. According to both Scientific and Technological Research Council of Turkey and Turkish Academy of Sciences, the teacher education programs should prepare pre-service mathematics and science teachers with a capacity to facilitate STEM education. Educational organizations in several countries, including influential institutions in Turkey believed a wider access to STEM education entailed effective teacher education programs.

The Impetus for STEM Education in Turkey

Turkey's political leadership documented a scheme to be competitive in the age of innovation. Turkish central administration provided policy-making organizations with a vision through its *Vision 2023* foresight document. The main goal was to increase the nation's innovative human capital (Serbest, 2005). In designing *Vision 2023*, the K-12 Ministry and CoHE were charged with enacting legislation to precipitate the goals.

Ministry of National Education (MoNE), K-12 policy maker, independently developed strategies for K-12 education to enact *Vision 2023*. MoNE prepared a strategic plan with two goals. The first goal was to introduce STEM education to Turkish mathematics and science education. The second goal was to increase access to STEM education across the country (MoNE, 2009d, 2009e). In order to achieve the first goal, MoNE revised the K-12 school curriculum and integrated technology literacy standards

into the science education curriculum at the middle grades (fourth through eighth grade) of primary school level (first through eighth grade). In addition, MoNE established STEM education guidelines and curricular standards to encourage mathematics and science teachers to integrate their courses (MoNE, 2005, 2006, 2009a, 2009b). In order to achieve the second goal, MoNE increased the duration of secondary school education from three to four years (ninth through twelfth grade) to make STEM education accessible to larger populations (Tuzcu, 2006). Turkish political leadership envisioned goals to raise a generation of innovative minds and MoNE turned them into STEM education reforms.

CoHE also independently introduced superficial changes to the standard teacher education program in Turkey. Majority of the faculties of education in the country enacted the CoHE's standard program with minor modifications as it was recommended by CoHE (Ozoglu, 2010). The changes in the program were not congruent with those enacted by MoNE for the K-12 program nor did they foster pedagogical content area learning (Corlu & Corlu, 2011). In fact, the standard program has been subject to frequent changes since the 1980's in search of a better teacher education at Turkish universities (Kartal, 2011). The pre-service teacher education program in Turkey was independently designed and frequently changed by CoHE without considering external stakeholders.

The Impact of STEM Education Reform in Turkey

The impact of STEM education reforms in Turkey was limited. At K-12 school level, reforms had little effect on student performances based on Trends in International

Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA) (Aksit, 2007; Alacaci & Erbas, 2010; OECD, 2009b; Zembat, 2010). At the higher education level, teacher education programs at universities struggled to meet CoHE standards (Turkish Academy of Sciences, 2010). According to the Teaching and Learning International Survey (OECD, 2009a), the need for quality teachers was more than twice the OECD average. The enacted reforms of STEM education fell short of producing effective results.

Researchers criticized the way Turkish reforms in education were introduced and their scope. A major objection was the lack of coordination among the two primary policy developers (Gur & Celik, 2009; Ozoglu, 2010). Reforms were criticized for not addressing well-articulated problems of Turkish education. Among these problems was the standard teacher education program that emphasized theory (content or pedagogy theory) over practice (pedagogical content practice) (Corlu & Corlu, 2010; Kartal, 2011; Ozoglu, 2010). As a result, departmentalized teaching of STEM subjects to the selection tests at the K-12 level continued to not foster innovative thinking (Corlu, Capraro, & Capraro, 2011; Haladyna, Nolen, & Haas, 1991) and in-service and pre-service mathematics and science teachers were left without STEM educational experiences founded in pedagogical content knowledge (Bulut, 2007). STEM reforms missed the major problems of the current mathematics and science education in Turkey because of a lack of coordination.

Reforms could not achieve the *Vision 2023* goal for developing a generation with innovative mindsets without the support of STEM teachers (Department of Education,

2007). Turkey needed mathematics and science teachers, who were equipped with the teaching knowledge to implement STEM education. Reforms in Turkish STEM education might be successful if mathematics and science teachers were educated with programs that facilitate STEM education with innovative and integrated thinking.

The Journey from STEM to STEM Education

STEM appeared in the literature two decades ago as an acronym that referred to four separate and distinct research fields. When educators applied the notion of STEM to education at K-12 school settings, STEM construct evolved into the integration of mathematics and science subjects (Sanders, 2009). In this perspective, technology (Scott, 2009) and engineering were embedded in the science education curriculum (Williams, 2011). As a result, STEM in K-12 school settings was generally been interpreted as the integration of mathematics and science subjects.

Educational researchers have grounded their understanding of STEM in the far-reaching curriculum integration theories. Curriculum integration aimed to guide students to develop a greater appreciation of the relevance of their education (Beane, 1997; Frykholm & Glasson, 2005; Gehrke, 1998; Jacobs, 1989; Pang & Good, 2000; Roth, 1993; Roth & Bowen, 1994; Taft, 2007). However, empirical evidence for curriculum integration was scarce and was mostly composed of testimonials (Czerniak, Weber Jr., Sandman, & Ahern, 1999). Curriculum integration could only be conceptually defined with several distinct models (Berlin & White, 1994, 1995). Educational researchers needed a comprehensive definition of STEM education.

STEM education is integrated by definition. STEM education, which is integrated, does not fail to consider the unique characteristics, depth, and rigor of individual STEM disciplines (National Research Council, 2011). STEM education emerges as the stance against the hegemonic departmentalized teaching and provides mathematics and science teachers at the K-12 level with the rationale and tools to integrate parallel and correlated STEM subjects (Venville, Rennie, & Wallace, 2012). In this perspective, STEM education has been defined as a model within K-12 subjects, in which mathematics and science teachers guide their students “to think critically, synthesize knowledge, reflect on their own thought processes and get their feet wet in interdisciplinary thinking” (Gardner, cited in Gross, 2003, ¶14). STEM education occurs as a result of the collaboratively constructed knowledge and interests of students and teachers (Breiner, Harkness, Johnson, & Koehler, 2012). Thus, STEM education provides myriad interdisciplinary opportunities that are created naturally and realistically at the intersections of STEM subjects.

STEM Teacher Education

STEM teacher education has been anchored in a normative view of effective STEM education. In many studies, effectiveness of the programs was aligned with what policy suggested (Wilson, 2011). In addition, researchers mentioned the need for good metrics for making decisions about program effectiveness (Wilson, Floden, & Ferrini-Mundy, 2001). STEM teacher education needed empirical studies that would establish a measure of program effectiveness.

Content knowledge courses have been suggested as critical to effective STEM teacher education. For example, National Academy of Education (2009) associated more content courses for entry or exit levels of the STEM education programs with effective teacher preparation. A recent major cross-national study of teacher education found that future elementary teachers in high-achieving countries, achievement was measured in terms of content (CK) and pedagogical content knowledge (PCK) of teacher candidates, were given more opportunities to learn university and school level mathematics. Same study also concluded that male teachers had higher means on content knowledge than females (Tatto & Senk, 2011). Reporting out on the same study, other researchers indicated that “[g]eneral ability seemed to be an important predictor of achievement in teacher education” (Blomeke, Suhl, & Kaiser, 2011, p.166). Content knowledge in teacher education programs, particularly with an emphasis on mathematics, emerged as a strong predictor of future teachers’ competency in STEM education.

Some researchers suggested teacher education programs with an integrated curriculum emphasis. In early studies, teacher educators assessed poor emphasis on integrated curriculum to be a major limitation of mathematics and science teacher education programs in the U.S. (Czerniak et al., 1999; Mason, 1996). Teacher educators recommended a reorganization of the teacher preparation programs to introduce integrated curriculum pedagogy to the pre-service teachers (Lonning & DeFranco, 1994, 1997). More recently, researchers found evidence that an integrated mathematics and science teacher education program increased pre-service teachers’ awareness on the challenges of STEM education (Berlin & White, 2010). In another recent study,

researchers concluded that if pre-service teachers did not observe and experience integrated curriculum, after becoming comfortable in traditionally departmentalized curriculum, they would become more reluctant to make changes (Schleigh et al., 2011). STEM education with the goal of raising innovative minds could only be realized if STEM teachers were provided with in-service and pre-service education that fostered integrated approaches.

Research Constructs

The major issue addressed in this study was K-12 student mistakes occurred on tasks that required knowledge of more than one STEM subject (Meisel, 2005). Therefore, in the present study, two constructs were defined: Integrated teaching knowledge (ITK) and mathematics used in science (MuS). The construct of ITK has been defined as (a) the capacity of a mathematics or science teacher to accurately recognize student mistakes; (b) effectively respond to those student mistakes (Ernest, 1984). The current study focused on one particular interaction between two STEM disciplines: mathematics and science. The interaction has been well-defined as MuS. The MuS construct has been an integral part of both mathematics and science, which are two indispensable content areas (Garavaso, 2005). In this particular study, the construct of MuS has been grounded in the post-modern perspective that claimed mathematics was indispensable to science with a pluralistic understanding of concrete applications and the functionalities that people gave to it (Skovsmose, 2010). The nexus of ITK and MuS is the Mathematics used in Science–Integrated Teaching Knowledge or MuSITK, which can help students overcome misconceptions.

The purpose of the current study is to determine whether pre-service mathematics and science teachers in Turkey are foundationally prepared to implement STEM education. The present study explores possible relationships between independent variables—gender, department (mathematics or science teaching), and teacher education program (CoHE’s standard program or alternative integrated program)—and the dependent variable—pre-service teachers’ integrated teaching knowledge of mathematics used in science (MuSITK) scores. Specifically, I seek answers to the following four research questions: (a) Is MuSITK performance of pre-service male teachers statistically significantly higher than that of the pre-service female teachers? (b) Is MuSITK performance of pre-service teachers studying at an institution with an integrated teacher education program statistically significantly higher than that of the pre-service teachers studying at an institution with the standard teacher education program? (c) Is MuSITK performance of pre-service mathematics teachers statistically significantly higher than that of the pre-service science teachers? (d) Is MuSITK mean score of pre-service teachers affected by any interaction of department, program, and gender main effects?

Theoretical Framework

Integrated Teaching Knowledge of Mathematics Used in Science

Content and pedagogy of MuS have been a mutual concern to both science and mathematics teachers. Pre-service teachers in Turkey believed knowledge of mathematics was essential to effectively teach science (Bulunuz & Ergul, 2001). In another study, pre-service primary school science teachers emphasized the importance of

mathematics for life and success at their teacher education program (Basturk, Mutlu, Yamac, Gultekin, & Suyun, 2005). Based on the teachers' practices, some researchers attempted to specify the challenges in teaching MuS, which converged at several issues, such as language differences (e.g., distance versus displacement), ambiguity in parallel concepts (e.g., no acceleration and no slope), and misconceptions (e.g., soil as a homogenous composition of clay, silt and sand, whereas a fraction models the parts distinctively) (Offer & Mireles, 2009). The MuS construct has been a shared responsibility of mathematics and science teachers, which brought several challenges to teachers of both subjects.

The notion of MuSITK in the current study has been defined as the ability of teachers to recognize student mistakes through their CK and to provide effective feedback through their PCK in MuS (Hill, Schilling, & Ball, 2004; Schilling & Hill, 2007; Shulman, 1986). The MuSITK construct was built on the assumption that it would be unrealistic to assume pre-service teachers to be competent in CK and PCK of both mathematics and science (Frykholm & Glasson, 2005). The notion of MuSITK was based on the conceptual definitions of MuS and ITK, which raised several challenges for both science and mathematics teachers.

Methods

Participants

The sample for the current study was purposively drawn from pre-service mathematics and science teachers. Participants were studying at state universities (faculty of education at university A or faculty of education at university B) to graduate

as primary school teachers with middle grades specialization (fourth through eighth grade). Participants were seniors in the last semester of their program. The universities were located in a major metropolitan city in Turkey. Further, the participants in the sample met two criteria: (a) they were eligible to graduate at the end of the term; (b) they were enrolled in their last methods courses.

The total sample size was 226: university A mathematics = 50 (Female = 25), university A science = 19 (Female = 12), university B mathematics = 49 (Female = 24), and university B science = 108 (Female = 75). The average age of the participants was 22. The methods course instructors awarded trivial extra credit to participants. The overall response rate for the participants taking the methods courses was 80%.

Program Analyses

In order to provide a clear description of each program at each university, first, I examined whether departments had similar entry-level requirements for pre-service teachers. Second, I investigated the websites of the universities and retrieved program descriptions, including the names, descriptions of the required and elective courses, and respective credit hours awarded for each course. Third, I compared the programs of four departments with CoHE's standard program for primary schools middle grades mathematics and science teacher education (Council of Higher Education, 2007). Finally, I categorized the courses in each program by using an adaptation of the coding scheme used by Kim, Ham, and Paine (2011, p.54).

Instrument

An instrument with eight open-ended questions was developed to measure participants' MuSITK levels. Participants were expected to recognize a student mistake and consequently develop effective feedback for items in eight MuS content areas (basic arithmetic in atomic weight calculations, dimensional analysis in unit conversions, reading graphs in time-velocity-displacement, plotting graphs in force-mass-acceleration, probability in Punnett squares, exponentials in large numbers of science, trigonometry in vectors, and algebra in balancing chemical equations).

Data Analyses

In the current study, the dependent variable was MuSITK scores and the independent variables were gender, program, and department. First, data were analyzed descriptively by finding the means and standard deviations for each item (ITK1 through ITK8). In addition to the psychometric properties of the items (item discrimination, item difficulty, and average completion time), analyses at the item-level included inter-item correlations and a confirmatory factor analysis. The factor analysis with one factor was conducted with a structural equation model (SEM) in Analysis of Moment Structures (AMOS) software, which used a maximum likelihood estimation on covariance matrices (Arbuckle & Wothke, 1999).

Second, data were analyzed for internal consistency of the scores for MuSITK variable. While there were several methods for estimating the reliability of the scores in the data, Cronbach's *alpha* was chosen because it has been one of the most widely used reliability measures (Bryman & Cramer, 1997; Capraro, 2004). Effect sizes were

reported for correlation-based measure of effect-size as well as variance-accounted-for. Observed power was reported only when there was not any statistically significant effect (Cohen, 1965). Thus, effect sizes were interpreted with respect to previously conducted research and the results obtained from post-hoc power analysis (Capraro, Capraro, & Henson, 2001; Capraro, 2004).

Third, data were analyzed at the descriptive level using MuSITK variable, including means and standard deviations for each group of participants. Next, the total sum of squares was partitioned (Sequential Type I method) in a three-way ANOVA model with gender, program, and department independent variables. Type I method was chosen to permit the actual cell sizes to contribute to the analysis with different priorities given to main effects, thus the overlaps of other two main effects could be adjusted for each main effect. Regardless of the order followed for the main effects, the test for the lowest order interaction remained the same (Maxwell & Delaney, 1990; Tanguma & Speed, 2000). Analysis was further extended by confidence intervals, providing a visual measure of how sure researchers were of their results (Zientek, Capraro, & Capraro, 2008).

Finally, a path diagram for the multiple-indicator, multiple-causes (MIMIC) model was developed to support the results of the ANOVA, which could also be used to investigate the item bias across the dichotomous gender, program, and department variables (Skronidal & Rabe-Hesketh, 2005).

Results

Program Evaluation

According to the results of the Student Selection and Placement Examination (SSPE), a centrally-administered standardized test used for placement of high school graduates to higher education institutions, all four departments had a consistent tradition of accepting high school graduates with the highest mathematics and science baseline scores in the city (Student Selection and Placement Center, 2007). All four departments graduate pre-service teachers who were employed by MoNE at public schools or private primary schools at the middle grades level. The departments issue teaching certifications that allow their graduates to teach either mathematics or science with a minor in the other subject area. Two major differences exist between the two faculties of education: (a) organization of the classrooms; (b) the course descriptions of the teacher education programs. Table 1 contains a summary of the programs.

Table 1
Comparison of the Courses in Integrated and Departmentalized Programs

Course Categories	Integrated program		Departmentalized program	
	Faculty of education A		Faculty of education B	
	Mathematics	Science	Mathematics	Science
Mathematics content theory courses (e.g., calculus, numerical analysis)	20CH	16CH	54CH	10CH
Science content theory courses (e.g., physics for mathematics; physics, chemistry and biology for science)	12CH	30CH	10CH	62CH
Pedagogy theory courses (e.g., classroom management)	18CH	18CH	28CH	28CH
Subject specific pedagogical content courses (e.g., teaching mathematics for mathematics; teaching science for science)	26CH	20CH	14CH	23CH
Integrated teaching courses (e.g., assessment in mathematics and science education; fieldwork in mathematics and science)	20CH	20CH	0CH	0CH
Department electives (e.g., courses offered by the departments or mathematics and science content theory courses, respectively for mathematics and science)	12CH	6CH	12CH	4CH
Unrestricted electives and other courses (e.g., computer, Turkish, foreign-language)	28CH	28CH	28CH	26CH
Total credit hours	136CH	138CH	146CH	153CH

Note. Number of credit hours (CH) indicated the total credits awarded for the courses in each category.

Integrated Program. Table 1 shows that program for mathematics and science teacher education departments in the faculty of education at university A had a balanced distribution of credit hours across each category. The program in the faculty of education A included more pedagogical content knowledge courses (26CH and 20CH for mathematics and science, respectively) than pedagogy theory courses (18CH for mathematics and science). Pre-service teachers in both departments were required to take a number of courses in their minor teaching area (12CH of general physics and chemistry for pre-service mathematics teachers and 16CH of general mathematics, including calculus, matrix algebra, and differential equations for pre-service science teachers). Students of all faculties in university A (e.g., education, engineering, business

administration) were taught the fundamental mathematics and science content courses (e.g., calculus, physics, chemistry, etc.) together. Pedagogy theory courses (e.g., classroom management, etc.) were mandatory for all students in all departments (e.g., pre-service teacher education, guidance counseling, etc.) in the faculty of education A. In addition, pre-service mathematics and science teachers were required to earn 20 credit hours in integrated teaching courses (e.g., assessment in mathematics and science education, school experience in teaching mathematics and science, etc.). Thus, I identified teacher education programs in university A as integrated (integrated mathematics and integrated science teacher education programs).

Departmentalized Program. Table 1 shows that program for mathematics and science teacher education departments in the faculty of education at university B were clearly theory intensive, both in content knowledge in pre-service teachers' majors (54CH and 62CH for mathematics and science, respectively) and pedagogy (28CH for mathematics and science). The program in the faculty of education B included more pedagogy theory courses than pedagogical content knowledge courses (14CH and 23CH for mathematics and science, respectively). The program did not include any integrated teaching course. Pre-service mathematics teachers were required to be enrolled in several courses in their major as advanced as numerical analysis, while pre-service science teachers were required to take advanced courses over three domains: physics, chemistry, and biology. Students in both departments were required to earn only 10CH in their minor (general physics and chemistry for pre-service mathematics teachers and general mathematics, including calculus for pre-service science teachers). In addition to

the finding that students in the faculty of education were separated from rest of the university, pre-service mathematics and science teachers did not have any common coursework, either. Students in both departments at the university B were required to take all courses in separate classrooms only with their peers in their departments. Thus, I described teacher education programs in university B as departmentalized (departmentalized mathematics and departmentalized science programs).

Standard Teacher Education Program. I observed that CoHE's standard pre-service teacher education program was similar to the programs implemented in university B. Thus, I described CoHE's standard education program as departmentalized.

Validation

Content Validity. For instrument development purposes, I contacted an expert Turkish science teacher and discussed the level and content of the mathematics topics in the Turkish middle grades science curriculum. The expert science teacher and I compared our initial findings with the mathematical content areas covered in Integrated Curriculum Practices and Perceptions Survey (Meisel, 2005). After several rounds of discussion, eight MuS content areas remained on the instrument. Later, an expert Turkish mathematics teacher was contracted to determine common student mistakes in each of the content areas, which followed the development of incorrect student responses for each of the eight MuS areas. Finally, eight items were developed. Each item included a question and a student solution that contained the common mistake. See Appendix A for the questions and Appendix B for the corresponding student solutions.

For validation purposes, the expert mathematics and science teachers evaluated the initial version of the instrument for content. After minor modifications, validation was carried a step further from initial arguments (Willson, 1991) and the instrument was piloted with pre-service mathematics ($N = 10$) and science ($N = 8$) teachers in a faculty of education located in another metropolitan Turkish city. The sample in the pilot study consisted of all females, thus an independent t -test was used to compare the estimated means in MuSITK variable. An effect size Cohen's $d = 0.41$ was estimated with a statistically significant difference ($p < .05$), favoring the pre-service mathematics teachers in the multiple choice ITK test. G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007) was used to estimate a-priori sample size ($N = 199$) for a power of 80% in main and interaction effects of a three-way analysis of variance (ANOVA) design (Cohen, 1988). Based on the analysis of data from the pilot study, the instrument was finalized by converting multiple-choice items into open-ended questions.

Participant responses were assessed with a rubric (see Appendix C), which was used as a scoring guideline to quantify the characteristics of the different levels of performance in MuSITK (Gronlund, 1998). The rubric was designed collaboratively with the methods instructors of the participants to assign a minimum score of 0 (indicating inability to recognize the student mistake), a score of 1 (indicating a partial understanding of the misconception or a partial attempt at feedback to address the misconception), and a maximum of 2 (indicating an ability to recognize the mistake and provide effective feedback). Cohen's K (Kappa) statistic (Cohen, 1960, 1988) was used to calculate inter-rater reliability of the scores from the rubric for two expert raters, one

of whom was the researcher. Both raters were blind to the students' identities, as well as the other rater's scores. Mean Cohen's K (Mean = .75; $SD = 0.04$) indicated a good estimate of inter-rater reliability for non-dichotomous items (Cohen, 1960). Two raters discussed and reached a consensus on the items when there was no initial agreement. Finally, three professors with chemistry, physics, and mathematics education specialities and two graduate students of biology evaluated the items in the final instrument and the corresponding rubric. Minor modifications were applied to the instrument to match the content level of pre-service teachers.

The instrument was administered online and participants could complete it within a 24-hour period at their convenience. To ensure participant answers were not random, their completion time was monitored and participant response to each item was required. The mean completion time was 19 minutes ($SD = 5$ minutes).

Construct Validity. Descriptive statistics, including the means, standard deviations, and characteristics of each item are presented in Table 2.

Table 2
Descriptive Item Statistics for Items in MuSITK Instrument

Items	Mean	Standard deviation	Item difficulty (percentage of participants who obtained full points)	Item discrimination (corrected item total correlation)	Average completion Time (minutes)
ITK1	1.09	0.67	27%	.34	2.28
ITK2	1.56	0.69	67%	.30	2.29
ITK3	1.06	0.92	45%	.35	2.59
ITK4	0.44	0.75	16%	.32	2.57
ITK5	1.33	0.72	48%	.33	1.93
ITK6	1.01	0.72	27%	.30	3.83
ITK7	1.57	0.70	69%	.37	2.46
ITK8	1.62	0.66	73%	.38	1.41

Table 2 shows certain characteristics of the items in the instrument. For example, item 4 was clearly more difficult than the other items. Participants spent the most time on item 6. In the current study, corrected item-correlations were all equal or above the .3 threshold, indicating that none of the items needed to be dropped from the instrument (Pallant, 2001).

Table 3
Inter-item Correlations for Items in MuSITK Instrument

	ITK1	ITK2	ITK3	ITK4	ITK5	ITK6	ITK7	ITK8
ITK1	1.00	.11	.24**	.20**	.19**	.19**	.15*	.20**
ITK2		1.00	.12	.16*	.25**	.10	.20**	.22**
ITK3			1.00	.27**	.15*	.18**	.22**	.15*
ITK4				1.00	.14*	.14*	.14*	.16*
ITK5					1.00	.12	.21**	.23**
ITK6						1.00	.20**	.23**
ITK7							1.00	.29**
ITK8								1.00

Notes: * $p < .05$, 2-tailed. ** $p < .01$, 2-tailed.

The inter-item correlations were estimated by Pearson's r product moment correlation coefficient (see Table 3). Almost all items (except ITK1 and ITK2; ITK2 and ITK3 and ITK6; ITK5 and ITK6) were statistically significantly correlated. The inter-item correlations ranged from .11 to .29. The mean inter-item correlation among the items in the instrument was calculated as .26. Clark and Watson (1995) recommended a mean inter-item correlation in the range of .15 and .20 for broad constructs and a mean of .40 to .50 for more narrow constructs. Briggs and Cheek (1986) suggested that the optimal level of homogeneity for unidimensional measures occurred when the mean inter-item correlations were between .2 and .4. Scholars also emphasized that .1 should

be the lowest value of mean inter-item correlation for a unidimensional scale (Briggs & Cheek, 1986). The instrument used in the study was constructed to be unidimensional but found to be a fairly broad measure of ITK of pre-service mathematics and science teachers in MuS, in part because it measured both mathematics and science concepts broadly. Thus, the instrument was interpreted as a broad measure of the concept.

Figure 2 shows the model for the confirmatory factor analysis of the instrument. The standardized factor loadings, which were fairly close to one another, are given with numbers on arrows from the latent endogenous variable (MuSITK) to the observed exogenous variables (ITK1 through ITK8). The numbers on the exogenous variables indicate the extent that the corresponding factor explained the variance in that particular item. All regression weights were statistically significantly different from zero ($p < .001$) and the constrained scaling variable was ITK8. Close values of factor loadings within the range of .39 to .50 supported the one-factor model.

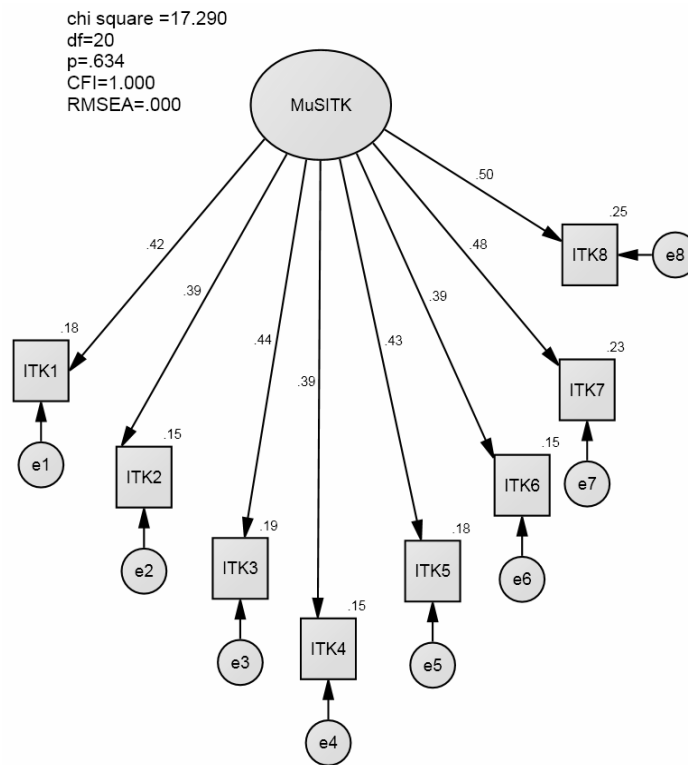


Figure 2. Confirmatory factor analysis model for MuSITK scores.

The sample size in the present study ($N = 226$) was above the minimum sample size requirement of 200 for the structural equation model to yield robust estimates. In addition, all univariate distributions were evaluated to be normal with respect to the absolute values of skewness and kurtosis (Kline, 2007). Several fit indices were used for the model: (a) $\chi^2 = 17.29$ failed to provide a statistically significant value ($p > .05$) for lack of fit (Barrett, 2007); (b) Comparative Fit Index (CFI) = 1 was particularly a good evaluator of model fit, as the sample size was not large (Tabachnick & Fidell, 2007) and given that threshold value of CFI for a good model fit should be above .95; (c) a maximum value of .06 was met for the Root Mean Square Error of Approximation

(*RMSEA*) (Hu & Bentler, 1999). Thus, the model reflected an acceptable or excellent fit to data.

Reliability. Internal consistency of scores was acceptable in exploratory research, when *alpha* values were below .70 (Hair, Anderson, Tatham, & Black, 1995). Likewise, Nunnally (1978) suggested that an *alpha* value below .70 would be tolerated in the early stages of research. Reliability of the scores in the current exploratory study was estimated with Cronbach's *alpha* ($\alpha = .64$, mean inter-item correlation = .26), indicating a promising measure for future development of the instrument and an upper limit of .80 for validity (Angoff, 1988).

Integrated Teaching Knowledge

The instrument, in which participants' ITK levels were assessed with the scoring rubric, included eight-items. The descriptive statistics for each group's overall mean score with a range of 0 to 2 are displayed in Table 4. The highest scoring group was the females in integrated science teacher education (Mean = 1.49, *SD* = 0.33), while pre-service teachers in integrated programs (Mean = 1.44, *SD* = 0.33) had higher scores on the average than their peers in departmentalized program (Mean = 1.11, *SD* = 0.37).

Table 4
Descriptive Statistics of MuSITK Scores for Each Group

Programs	Departments	Gender	Mean	SD	N
Integrated program	Mathematics	Female	1.39	0.38	25
		Male	1.46	0.29	25
		Total	1.43	0.34	50
	Science	Female	1.45	0.39	12
		Male	1.57	0.20	7
		Total	1.49	0.33	19
	Total	Female	1.41	0.38	37
		Male	1.48	0.27	32
		Total	1.44	0.33	69
Departmentalized program	Mathematics	Female	1.31	0.31	24
		Male	1.33	0.38	25
		Total	1.32	0.34	49
	Science	Female	1.04	0.33	75
		Male	0.96	0.38	33
		Total	1.01	0.34	108
	Total	Female	1.10	0.34	99
		Male	1.12	0.42	58
		Total	1.11	0.37	157
Total	Mathematics	Female	1.35	0.35	49
		Male	1.39	0.34	50
		Total	1.37	0.34	99
	Science	Female	1.09	0.36	87
		Male	1.07	0.42	40
		Total	1.08	0.38	127
	Total	Female	1.19	0.38	136
		Male	1.25	0.41	90
		Total	1.21	0.39	226

In order to determine if there were statistically significant differences across the groups in MuSITK scores, three-way ANOVA was conducted with independent variables gender (female = 0, male = 1), department (mathematics = 0, science = 1), program (integrated = 0, departmentalized = 1). Effect sizes were interpreted with respect to previously conducted similar research findings (See Table 5).

Table 5
Effect Size Estimates in Previous Studies on Student Achievement

Authors	Mean effect sizes (Cohen's <i>d</i> and <i>SD</i>)	Description
Hartzler (2000)	Overall = 0.48 (0.09) Mathematics = 0.42 (0.09) Science = 0.61 (0.19) Experienced teachers = 0.42 (0.10) Teacher-initiated = 0.13 (0.14)	Meta-analysis of 31 studies investigating the effect of curriculum integration on students' achievement
Hurley (2001)	Mathematics = 0.27 (0.09) Science = 0.37 (0.12)	Meta-analysis of the effect of curriculum integration on achievement data; 29 studies in mathematics and 21 studies in science.
Berlin and White (2011)	Difficulty = 0.45 (single pre-post test difference)	The effect of an integrated pre-service teacher education program on how difficult integration of STEM was perceived.

In three-way ANOVA, Levene's homogeneity of variance test indicated that the variances were not statistically significantly different: $F(7, 218) = 0.79, p = .60$. Sum of squares was partitioned sequentially with Type I method in the gender, program, department, gender by program, gender by department, , department by program, and gender by department by program order. The main effect of gender on MuSITK scores, when adjusted for the effects of all other factors, was not statistically significant: $F_{\text{gender}}(1, 218) = 1.83, p = .18, \eta^2 = .006$. The correlation between MuSITK scores and gender was not statistically significant ($r = .09, p > .05$). Observed power for gender main effect was (27%). For interaction effects, which were not statistically significant ($p > .05$), observed powers were program by gender (17%), department by gender (13%), and program by department by gender (9%). Parameter estimates showed that the integrated program, mathematics department, and their interaction were statistically significantly related to pre-service teachers' MuSITK scores. The three-way ANOVA model

explained 26% of the variance in the dependent variable MuSITK scores: $R^2 = .26$ (*adjusted* $R^2 = .23$). Thus, analysis showed that gender was not a statistically significant predictor of pre-service teachers' MuSITK scores (including main and interaction effects), three-factor term was dropped, and two-factor model was tested.

Table 6
Parameter Estimates for Two-way ANOVA (Sequential Type I)

Order	Parameters	<i>B</i>	Standard Error	<i>t</i>	<i>p</i>
Model 1	Intercept	1.01	0.03	30.87	<0.01
	Program	0.48	0.08	5.67	<0.01
	Department	0.31	0.06	5.21	<0.01
	Program*Department	-.038	0.11	-3.44	<0.01
Model 2	Intercept	1.01	0.03	30.87	<0.01
	Department	0.31	0.06	5.21	<0.01
	Program	0.48	0.08	5.67	<0.01
	Program*Department	-0.38	0.11	-3.44	<0.01

Note: Departmentalized program and science department were the reference cells in the intercept.

In two-way ANOVA with department and program factors, Levene's test of equality of error variances was not statistically significant: $F(3, 222) = 0.045, p = .99$. In model 1, the uncontrolled main effect of program on MuSITK scores was statistically significant: $F_{\text{program}}(1, 222) = 46.45, p < .01, \eta^2 = .16$, Mean Square Error = .116 (See Table 6). The correlation between MuSITK scores and program was statistically significant ($r = -.40, p < 0.01$). Thus, pre-service teachers in the integrated program were more likely to get a higher score in MuSITK than the pre-service teachers in the departmentalized program. Pre-service teachers in the integrated program (Mean = 1.46) had higher MuSITK scores on the average than the pre-service teachers in the departmentalized program (Mean = 1.17). The effect size was estimated with Cohen's *d*

= 0.83, calculated as the difference between group means divided by the square root of the mean square error when corrected for sample sizes (Thalheimer & Cook, 2002). In model 2, the uncontrolled main effect of department on MuSITK scores was statistically significant: $F_{\text{department}}(1, 222) = 39.66, p < .01, \eta^2 = .13$. The correlation between MuSITK scores and department was statistically significant ($r = -.37, p < .01$). Pre-service mathematics teachers (Mean = 1.37) had higher MuSITK scores on the average than the pre-service science teachers (Mean = 1.25). The effect size was estimated with Cohen's $d = 0.35$. When compared to mean effect size estimates in Hartzler (2000) and Hurley(2001), the effects were practically significant. See Figure 3 for the estimated marginal means used in effect size calculations for programs and departments.

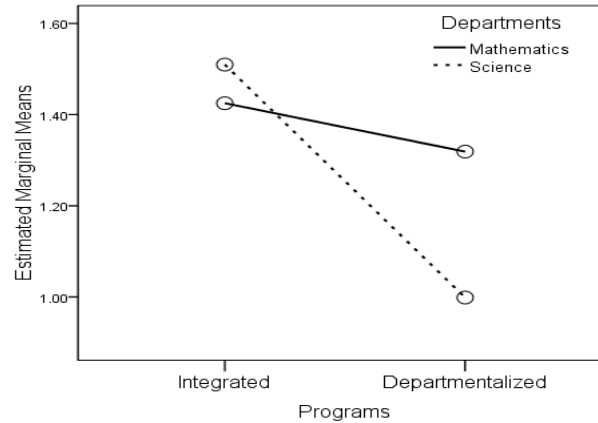


Figure 3. Estimated marginal means for programs by departments in MuSITK study.

The interaction effect of program by department was statistically significant: $F_{\text{program by department}}(1, 222) = 11.80, p < .01, \eta^2 = .04$. When programs were investigated separately, the correlation between MuSITK scores and department was statistically

significant in the departmentalized program ($r = -.38, p < 0.01$). Pre-service mathematics teachers in the departmentalized program (Mean = 1.37) had higher MuSITK scores on the average than the pre-service science teachers in the departmentalized program (Mean = 1.01). The effect size was estimated with Cohen's $d = 1.06$. When departments were investigated separately, the correlation between MuSITK scores and program was statistically significant for pre-service science teachers ($r = -.45, p < 0.01$). Pre-service science teachers in the integrated program (Mean = 1.49) had higher MuSITK scores on the average than the pre-service science teachers in the departmentalized program (Mean = 1.01). The effect size was estimated with Cohen's $d = 1.42$. Estimated $R^2 = .25$ (*adjusted* $R^2 = .24$) showed that the two-way ANOVA model explained 25% of the variance in the MuSITK scores.

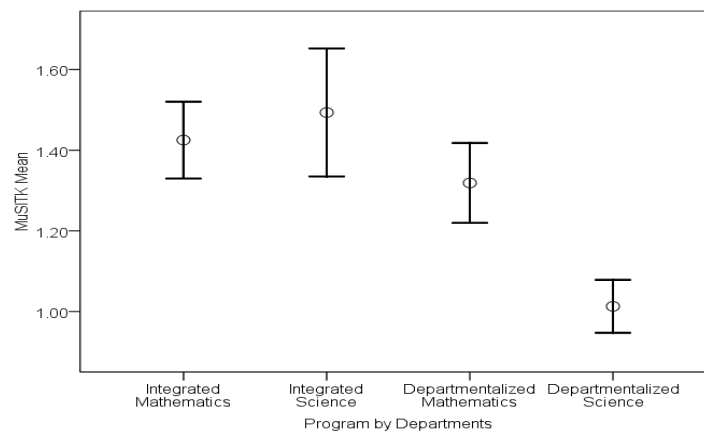


Figure 4. Confidence intervals (95%) for MuSITK mean scores of programs by departments.

Confidence intervals were used to represent the error bars for each group. Figure 4, which visually shows that pre-service science teachers in the departmentalized

program might have lower ITK scores in MuS, indicates that calculated confidence intervals would encompass the true population 95% of the time (Capraro, 2004). In Figure 5, the path diagram for the MIMIC model with standardized regression weights and fit indices is shown.

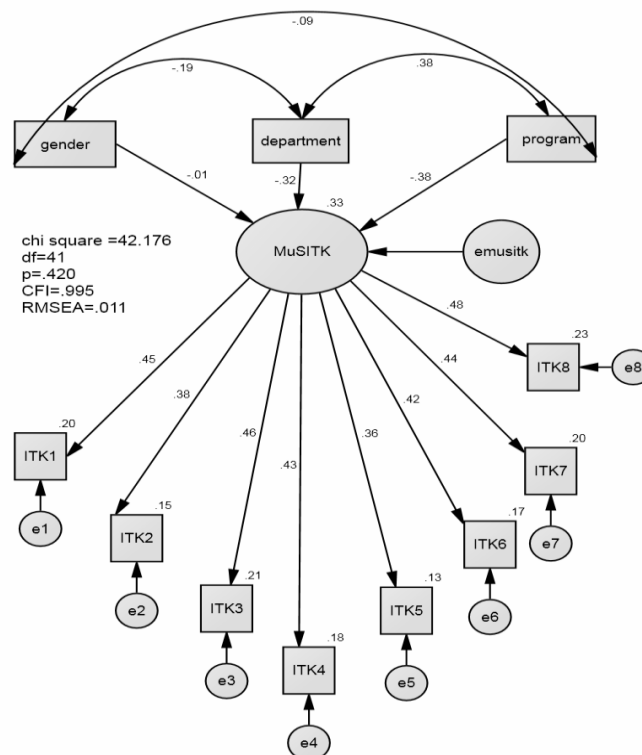


Figure 5. The MIMIC model for MuSITK study.

The MIMIC model was observed as a good fit to data with statistically significant regression weights, except for the gender variable ($p < .001$). Fit indices, which is shown on the Figure 5, met cut-off values for an acceptable or excellent fit to the data, observing $\chi^2 = 42.2$, $p = .42$ (Barrett, 2007), $CFI = 1.00$ (Tabachnick & Fidell,

2007), and $RMSEA = 0.11$ in the model (Hu & Bentler, 1999). The MIMIC model explained approximately 33% of the variance in MuSITK, offering comparable results with the ANOVA analyses and providing an insight into the item-level interpretation of bias with available covariates (Skrondal & Rabe-Hesketh, 2005).

Discussion

The instrument yielded data that indicates the instrument is useful for investigating MuSTIK with similar samples. It is important to conduct further studies to examine how the instrument performs with other samples and demographic groups. The instrument can be used for making decisions about effectiveness of pre-service teacher education programs (integrated or departmentalized programs) on teachers' ITK knowledge (cf. Wilson, Floden, & Ferrini-Mundy, 2001). The instrument needs further development to improve its item discrimination and item difficulty.

The findings are mixed with regard to the effect of gender on pre-service teacher's knowledge. The findings in this study indicate that there is no difference by gender whereas other studies suggest females outperform males in mathematics and science in Turkey (e.g. Alkan, Carkoglu, Filiztekin, & Inceoglu, 2008) or that males have better content knowledge than females (Tatto & Senk, 2011). This disparity may be explained with the fact that the population of the current study was all high performing students and the sample included pre-service teachers from highly competitive university programs.

Why did the pre-service teachers in the integrated program outperform pre-service teachers in the departmentalized program? CoHE argues for departmentalized

programs whereas Scientific and Technological Research Council of Turkey (2010), Turkish Academy of Sciences (2010), and several other stakeholders (Corlu & Corlu, 2010; Kartal, 2011; Ozoglu, 2010; Turkish Education Association, 2010) have and continue to support an integrated teacher education program that facilitates STEM education. The opportunities offered at the integrated program, such as balanced coursework of content, pedagogy, and pedagogical content knowledge (Carroll, 2007; Sanders, 2009), integrated teaching courses (Berlin & White, 2010; Schleigh et al., 2011), and the increased peer stimulation in classrooms (Subotnik, Tai, Rickoff, & Almarode, 2010) may be the reasons of the practical significance of the difference between the two programs.

The noteworthy difference between the scores of mathematics and science pre-service teachers can be explained by pre-service mathematics teacher' intense mathematics content education (Lehman, 1994; Stinson, Harkness, Meyer, & Stallworth, 2009), while pre-service science teachers in the departmentalized program are exposed to a comparably less mathematics content. Thus, it may be the case that the practical significance of the integrated program for pre-service mathematics and science teachers can be compensated to a lesser extent by mathematics content knowledge (cf. Tatto & Senk, 2011).

Conclusion

I believe that pre-service science teachers in the departmentalized program were not ready to facilitate STEM education. I recommend two solutions: (a) increase the mathematics content courses in the program; (b) design the program to allow science

education students to experience more mathematics teaching methods and content by sharing experiences with the students in the mathematics education program.

The conclusions of the current study are limited to university programs in a major metropolitan city in Turkey and the results should not be generalized to the rest of the universities across Turkey that adopt the standard teacher education program of CoHE. More research on STEM teacher education is needed at a larger scale. In addition, more in-depth analysis of the mathematics and science teacher education programs in the country is called for.

CHAPTER III

**AN EXPLANATORY MIXED METHODS STUDY: TEACHING
SELF-EFFICACY BELIEFS OF PRE-SERVICE MATHEMATICS
AND SCIENCE TEACHERS IN TURKEY**

Overview

The author of this article argued that an explanatory mixed methods approach was useful in understanding the complexity that underlies STEM education teaching self-efficacy beliefs. Data were collected from pre-service mathematics or science teachers in Turkey ($N = 81$), who were enrolled in two separate teacher education programs (integrated or departmentalized). After completing a survey measuring teaching self-efficacy beliefs (Cronbach's $\alpha = .83$), six pre-service teachers with deviant and maximum variation sampling methods were recruited for interviews. The quantitative data were examined for factors that might predict teaching self-efficacy beliefs, whereas the qualitative approach used constant comparative method to provide additional insights into teaching self-efficacy. Results indicated a complex range of factors that may affect teaching self-efficacy, including pre-service teachers' departments, self-evaluations in mathematics and science, past experiences, and post-graduation concerns.

Introduction

Innovation is critical for countries to achieve sustainable economic growth in the 21st century. Organisation for Economic Co-operation and Development (OECD, 2010a) describes innovation as the broad utilization of new knowledge that transcends science, technology, engineering, and mathematics (STEM). Innovation, which is derived from STEM advances (National Academy of Sciences, National Academy of Engineering, & Institute of Medicine, 2011), is critically important for the prosperity of nations because innovation creates jobs in the 21st century economy (Lacey & Wright, 2009). Innovation is tightly connected to life and innovation occurs as a result of the interdisciplinary work.

STEM education's foremost aspiration is to develop innovative minds. To achieve this goal, STEM education needs well-educated teachers, who are able to provide students with learning opportunities that transcend isolated STEM subjects (National Research Council, 2011). From this perspective, STEM education is integrated and differs from teaching STEM subjects as disparate curricular subjects (Jardine, 2006). STEM teachers, who are equipped with integrated teaching knowledge, can facilitate STEM education by integrating their subject area with other STEM subjects, so that students can learn how to utilize STEM knowledge (Corlu, 2012). STEM education casts the teacher in the role of a STEM education facilitator who raises the current generation with a capacity to innovate.

Turkish STEM Education Reforms

Turkish political leadership has provided policy makers in the country with a vision to become a competitive nation in the 21st century (Serbest, 2005). Ministry of National Education (MoNE), K-12 policy maker and the country's largest teacher employer, and Council of Higher Education (CoHE), higher education policy maker, were in charge of developing strategies to realize the vision of Turkish political leadership. Both policy makers independently introduced several reforms to change the status quo practices in mathematics and science education that do not foster STEM education.

STEM education reforms at the K-12 level were introduced by MoNE. The K-12 policy maker designed and introduced a new mathematics and science curriculum (MoNE, 2009d, 2009e). Among the changes in the new curriculum was that the old science education standards were replaced with a new set of integrated science and technology standards at middle grades (fourth through eighth grade) (Corlu, 2012). In addition, MoNE established guidelines to persuade mathematics teachers to integrate their courses with science (MoNE, 2005a, 2005b, 2009b). However, research showed that mathematics and science teachers were not adequately prepared or ready to implement integrated courses (Baskan, Alev, & Karal, 2010). STEM education reforms at K-12 level produced limited effects.

Council of Higher Education (CoHE) independently made superficial changes to the standard pre-service teacher education program. The higher education policy maker revised the standard program and introduced middle grades specialization in primary

school teacher education. Because the standard program was recommended by CoHE, the majority of the faculties of education adopted the standard program with minor modifications (Ozoglu, 2010). However, research indicated that the theory-intensive standard program was fostering neither subject-specific pedagogy (pedagogical content knowledge) nor STEM education (Corlu, 2012; Deniz & Sahin, 2006; Yuksel & Adiguzel, 2011). Some teacher educators believed that the standard program was limiting their ability to effectively prepare pre-service teachers for the teaching profession (Ozden, 2007). In fact, OECD's Teaching and Learning International Survey (TALIS) illustrated the need for quality teachers at Turkish schools was two times greater than the OECD average (Buyukozturk, Akbaba Altun, & Yildirim, 2010; OECD, 2009a). STEM teacher education reforms did not persuade external stakeholders to believe in the effectiveness of the standard teacher education program.

Undermining Reform Efforts

The competition for government jobs became highly competitive. MoNE began using a standardized multiple-choice state administered exam (Public Personnel Selection Examination [PPSE]) to select teacher candidates for jobs. There were more than 350,000 candidates for which there were far fewer jobs (Ozoglu, 2010). The PPSE was a uniform general ability test for teacher candidates of all subject areas. Thus, PPSE tested neither content nor pedagogical content knowledge (CoHE, 2007). Pre-service teachers believed that PPSE diminished the importance and relevance of their education at the universities because PPSE was the gatekeeper to employment and not the quality

of their education (Ozoglu, 2010). Reforms in the teacher assessment system damaged the credibility of teacher education programs at the universities.

Research Constructs

In the present study, participants were asked to self-evaluate their mathematics (sevmath) and science (sevscience) content knowledge on a continuous scale from 0 to 100. In addition, two research constructs were adapted from earlier studies: pre-service teachers' Teaching self-Efficacy Beliefs (TEB) (Bursal, 2010) and Mathematics used in Science (MuS) (Corlu, 2012). First, self-efficacy is defined as the self-confidence of pre-service or in-service teachers in their ability to implement STEM education (Bandura, 1997; Bursal, 2010; Enochs, Smith, & Huinker, 2000). Teaching efficacy of pre-service teachers did not encompass self-judgments to bring about desired outcomes of student learning (outcome expectancy) (Tschannen-Moran, Hoy, & Hoy, 1998), which is assumed to be specific to in-service teachers. However, teaching efficacy included pre-service teachers' (a) self-evaluation of their content knowledge in mathematics, science or both; and (b) self-efficacy in facilitating STEM education. Figure 6 presents the conceptual framework for the efficacy construct and illustrates where TEB is located with respect to related dimensions of efficacy. Second, in an earlier study, the researcher described MuS as the interaction between mathematics and science (Corlu, 2012). The construction of MuS included a pluralistic understanding of applications that have been derived from students' and teachers' interests in K-12 mathematics and science subjects and was one of the interdisciplinary interactions among STEM (Corlu, 2012; Skovsmose, 2010).

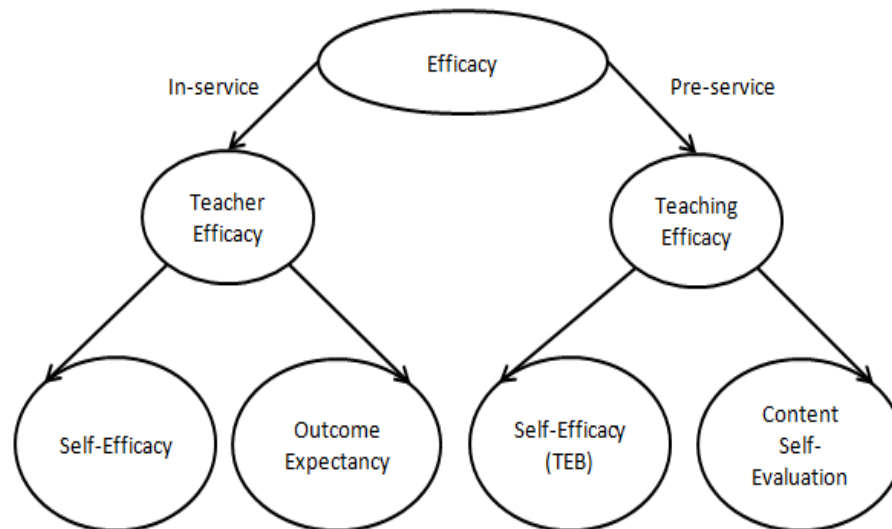


Figure 6. Efficacy conceptual framework.

The nexus of TEB and MuS was the Mathematics used in Science–Teaching Self-Efficacy Beliefs or MuSTEB, which could help teachers confidently implement STEM education. The purpose of the current study was to investigate whether pre-service mathematics and science teachers in Turkey, who are certified to teach both subjects at the middle grades level, believed in their capacity to facilitate STEM education. Thus, the main research question addressed in the paper was: How confident were pre-service mathematics and science teachers to facilitate STEM education?

Because the phenomenon addressed in the current study was multidimensional, it was necessary to use a variety of methods to understand the depth of the complexities (Greene & Caracelli, 1997). Explanatory mixed methods (sequential multimethod) research approach was needed and offered the researcher an ability to develop a deeper

understanding of the factors that affected extreme MuSTEB of a small number of pre-service teachers, while expanding understanding by looking at a larger sample (Tashakkori & Teddlie, 1998).

Research Questions

Quantitative Research Question. What were the relationships between independent variables, program (standard or integrated pre-service teacher education), department (mathematics or science teacher education) and gender, and the dependent variable MuSTEB score, when the effects of sevmath (self-evaluation in mathematics content knowledge) alone and sevmath and sevscience (self-evaluation in science content knowledge) combined were controlled?

Qualitative Research Question. Would qualitative data, which were collected from individuals with extreme MuSTEB, reveal dimensions of teaching efficacy that were not captured by MuSTEB?

Mixed Methods as the Complementary Third Wave. How could the findings of quantitative and qualitative research be integrated to illustrate the MuSTEB of pre-service mathematics and science teachers in Turkey?

Theoretical Framework

Teacher Efficacy

Researchers have grounded teacher efficacy on Bandura's (1997) self-efficacy construct, defined as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p. 2) and posited self-efficacy as a predictor of an individual's performance (Bandura, 1979, 1997). Other researchers

believed that teachers with high efficacy were more likely to have a positive influence on students' self-efficacy beliefs and motivation (Tschannen-Moran & McMaster, 2009). Some researchers attempted to conceptualize teacher efficacy as (a) teachers' confidence of their ability to teach their subject (self-efficacy); (b) their judgments in bringing about desired outcomes of student learning (outcome expectancy) (Tschannen-Moran et al., 1998). In this conceptual model, self-efficacy was the result of some internal factors, such as teachers' confidence of teaching their subject (Bandura, 1997) or teachers' self-evaluation of their content knowledge in their teaching area (Ashton & Webb, 1986). In contrast, outcome expectancy was "limited by factors external to the teacher" (Gibson & Dembo, 1984, p. 574), such as environment, background, and external influences (Gibson & Dembo, 1984). Teacher efficacy and self-efficacy were both domain-specific constructs that were affected by several internal and external factors.

Teacher Efficacy Beliefs of Turkish Teachers

Turkish teachers had similarly high efficacy beliefs as teachers in other OECD countries (OECD, 2009a). Some researchers reached a similar conclusion for mathematics and science teachers from a secondary analysis of TALIS data (Corlu, Erdogan, & Sahin, 2011; Oztelli, Corlu, Corlu, & Capraro, 2011). Another secondary analysis of TALIS data found that there was no statistically significant difference between mathematics and science teachers; however, female teachers were more efficacious than male teachers (Buyukozturk, et al., 2010). Turkish mathematics and science teachers had strong beliefs in their ability to teach their subjects.

Quantitative Measures of Teaching Self-Efficacy

Several researchers argued that teacher self-efficacy beliefs were most likely to develop during early years of teaching or during the pre-service education program (Hoy & Spero, 2005). Pre-service teacher education emerged as a critical stage to foster high teaching self-efficacy beliefs because self-efficacy beliefs were resistant to change after pre-service teacher education (Sahin-Taskin & Haciomeroglu, 2010). However, there has been a lack of agreement on how the teacher/teaching efficacy construct should be conceptualized and measured (Ward, 2009). Researchers have agreed on the necessity to develop an efficacy measure specific to pre-service teachers.

The development of an efficacy measure specific to pre-service mathematics and science teachers occurred in two stages. First, some researchers adapted Gibson and Dembo's (1984) general efficacy scale and designed the Science Teaching Efficacy Beliefs Instrument (STEBI) (Enochs & Riggs, 1990; Enoch, Scharmann, & Riggs, 1995). Second, some researchers replaced the word *science* with *mathematics* and designed Mathematics Teaching Efficacy Instrument (MTEBI) (Enochs et al., 2000; Vinson, 1995). The instrument was designed with two factors: self-efficacy and outcome expectancy. Some researchers expressed their concerns on the outcome expectancy construct (Roberts & Henson, 2000), while M. Bursal expressed his concerns over outcome expectancy factor to derive valid conclusions (*personal communication*, 2 March, 2011). Therefore, outcome expectancy was not considered as a part of the study. Some researchers claimed that the instrument was the only (Ward, 2009) or the most

widely used teaching efficacy instrument in the literature (Kieftenbeld, Natesan, & Eddy, 2010).

Teaching efficacy beliefs of pre-service teachers' were measured in two subscales: self-efficacy (13 items) and outcome expectancy (eight items). The instrument provided researchers with reliable scores both in the U.S. (self-efficacy $\alpha = .88$; outcome expectancy $\alpha = .75$) (Enochs et al., 2000) and in Turkey (self-efficacy $\alpha = .83$; outcome expectancy $\alpha = .77$) (Isiksal & Cakiroglu, 2006). In a more recent study, Bursal (2010) utilized only the self-efficacy construct by modifying the instrument for Turkish pre-service teachers ($\alpha = .90$).

Pre-Service Teachers' Teaching Self-Efficacy Beliefs

Several researchers investigated pre-service mathematics and science teachers' self-efficacy beliefs in Turkey. Researchers indicated that pre-service teacher education program (between two programs that were similar to CoHE's standard program) (Isiksal & Cakiroglu, 2006), department (Aksu, 2008), years in the program (Isiksal & Cakiroglu, 2006; Taskin-Can, Canturk-Gunhan, & Ongel-Erdal, 2005), grade point average (Akkus, 2008) or gender (Bursal, 2010; Cakiroglu, 2008; Cakiroglu, Cakiroglu, & Boone, 2005) did not have statistically significant effects on mathematics or science teaching self-efficacy beliefs of pre-service teachers. Turkish pre-service teachers' self-efficacy beliefs in teaching mathematics and science were associated ($r = .54, p < .01$). However, participants were found to exhibit statistically significantly lower teaching self-efficacy in science than in mathematics ($p < .001$; Cohen's $d = .64$) (Bursal, 2010).

Some researchers focused on the effects of pre-service programs on teaching self-efficacy levels. When researchers investigated the change in teaching self-efficacy of pre-service teachers in the U.S. between the control and experimental groups (integrated mathematics and science course intervention), they found a statistically significant increase (post- and pre-test difference) in pre-service teachers' science teaching self-efficacy beliefs. However, researchers reported no statistically significant increase in mathematics teaching self-efficacy beliefs (Moseley & Utley, 2006). In a similar study, pre-service mathematics teachers, who were able to relate mathematics to some science oriented activities of daily life (earth surface, global warming, etc.), were more mathematically efficacious. In the same study, the researcher quoted a senior pre-service mathematics teacher, explaining how he was teaching MuS: "When I enter the classroom I talk about the events because of global warming like I am in TV show ... These are all dependent events and their probability of influencing each case might be calculated beforehand" (Akkus, 2008, p. 8). However, the study did not clearly identify at what level or environment the pre-service teacher was actually teaching.

Sequential Methodology

The present explanatory mixed methods study followed a sequential methodology: quantitative and qualitative sections (Creswell, 2003; Creswell & Plano Clark, 2007; Johnson & Onwuegbuzie, 2004). Data were collected with a sequential multimethod design to quantitatively explore the relationships between the dependent and independent variables and qualitatively explore the teaching efficacy beliefs of a few individuals who were purposefully selected from the quantitative sample (Sieber, 1973).

The final report was written in two phases to provide a clear delineation for the reader, which was followed by the pictorial representation of the factors linked to high and low MuSTEB archipelago (Lawrenz & Huffman, 2002). The integration of the results occurred within the discussion section (Creswell & Plano Clark, 2007).

Participants

The sample ($N = 81$; 48 females) was purposively drawn from pre-service mathematics and science teachers at two universities (university A and B), which were located in a major metropolitan city in Turkey. Participants were eligible to graduate as primary school teachers with middle grades specialization (fourth through eighth grades). They were on average 23 years old and were in the last semester of their program. Participants were studying in four departments: (a) mathematics teacher education department at university A = 19 (12 female); (b) science teacher education department at university A = 16 (10 female); (c) mathematics teacher education department at university B = 21 (12 female); (d) science teacher education department at university B = 25 (14 female). The participants in the sample met two criteria: (a) were eligible to graduate at the end of the term; (b) were enrolled in their last methods courses.

The sample for the qualitative section was purposefully drawn with a combination of deviant and maximum variation sampling methods (Patton, 1990; Teddlie & Yu, 2007). Purposeful sampling techniques allowed the researcher to focus on the importance and richness of the information that was retrieved from the informants with extreme MuSTEB scores and who represented all four departments and both

genders (Lincoln & Guba, 1985). From the sample of the study, two outliers were detected by investigating data through box-and-whiskers graphs and standardized z -scores. Fourteen individuals, including the outlier cases, were invited for follow-up interviews. Six individuals agreed to participate (3 females), resulting in the participants being equally divided between low and high ends of the 1.5 standard deviation difference with respect to the mean of the scores in the dependent variable in the quantitative section (deviant sampling). All four departments and thus both programs were represented in the sample (maximum variation sampling).

Pre-Service Teacher Education Program Milieus. The investigation followed four steps: (a) examination of the program acceptance requirements for pre-service teachers; (b) investigation of the coursework of each program as they were presented through university websites; (c) description of each program according to the coding scheme used in an earlier study (Corlu, 2012); (d) comparison of programs of four departments with CoHE's standard program for middle grades mathematics and science teacher education (Council of Higher Education, 2007).

First, the results of the Student Selection and Placement Examination (SSPE), a centrally-administered standardized test used for placement of high school graduates to higher education institutions, indicated that all four programs accepted students who were ranked in the in the fifth percentile or above of one and a half million high school graduates (Student Selection and Placement Center, 2007). Thus, I assumed entry-level mathematics and science content knowledge levels of pre-service teachers in four departments were similar. Second, I found that mathematics and science teacher

education departments at university A followed similar programs, indicating a balanced distribution of courses with respect to content, pedagogy, and pedagogical content knowledge in pre-service teachers' major teaching areas (mathematics or science teaching). In addition, programs required pre-service teachers to earn considerable credit hours in their minor teaching area (mathematics or science teaching). Both programs also included some coursework in integrated mathematics and science teaching. Pre-service mathematics and science teachers took pedagogy, content, and integrated teaching courses together. Thus, I concluded that the programs in university A were similar to what the researcher in an earlier study described as an integrated program (Corlu, 2012). Third, the same study described CoHE's standard teacher education program as departmentalized, indicating that it was content and pedagogy intense and did not require any coursework on integrated mathematics and science teaching (Corlu, 2012). Thus, I concluded that the programs at university B were similar to CoHE's program while mathematics and science students at university B took pedagogy and content courses separately. Thus, the mathematics and science teacher programs in university A were integrated and programs in university B were departmentalized.

Quantitative Methods

Quantitative Data Collection. The data collection instrument used in the current study was an adaptation of Bursal's self-efficacy instrument (2010). The modification was restricted to the replacement of the word *mathematics* with *mathematics used in science*. To ensure a common understanding of MuS, participants were provided with the MuS definition and several examples that showed how mathematics was used in

science at the K-12 level (See Appendix A). The examples were used in a previous study (Corlu, 2012).

Bursal's (2010) self-efficacy instrument was adapted for a number of reasons: (a) the instrument was relevant to both mathematics and science teaching self-efficacy beliefs; (b) the instrument was specifically designed for pre-service teachers in Turkey; (c) the instrument was previously used with various relevant data sets in Turkey (e.g., Isiksal & Cakiroglu, 2006); (d) in a similar context good reliability estimates were reported in earlier studies, $\alpha = .88$ (Enoch, Smith, & Huinker, 2000) and $\alpha = .90$ (Bursal, 2010).

The instrument used in this study included 13 items (eight negatively and five positively worded) with a five-point Likert-type scale (strongly disagree = 1, disagree = 2, neutral = 3, agree = 4, and strongly agree = 5). Response values for the negatively worded items were reflected before calculating the mean for participant responses, which formed the Mathematics Used in Science Teaching Self-Efficacy Belief (MuSTEB) scores. The instrument was administered online and participants were allowed to complete the test anytime in a 24-hour period at their convenience. To ensure participant answers were not random, their completion time was monitored. Mean completion time was 5.5 minutes ($SD = 1.5$ minutes). There were no outliers in terms of completion time.

Earlier developers indicated that the instrument used in this study was in accordance with their instruments (L. Enoch, *personal communication*, 14 April, 2011; , M. Bursal, *personal communication*, 2 March, 2011). Reliability of the scores in the

current study was estimated with one of the most widely used measures in quantitative research (Cronbach's $\alpha = .83$), indicating a good measure of internal consistency of the scores (Bryman & Cramer, 1997; Capraro, 2004; Nunnally, 1978). The mean of the inter-item correlations was .30 ($SD = .15$). Researchers suggested that the mean inter-item correlations between .2 and .4 would provide the optimal level of homogeneity for unidimensional measures (Briggs & Cheek, 1986). Item-total correlations (Mean = .49; $SD = 0.13$; within .33 - .66 range) were aligned with the item-total correlations reported in earlier studies: Mean = .56; $SD = 0.08$ (Enoch et al., 2000) and Mean = .54; $SD = 0.12$ (Bleicher, 2004).

In addition to the MuSTEB dependent variable (range 1-5), two continuous independent variables were used: *sevmath* and *sevscience* (ranges 0-100). These variables were measures of participants' self-evaluations of their achievement levels in mathematics or science. Nominal independent variables gender (female = 0, male = 1), department (mathematics = 0, science = 1), and program (integrated = 0, departmentalized = 1) were coded as dummy variables.

Data were first explored with respect to normality, linearity, homoscedasticity, homogeneity of variance, and multicollinearity. Any violations were checked by means of graphical and statistical measures such as histograms, scatter-plots, skewness, kurtosis, Mahalanobis distances, and tolerance values (Tabachnick & Fidell, 2007). At the end of the initial examination, two outliers were detected and excluded from any further quantitative analysis. There were four missing data points in one of the predictor variables (*sevscience*) and a list-wise deletion procedure was performed.

Quantitative Analyses. Data were first analyzed with descriptive statistics for mean and standard deviations of the continuous variables (sevmath, sevscience, and MuSTEB), as well as their bivariate correlations. Second, hierarchical regression analysis (ENTER method) was used to assess the relationships between independent variables (program, department, and gender) and the dependent variable MuSTEBI score, by controlling for the effects of sevmath alone and sevmath and sevscience scores combined on the dependent variable in the given order (Tabachnick & Fidell, 2007). Three separate regression analyses were hierarchically performed given with three equations with standardized β (Beta) coefficients:

$$Z_{\text{MuSTEB}} = \beta_1 * Z_{\text{sevmath}}$$

$$Z_{\text{MuSTEB}} = \beta_2 * Z_{\text{sevmath}} + \beta_3 * Z_{\text{sevscience}}$$

$$Z_{\text{MuSTEB}} = \beta_4 * Z_{\text{department}} + \beta_5 * Z_{\text{sevmath}} + \beta_6 * Z_{\text{sevscience}} + \beta_7 * Z_{\text{program}} + \beta_8 * Z_{\text{gender}}$$

The change in R^2 and its corresponding change in F and p values were the statistics of interest (Wampold & Freund, 1987). Thus, the overall fit of the model was assessed with adjusted R^2 value in the final model.

Qualitative Methods

Qualitative Data Collection. The investigator was the main qualitative data collector. Data collection for the qualitative section was a “dialectic and responsive process” (Lincoln & Guba, 1985, p. 44-45). The process was initiated by contacting the method course instructors of the participants. The instructors provided information about the characteristics of the programs at each department (integrated mathematics, integrated science, departmentalized mathematics, and departmentalized science). As the

gatekeeper, course instructors helped the researcher gain access to the informants (Creswell, 2003).

Participants for the interview were recruited after the preliminary analysis of the survey was completed. Respondents to survey, who were interested in a follow-up interview, were asked to provide their contact details at the end of the survey. Contact was established with all pre-service teachers who were interested in the follow-up interview. Based on the analyses of quantitative data, a total of 14 pre-service teachers were invited for follow-up online interviews and six of them accepted the invitation. The informants were not required to have Internet connection because the gatekeeper provided them with appropriate physical conditions. However, all six participants expressed their availability and upon their preferences, the interviews were conducted online at the setting of their choice. Although the participants indicated they were proficient in English, all of them indicated that they would be more comfortable if the interviews were conducted in Turkish, the native language of the participants and the researcher. Pseudonyms were used for all participants. Remarkable quotes extracted from data (translated by the researcher) were numbered in squared brackets throughout the text and given in Turkish in Appendix E. A native speaker of English and Turkish helped researcher with the accuracy of the English quotes in the final report. The approximate duration of the interview, which was audio taped, was one hour.

Unobtrusive data were defined as additional tools that could assist in limiting selection or interviewer biases (Webb, Campbell, Schwartz, & Sechrest, 2000). Unobtrusive data were provided to the researcher by the participants. All participants

provided at least one lesson plan that they created during their methods course. In addition, two interviewees sent copies of some reports with regard to their observations during the practicum at schools. After each interview, the researcher noted his general impression of the experience. Other observations during the interviews and informal conversations with the methods course instructors were recorded in a reflexive journal, which also included the insights of the data collection methodology (Lincoln & Guba, 1985). Thus, data for the qualitative section were collected from four sources: (a) analysis of the programs of the institutions that respondents attended; (b) interviews; (c) reflexive journal; (d) unobtrusive data.

A semi-structured interview technique with an interview guide approach (See Appendix D for the interview protocol) was followed to increase the comprehensiveness of the data collected (Cohen, Manion, & Morrison, 2005). The interview guide approach allowed the researcher to ask each participant slightly different questions. The variance in the questions was affected by participants' responses to the survey. An informal member check procedure during the interviews (answers were repeated or rephrased by the interviewer and participants were asked to verify) were supported by a formal member check procedure (preliminary interview report was sent to each individual via email). All but one interviewee responded to the formal member check procedure.

“Working hypotheses exist in seminal form before the research process begins and continue to take shape through the completion of the study” (Erlandson, Harris, Skipper, & Allen, 1993, p. 59). The initial working hypothesis of the study was that the pre-service mathematics teachers would be more efficacious in mathematics used in

science. The beliefs about the nature of mathematics and science, pedagogy, and teaching were predicted as other factors of the extreme self-efficacy beliefs.

“Trustworthiness covers all areas that ultimately determine the study’s integrity” (Gonzalez y Gonzalez, 2004, p. 62). Thus, the prolonged interviews, the analysis of the programs and curricula at each institution, member checks, triangulation of the institution level observations with the methods course instructors, as well as working hypothesis shaped by thick descriptions were the pieces of evidence for the trustworthiness of the qualitative section of this study.

Qualitative Analyses. The constant comparative method (Glasser & Strauss, 1967; Lincoln & Guba, 1985) was implemented to analyze data obtained from the interviews. Constant comparative method included unitizing data, categorization, and identifying patterns. The researcher in the study investigated patterns that implied recurring regularities and created themes that described frequently occurring patterns (Gonzalez y Gonzalez, 2004).

Interview data were first transcribed from audiotapes into computer files in Microsoft Word. With the help of the *Review* feature of the computer software, the transcripts were broken into units of data. Next, the units were coded with the comment feature of the software in terms of the source of information, department, program, date, and the corresponding memo of the researcher about the unit. A macro file was used to extract the memos and associated units into a second Microsoft Word file with associated numbers. The soft copy of the document was printed out on thick paper and cut into units to allow comparison and organization into higher order meta-categories.

Data with pseudonyms were analyzed in Turkish. The comparison procedure was initiated with the first card being compared to the second card and then grouped accordingly. The procedure was repeated until all cards were grouped according to the common patterns that emerged. The unrelated cards were grouped together and compared to the emerged categories, added or discarded. Fourteen categories were formed at the end of this process, which were further combined into five themes.

Findings

Quantitative Results

The means and standard deviations for the continuous variables were *sevmath* (Mean = 79.15, *SD* = 13.30), *sevscience* (Mean = 72.10, *SD* = 14.20), and *MuSTEB* (Mean = 4.11, *SD* = 0.43). Descriptive statistics showed that the participants on average were self-efficacious with respect to teaching MuS. Correlation matrix in Table 7 shows the Pearson's *r* product moment correlation coefficients between continuous variables (*sevmath*, *sevscience*, *MuSTEB*) and nominal variables that were dummy coded: program (integrated = 0, departmentalized = 1), department (mathematics = 0, science = 1), gender (female = 0, male = 1).

Table 7
Correlation Coefficients in MuSTEB Study

	sevmath	sevscience	MuSTEB	program	department	gender
sevmath	1.00	.47**	.39**	-.19	-.31**	.11
sevscience		1.00	.47**	-.16	.44**	.17
MuSTEB			1.00	.11	.23*	.04
program				1.00	.089	.04
department					1.00	.02
gender						1.00

Notes: * $p < .05$, 2-tailed. ** $p < .01$, 2-tailed.

The predictor variables that were statistically significantly correlated with the MuSTEB criterion variable were sevmath ($r = .39, p < .01$), sevscience ($r = .47, p < .01$) and department ($r = .23, p < .01$), indicating that pre-service teachers with stronger self-evaluation of their content knowledge in both mathematics and science tended to be more self-efficacious in MuS. In addition, pre-service teachers tended to have stronger self-evaluations in their major subject areas: $r = -.31, p < .01$ for sevmath and $r = .44, p < .01$ for sevscience compared to department. The highest correlation ($r = .47, p < .01$) was between pre-service teachers' self-evaluations of their knowledge in science (sevscience) and mathematics (sevmath), indicating the close relationship between mathematics and science content knowledge. The findings were related to previous research that found teachers perceived mathematics and science as closely related subject areas (Bulunuz & Ergul, 2001; Corlu, 2012; Frykholm & Glasson, 2005; Frykholm & Meyer, 2002; Offer & Mireles, 2009). Earlier studies showed that Turkish pre-service teachers' self-efficacy beliefs in teaching mathematics and science were associated ($r = .54, p < .01$) (Bursal, 2010). Therefore, compared to the earlier studies, the correlations between variables were interpreted as modest.

Three regression models were developed hierarchically. Based on the conceptual definition of MuS, which focuses on *mathematics* used in science, and the finding that teachers' self-evaluation of their content knowledge in their teaching area might affect their self-efficacy beliefs (Ashton & Webb, 1986), pre-service teachers' self-evaluations of their mathematics proficiency (sevmath) was entered alone into model 1 and it statistically significantly predicted MuSTEB scores, $F(1, 73) = 12.56, p < .001$, adjusted $R^2 = .14$. When pre-service teachers' self-evaluations of their science proficiency (sevscience) was entered in the second block, sevmath and sevscience statistically significantly predicted MuSTEB scores, $F(2, 72) = 12.46, p < .001$, adjusted $R^2 = .24$. In addition to the variables in model 2, third model included the gender, program, and department variables. Variables in model 3 statistically significant predicted MuSTEB scores, $F(5, 69) = 7.36, p < .001$, adjusted $R^2 = .30$. The R^2 change across the models are presented in Table 8.

Table 8
Hierarchical Regression Model Summary for MuSTEB Study

Model	R	R ²	Adjusted R ²	Standard error	R ² Change	F Change	df1	df2	Significance F Change
Model 1	.38 ^a	.15	.14	.40	.15	12.56	1	73	.001
Model 2	.51 ^b	.26	.24	.38	.11	10.70	1	72	.002
Model 3	.59 ^c	.35	.30	.36	.09	3.20	3	69	.029

Notes: ^a Constant and sevmath. ^b Constant, sevmath, and sevscience. ^c Constant, sevmath, sevscience, gender, program, and department.

The R^2 change was statistically significant as variables were added to the models in each step. When program, department, and gender were added to the final model, the

variance was further explained by 9%, indicating the effect of the nominal variables when controlled for sevmath and sevscience. Thus, the final model explained 35% of the variance accounted for, which can be evaluated with a 30% adjusted R^2 value indicating the fit. Standardized regression coefficients are presented in Table 9 for each corresponding model.

Table 9
Hierarchical Regression Model Statistics for MuSTEB Study

Model	Predictors	Standardized Beta Coefficients	<i>t</i> -values	<i>p</i> -values	Tolerance
Model 1	constant		11.34	< .001	
	sevmath	0.38	3.54	.001	1.00
Model 2	constant		9.67	< .001	
	sevmath	0.21	1.80	.08	.78
	sevscience	0.38	3.27	.002	.78
Model 3	constant		8.13	< .001	
	sevmath	0.45	3.10	.003	.44
	sevscience	0.15	0.93	.35	.37
	program	0.17	1.70	.09	.92
	department	0.33	2.24	.03	.44
	gender	-0.04	-0.39	.70	.95

Table 9 shows that the tolerance values for the variables in each model were above .1, indicating that multicollinearity was not a threat to the precision of the estimates (Hair, Anderson, Tatham, & Black, 1995). The final equation of the model with standardized β (*Beta*) coefficients was:

$$Z_{\text{MuSTEB}} = 0.33 * Z_{\text{department}} + 0.45 * Z_{\text{sevmath}} + 0.15 * Z_{\text{sevscience}} + 0.17 * Z_{\text{program}} - 0.04 * Z_{\text{gender}}$$

The standardized β (*Beta*) coefficients showed that sevmath and department were statistically significantly predicting pre-service teachers' MuSTEB scores. Examining the predictor-dependent variable correlations showed that sevmath was the most important variable, followed by department, sevscience, and at a lesser extent by program variables (Thompson & Borrello, 1985). The model provided with the evidence that gender did not contribute to the model in predicting the MuSTEB scores (Thompson, 2006).

Qualitative Results

Table 10 shows interviewees' specific responses to each item in the survey.

Table 10
Informants' Responses to Each Item in MuSTEB Instrument

Items	Atakan	Bengu	Cem	Davut	Efe	Ferdi
I will find better ways to teach MuS	neutral	agree	neutral	strongly agree	strongly agree	neutral
I won't be able to teach MuS as well as other subjects regardless of my effort.	neutral	strongly disagree	disagree	strongly disagree	strongly disagree	agree
I know the methods how to effectively teach concepts of MuS	disagree	strongly agree	disagree	strongly agree	strongly agree	agree
I won't be effective in monitoring MuS activities	disagree	disagree	neutral	strongly disagree	strongly disagree	disagree
I won't be able to teach MuS effectively	disagree	strongly disagree	neutral	strongly disagree	strongly disagree	agree
I understand enough about the concepts of MuS to teach effectively	disagree	strongly agree	agree	strongly agree	agree	agree
I won't be able to explain how solutions to MuS problems work	neutral	strongly disagree	neutral	strongly disagree	disagree	disagree
I will be able to answer students' MuS questions	agree	strongly agree	neutral	strongly agree	strongly agree	neutral
I doubt I will have the skills to teach MuS	neutral	strongly disagree	disagree	strongly disagree	disagree	neutral
I would not invite the principal to evaluate my teaching MuS	neutral	neutral	agree	strongly disagree	strongly disagree	agree
I won't be able to help students understand concepts of MuS	neutral	strongly disagree	agree	strongly disagree	strongly disagree	agree
I will welcome student questions in MuS	disagree	strongly agree	disagree	strongly agree	strongly agree	neutral
I don't know what to do to turn students on to MuS	neutral	strongly disagree	neutral	strongly disagree	strongly disagree	neutral

Profiles. Qualitative results included a short description of the informants, including their background (how they were admitted to their respective program and departments) and what their beliefs were on mathematics or science. The purpose of depicting a profile of each respondent is to help readers make sense of the themes (Cohen et al., 2005).

Atakan, who was born in 1988 in a small Anatolian town, said, "I took the university exam again just to get into mathematics" [1], expressing his determination to

be a mathematics teacher. He maintained a high level of interest in mathematics since his high school years at the teaching specialized high school he attended. He believed, “mathematics at university requires more work” [2], however, this did not bother him, “mathematics has a unique place” [3] in his heart.

Bengu was born in 1990 in the capital of Turkey, Ankara. She had started schooling earlier than her peers had, and she expressed her philosophy of life as a competition. According to her, “life is about being better than others” [4]. She was abroad when she learned the result of her university examination (SSPE). She was very happy to have been admitted to University A mathematics teacher education program. However, she found herself in a tighter competition at university A. As an example, she admitted failing physics three times although she had a respectable average. She believed the curve system at university A was interfering with her competition: “I don’t see the point of competing against the physics majors” [5]. Remarkable about her was the quality of her lesson plans, which were all written in great detail. She said, “I benefit a lot from my mother” [6], who was also a teacher. Bengu was also the only respondent in our sample who did not attend a teaching specialized high school (cf. Ozel, Yetkiner, Capraro, & Kupcu, 2009).

Cem was born in 1989 and had attended school in a rural city in eastern Turkey. He came to Istanbul for the first time when he was accepted to the University B to become a science teacher. He was surprised to get the required score, because he always believed the low success of his peers at his high school might limit his individual success (Students’ final scores in SSPE come from two sources: (a) heavily from their individual

scores at the test; (b) from the product of their high school grades and the scores of their peers at their high school). He said, “my entire school life and even my social life, all are for after school, whether I’ll have a job or not” [7]. By saying so, he gave the interviewer the impression that he was spending a considerable amount of time to prepare himself for PPSE. He confirmed this statement during the formal member check process.

Davut, 22, who could not think of himself leaving Istanbul, was accepted to the mathematics teacher education program at University B in 2007. He was happy to stay in his hometown. He originally wanted to be a biology teacher before the SSPE, because mathematics for him always required more effort. He thought biology teacher education department would be easy. However, the downside for him was the duration of the program. He said: “five years! Just to be a teacher is just too long” [8]. Therefore, he reevaluated his options by also considering his father’s advice and decided to stay in Istanbul and study teaching mathematics. His fear of mathematics was boosted when he saw 80% of the class failed in the first calculus course. After all, he had concerns about how he was going to teach as he thought he was not learning much.

When accepted by the science education program at university A four years ago, Efe was 19. For him, matters such as being able to teach in a class or having control over the students were not difficult tasks. Because he believed, “I am already doing all those things in class” [9], indicating that he was content with practicing teaching at his methods courses. According to Efe, science was more concrete when compared with the abstract nature of mathematics. Science, he said, “deals with facts” [10].

Ferdi was born in 1989 and was attending university B mathematics teacher education program. Having to live apart from his family, who were settled far from Istanbul, made his adaptation to school very hard. He dreamed of himself as a mathematics teacher from a young age. However, he stated that for the courses except mathematics, “I actually struggled a lot” [11]. Mathematics, for him, was “a way to think” [12]. After he started his practicum at a primary school, he started to believe he would be able to handle the job, although he was anxious about becoming a teacher before.

Themes. In this section, researcher explored the phenomenon by presenting the ideas expressed by the respondents. Their ideas will be presented in the themes emerged from the analysis.

Defining MuS. It was important to determine whether MuS was understood in a similar fashion by all individuals coming from different backgrounds with different education styles. Responses were very close to each other and were in accordance with the MuS definition and examples given at the beginning of the survey (See Appendix A). Most of the answers included extra examples about solving equations, using large numbers or manipulating formulas. However, I also heard responses like numerical data, analysis, analytical thinking skills, problem solving, and calculations. I observed physics appeared to be the area that MuS was heavily mentioned in respondents’ opinions.

Bengu defined MuS as “mathematical interpretation of scientific data” [13]. She expressed her interpretation about the relationship between mathematics and science, “roots of science lays on mathematics” [14]. She added, “gravity, speed and chemical

reactions already exist in the nature but their mathematical data is what turns them into science” [15]. According to her, MuS was also a combination of logic and problem solving, emphasizing both subject areas would share the same inquiry processes. According to Ferdi, science owed a lot to advances in mathematics and they were inseparable in content. Atakan supported the view that mathematical content knowledge built the foundation of science that provided an analytical point of view, and without analytical thinking, he said, “science would be sorcery” [16].

Teaching MuS. Participants believed that they should have not been held responsible for teaching in their minor subject unless they were given proper education. Some pre-service mathematics teachers believed MuS was optional for their subject, rather than a necessity, while both science teacher candidates (Cem and Efe) in our sample indicated the necessity of knowing MuS for teaching in science. However, they did not necessarily believe that they needed to know how to teach MuS. Experience seemed to be the most important factor in portraying the self-efficacy beliefs of pre-service teachers, but the type of experience they should have remained as a matter of debate.

All but Davut complained about their lack of knowledge on the curriculum of the other subject when their opinion was asked about teaching mathematics used in science. Atakan and Bengu touched an important point by stating that they would be opining regarding solely their own pupilage and that they were not aware how the actual practice in the classroom was. Bengu said, “I do not have much information on the latest reforms in depth” [17] but she added “I had great teachers in school” [18] and she would

model her teaching after them. When asked if her teachers were integrating mathematics and science, she said her science teachers knew their mathematics, but they did not have much time to teach mathematics in depth. Cem said, “many times, my science teachers had to teach the mathematics content because it was required in science but not yet covered in mathematics” [19]. He explained, “I would like to do better job but not sure if I know what mathematics requirements are in science curriculum” [20].

Researcher observed Bengu was implicitly referring to American (National Council of Teachers of Mathematics [NCTM]) standards as the objectives in her lesson plans, which were all very well planned with a STEM education perspective. Bengu was investigating resources in English on the Internet while doing her assignments. She confirmed and added she benefited from taking her courses with the science teachers, as well. That was how, she indicated, she learned how to reach the science teaching resources. Thus, "I doubt I will have the skills to teach MuS" was strongly disagreed by Bengu. “I feel confident in teaching MuS because I saw how people taught science at our micro teaching sessions” [21]. However, she also said: “I have zero teaching experience in real classrooms. I do not know how people do [MuS] in real classes” [22]. According to her, even her friends in the science education department did not know what objectives were covered in the science curriculum. Efe, as a science education student in the same program confirmed his inadequate knowledge on MoNE’s new curriculum; however, his lesson plans included objectives from the new integrated science and technology courses at the middle grades level, indicating that he was aware of some of the Turkish teaching resources. Efe firmly believed that “science teachers

should be able to teach the mathematics if the content mandates” [23]. However, he proposed, “mathematics teachers should support science people [teachers], for example they can share or direct them to relevant resources” [24].

When Ferdi was asked to back up his *agree* statement to, "I know the methods how to effectively teach concepts of MuS", he stated that he gained skills around at his department. Many times, he repeated during the interview that mathematics was still mathematics. He further added, "We are just accommodating ourselves on how to teach mathematics" [25a] and "by focusing on developing a skill on mathematics"[25b]. I had the impression that he believed a good knowledge of mathematics would be enough to teach MuS. He corrected the impression during the formal member check by stating that pedagogy was also very important to understand students' thinking processes. He added science teachers should take more mathematics courses if they wanted to help their students with the MuS. He, however, believed his job was harder, because "I have to link mathematics to real-life, but life is not all about science" [26]. Similarly, Atakan, said his job as a mathematics teacher was about teaching the fundamental mathematics very well. According to him, how mathematics was applied to science was the responsibility of the science teachers and he should not be accounted for their lack of knowledge of applied mathematics. Not being cognizant of teaching mathematics, Cem was having difficulties. He conveyed his difficulty, "at the moment, I don't even know how I would teach to measure an angle or if they have problems with multiplying and division. I don't know how to teach them this. I did not receive any education on this" [27].

Davut said his good knowledge of mathematics and science school curricula was based on his experience in private tutoring. He said he needed to help his students solve science problems on many occasions and added “I used my mathematics teaching skills to help them” [28]. He stated he overcame his lack of knowledge in science through his motivation to help students be successful at the school examinations; besides, parents did not care if he was a mathematician or not, they wanted their child to be successful in core subjects, such as mathematics, science, or language. Cem, too had some private tutoring experiences, however he was not a strong believer in his ability to teach MuS as Davut was. Concerning teaching self-efficacy in MuS, Cem’s experiences of tutoring at a private tutoring institution were not equally positive as Davut’s experiences with tutoring in small groups. Cem said “Honestly, I am only teaching whatever the test questions ask. I do not know about mathematics teaching much” [29]. He added that the high school entrance exams were relevant to MuS; however, science questions in the SSPE were very specific to science.

All teacher candidates were sure they would be able to answer students’ questions in MuS, however only Bengu, Efe, and Davut said they would be happy to do it. None of the teacher candidates, except Davut, was sure what topics of mathematics were needed to teach the new science and technology curriculum successfully or what links were provided in MoNE’s mathematics curriculum to science. Davut, from university B, seemed to have compensated his lack of knowledge on the curricula through his experiences out of the university while the remaining informants from university B depended on their subject education in mathematics or science. Students in

university A, on the other hand relied on their exposure to teaching methods related to their minor during their integrated teaching courses.

Responsibility of MuS teaching. As the perceptions of mathematics used in science did not differentiate much from person to person, the matter of sharing the responsibility became an issue that divided interviewees.

Davut, who at the beginning, specifically mentioned that he was not very good at science, also stated that his previous experiences at university B content courses might have influenced his outlook to mathematics used in science as a discipline, rather than a school subject. He said he always loved biology classes that had little mathematics. However, he also remembered his physics professors, who constantly accused them of not being ready for learning physics because of their lack of knowledge in mathematics. Davut asked rhetorically “wasn’t it his job [referring to the physics professor] to help me learn that mathematics?” [30a]. He did not understand why the physics professor was blaming high school teachers, “high school mathematics teachers were just trying to help me get in to the university” [30b].

Ferdi spoke out that, “I understand some part of the basic mathematics is my responsibility” [31]. Yet, “science teachers can only do something on the foundation built by mathematics teachers” [32], he commented. Cem and Efe, in contrast, extended what Ferdi called the basic mathematics. They believed students in middle school level needed to come to the science classroom with abilities more than just adding and subtracting. Cem said, “it would be impossible to teach how to leave x alone in an equation while there are so many others to teach in the science curriculum” [33]. Efe

said students really needed to do more science related mathematics in mathematics classrooms. According to his observations during his practicum, Efe witnessed science students not being able to read the scale on a beaker. He believed mathematics teachers could teach measurement concept by asking the science teachers to provide them the materials if they needed. However, it was an agreement among all six teacher candidates that science teachers cannot ignore mathematics and should indeed know it. Both Efe and Ferdi, further believed the MuS, if not adequately covered in mathematics, would be suitable only for the most capable students. Because they both claimed, during the limited amount time that a science teacher had to teach MuS, only the high achieving students could learn MuS.

The mindset. All six-teacher candidates, except Bengu had obtained their high school degree from a teaching specialized high school in Turkey. At these schools, they had taken some pedagogy courses prior to coming to the teacher education programs at their universities. However, the pre-service teacher education programs seemed to have influenced the mindset of some respondents in a different direction. Some defined themselves as mathematicians/scientists rather than mathematics/science teachers or as a teacher with a MuS mindset.

Cem was concerned about the concrete-abstract contrast between mathematics and science. He said many of his answers to the survey were influenced by this contrast. In fact, when the abstract nature of mathematics and corresponding teaching methods were compared with the real-life connections of science, all six students intrinsically

thought it would be hard to jump back and forth between concrete and abstract during teaching in an integrated curriculum.

Post graduation concerns. High unemployment rates in teaching and the increasing number of university graduates in contrast to available jobs in the market still seemed to stress university students. Inevitably, the conversations got to the point that prospective teachers wanted to talk about their concerns regarding their future. I believed merging the related categories under post-graduation theme would be appropriate to have an insight to their teaching self-efficacy beliefs as prospective teachers of mathematics and science in Turkey.

Atakan, who had one of the lowest self-evaluation scores on mathematics knowledge (sevmath) described how mathematics had drifted away from its beautiful mind (referring to the popular movie) image when preparing for PPSE: "I think, PPSE clouded my mathematical thinking. I was better at reasoning and doing better at mathematics at high school. I miss that type of mathematics. Perhaps, I knuckled down to PPSE's test mathematics" [34]. Cem had concerns about the content of the PPSE, and how unrelated it was to teaching [PPSE is the sole criteria to be employed as a teacher at MoNE's state schools. It is a norm-based test and only a limited number of teacher candidates are employed]. He made it clear that the test was not encouraging them to facilitate STEM education. He said: "The test has nothing to do with science, or how mathematics and physics should be taught together. It is more like an aptitude test like the university examination" [35]. By all means, having the same opinions is not only Cem or Atakan. Studying his last year of university on becoming a science teacher, Ferdi

was also one of the other students who were denoting themselves to be concentrating and paying attention on preparation of the PPSE. As stated by Efe, “everybody solved the same questions” [36]. He also commented, "As it is not possible for us to see any question addressing using mathematics used in science, why would we waste our time concentrating on it; why should we even concentrate on teaching our main subject?"[37].

Davut made me, the researcher, look at this subject from a different dimension. He emphasized working for state schools was his last option, because if he did, he could be employed anywhere in the country, most probably in the Eastern cities, which was something he would not dream about because he wanted to stay in his native city. He believed his flexibility in teaching subjects, mathematics and science would be a big advantage in finding a job in a private school, or at a respected private tutoring institution. He said, “I am confident in myself being able to answer students’ questions on mathematics used in science at a private school” [38]. Bengu and Efe mentioned about their alternative options to state schools, too, such as working for private schools. According to them, graduating from university A would be an advantage for being employed at private schools. For them, their integrated programs at university A were well-respected among private schools that looked for creative and versatile teachers. They both believed that many private schools at the primary school level were less focused on the selection examinations. Bengu reckoned, “private schools prefer teachers with excellent teaching skills over mathematics experts with little teaching ability” [39]. Efe was convinced that he would be more flexible with implementing the curriculum at a private school and hoped more opportunities would rise to collaborate with other

teachers for STEM education. He said, “I would love to be working for a school with an international baccalaureate program” [40a], something he said, “that would be great to develop as a marketable teacher” [40b]. According to him, private schools promoted themselves with their students’ successes at the project competitions, and he observed, many times the winning science projects had good portion of rigorous mathematics.

Ferdi, with whom I talked about the double certification of mathematics teachers that allowed him to teach science, stated that MoNE naturally gave priority to mathematics majors, and practically the second certification (in their minor) was useless. Other teacher candidates expressed similar opinions about the double certification program and evaluated it as a temporary solution to a temporary teacher shortage, as it was abandoned for the coming students after them.

Cem said many of his friends were taking a semester off or taking easy courses to prepare for PPSE in the summer. When asked if he would be comfortable in teaching at a school with STEM education, Efe said “I am not seriously sure if I would be effective to teach at such a specialized school” [41]. He said his mathematics knowledge might not be enough to answer science questions that required advanced mathematics.

Mixed Methods Results

Linking the quantitative and qualitative data might explain the similarities and differences within the sample of the study to find the truth in a pragmatic third wave (Johnson & Onwuegbuzie, 2004; Greene, 2007). Figure 7 shows the high and low MuSTEB archipelago (Lawrenz & Huffman, 2002), linking the quantitative and qualitative findings. In the quantitative section of the figure, solid lines showed the

statistically significant regression weights ($p < .05$). The lines in the qualitative section represented the connections between the researcher's interpretation of the qualitative findings and the themes emerged from data. The analysis of data in terms of descriptive and correlation statistics and regression model were linked to the categories and themes emerged from the interviews (Creswell, 2003).

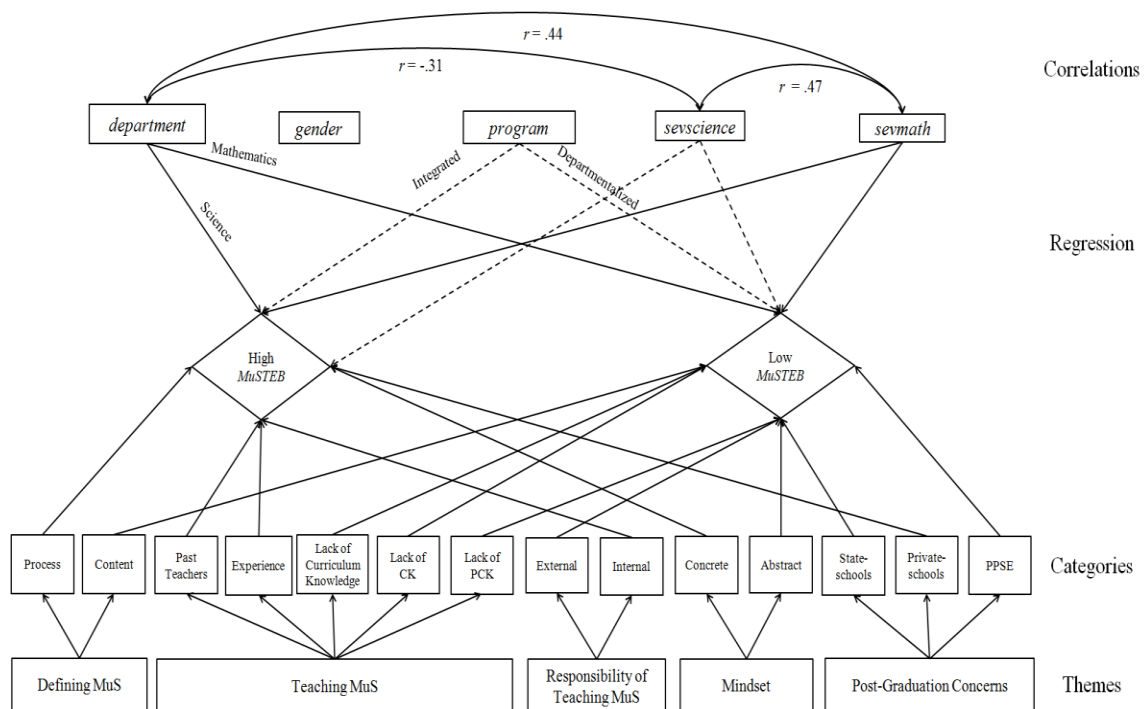


Figure 7. Mixed methods links in MuSTEB archipelago.

Discussion

The current study highlights the importance of mixed methods studies to develop a comprehensive understanding of the teaching efficacy construct. The qualitative findings exploit several additional dimensions that complement the findings of the

quantitative section (Johnson & Onwuegbuzie, 2005). By employing multiple research methods, the study provides a distinctive illustration of Turkish pre-service mathematics and science teachers' self-efficacy beliefs for mathematics and science integration.

It is evident from this study that Turkish pre-service mathematics and science teachers understand the role of mathematics in constructing scientific knowledge (cf. Corlu & Corlu, 2012). Pre-service teachers perceive mathematics as it contributes to science with its content or processes (Frykholm & Glasson, 2005; NCTM, 2000). Indications from this study highlight that an appreciation of the mathematical processes to construct knowledge in science lead to high self-efficacy beliefs in teaching mathematics and science integrated activities (cf. Akkus, 2008). Pre-service teachers' process-related definitions may indicate an understanding of STEM education that encompasses active exchanges of knowledge between mathematics and science (Corlu, 2011; Ernest, 2000).

Qualitative findings complemented the quantitative ones, dealing with correlation between pre-service teachers evaluations of their knowledge in mathematics and science. The correlation is practically important because the qualitative research *mindset* theme provided with some evidence that some pre-service teachers were having difficulty in adapting to the abstract-concrete contrast between mathematics and science (cf. Bulunuz & Ergul, 2001; Frykholm & Glasson, 2005; Offer & Mireles, 2009). As it was in the case of Ferdi, pre-service teachers, who struggled in one subject but highly successful in the other, may not believe that integrating mathematics and science was a task they can achieve (Akkus, 2008). The inverse relationship between self-evaluations in

mathematics and science can negatively affect some pre-service teachers' teaching efficacy beliefs for mathematics and science integration.

There was evidence that some pre-service mathematics and science teachers were well-informed about MoNE's revised mathematics and science curricula (cf. Kartal, 2011). Findings indicated that some pre-service teachers extended their understandings of MoNE's reforms through private tutoring for school success. Practical teaching experiences may help pre-service teachers develop high self-efficacy beliefs for mathematics and science integration (cf. Berlin & White, 2010; Oztelli et al., 2011). However, in contrast to Davut, who tutors students for success in school subjects, teaching for the tests at private tutoring institutions may not have the same positive impact on pre-service teachers' self-efficacy beliefs to teach in an integrated curriculum (Tansel & Bircan, 2006). Except Davut, all pre-service teachers had concerns with regard to their knowledge about MoNE's reforms at the K-12 level. With regard to reforms, Turkish universities may not be preparing pre-service teachers to teach according to the reforms at the K-12 level. Findings of this study support the concerns of stakeholders in Turkey, who complain about the lack of coordination between MoNE and CoHE (Corlu & Corlu, 2010; Gur & Celik, 2009; Kartal, 2011; Ozoglu, 2010; Scientific and Technological Research Council of Turkey, 2010, Turkish Academy of Sciences, 2010; Turkish Education Association, 2010).

Integrated and departmentalized pre-service teacher education programs had similar impacts on pre-service teachers' teaching self-efficacy beliefs. In one perspective, the integrated program provides pre-service teacher with opportunities to

learn how to facilitate STEM education (Corlu, 2012). The opportunities, such as balanced coursework of content, pedagogy, and pedagogical content knowledge (Carroll, 2007; Sanders, 2009), integrated teaching courses (Berlin & White, 2010; Schleigh et al., 2011), and the increased peer stimulation in classrooms (Subotnik, Tai, Rickoff, & Almarode, 2010) may help pre-service teachers internalize the responsibility of teaching mathematical applications used in science. For example, Bengu appreciated the micro teaching at her university and said her interactions with her peers in the science department helped her become self-confident in teaching in her minor teaching area. This provides with evidence that pre-service mathematics and science teachers critiquing their own teaching or evaluating their peers through micro-teaching sessions increase their content and pedagogical content knowledge in their minor teaching area and develop higher self-efficacy beliefs (Corlu & Corlu, 2012; Capraro, Capraro, Parker, Kulm, & Raulerson, 2005). The other perspective is in regard to the coursework in the departmentalized program. The amount of mathematics courses in the pre-service science teacher education program may be enough to help pre-service science teachers develop a solid mathematics content knowledge (Lehman, 1994; Stinson, Harkness, Meyer, & Stallworth, 2009), while excessive amount of mathematics courses may be the reason why mathematics pre-service teachers were less self-efficacious for mathematics and science integration. Mastery of content knowledge, either through a reasonable amount of content courses in the other subject or integrated teaching courses, may help pre-service teachers assume the responsibility of teaching MuS (cf. Taskin-Can et al., 2005).

Post-graduation concerns of pre-service mathematics and science teachers can be explained by the highly competitive teacher employment system in Turkey. Pre-service teachers are concerned about the selection process and the scope of PPSE, which was defined by Cem as a general ability test similar to university entrance examinations (Ozoglu, 2010). Cem, who said: “The test has nothing to do with science, or how mathematics and physics should be taught together”, may be the voice of thousands of pre-service teachers’ who expect a secure job at state schools after their graduation (Ozoglu, 2010). The way that the teacher employment system works may affect pre-service teachers’ self-efficacy beliefs, resulting in a lack of confidence in their education at Turkish universities (Ozoglu, 2010). Some pre-service teachers may also be reluctant to be employed at schools that are far from their hometown. Those pre-service teachers may search for a job at private tutoring institutions or private schools. Pre-service mathematics and science teachers at the integrated program may have higher efficacy beliefs for teaching in a private school. As a result, post-graduation concerns of pre-service teachers are related to external factors of the efficacy construct. Therefore, post-graduation concerns of pre-service teachers’ may indicate a relationship between teaching self-efficacy beliefs and outcome expectancies that were related to environmental factors (Gibson & Dembo, 1984; Tschannen-Moran et al., 1998).

Conclusion

I believe pre-service mathematics and science teachers need to be provided with more teaching experiences in their minor teaching area (cf. Taskin-Can et al., 2005). By offering more coursework in PCK and integrated teaching knowledge (Corlu, 2012), pre-

service teachers may not need alternative methods to learn teaching, such as through private tutoring. This practice may restore the credibility of teacher education programs in Turkish universities (Ozoglu, 2010). Thus, a teacher education program, which fosters both theory and practice, may increase the quality of STEM education teaching at Turkish schools and help MoNE achieve its goal of raising the current generation with innovative mindsets.

Both qualitative and quantitative research methods have their own limitations (Stake, 1995). The mixed methods approach followed in the current study included the limitations of both methods to a lesser degree (Creswell, 2003). One of the major limitations of the qualitative section was the limited exposure to study context. A more in-depth investigation of both teacher education programs (integrated or departmentalized) was warranted. Quantitative analyses were limited in their ability to generalize the findings to a broader community, such that the results may be applied to similar teacher education programs in the country. The design of future program evaluation and research studies regarding teaching self-efficacy beliefs of Turkish mathematics and science teachers should take these limitations into consideration.

CHAPTER IV

**INVESTIGATING THE ATTITUDES OF PRE-SERVICE
MATHEMATICS AND SCIENCE TEACHERS TOWARDS
MATHEMATICS USED IN SCIENCE**

Overview

There has been some criticism of the teacher education programs in Turkey, claiming that pre-service teachers were not well-prepared for the profession. This study explored the mental readiness of middle grades pre-service mathematics and science teachers to facilitate curriculum integration. Data were collected from Turkish pre-service teachers ($N = 226$) who were enrolled in either integrated or departmentalized teacher education programs. Data supported the usage of the instrument, which was designed as a measure of attitudes towards mathematics used in science. Data were analyzed using a three-way multivariate factorial analysis of variance model. The independent variables were program (integrated or departmentalized), department (mathematics or science), and gender while the outcome variables were the attitudes towards the nature and teaching of mathematics used in science. The results indicated that pre-service mathematics teachers in the integrated program had more positive attitudes towards teaching mathematics used in science than pre-service mathematics teachers in the departmentalized program. The study showed that an integrated program may be an effective alternative to the standard teacher education program.

Introduction

The Turkish political leadership's vision was to develop a competitive country in the 21st century. To accomplish this, the political leadership developed the Vision 2023 foresight document. Furthermore they charged policy making organizations to enact legislations that would increase the size and productivity of the innovative human capital of the nation (Serbest, 2005). Both Ministry of National Education (MoNE), K-12 policy maker, and Council of Higher Education (CoHE), higher education policy maker, independently developed strategies to improve mathematics and science education in the country (Corlu, 2012). The Turkish political leadership was supported by policy making organizations through reforms in mathematics and science education.

Reforms at K-12 and higher education levels were enacted with little coordination between policy making organizations. For example, MoNE changed the middle grades (fourth through eighth grade) standards and encouraged mathematics and science education teachers to integrate their subjects (MoNE, 2005, 2006, 2009b) while CoHE enacted a double certification program for middle grades mathematics and science pre-service teachers, which enabled them to graduate with a minor degree in the other subject. However, CoHE's superficial changes in the standard pre-service teacher education program required no coursework in integrated teaching and few courses in pre-service teachers' minor teaching area (Corlu, 2012; Corlu, Capraro, & Capraro, 2011). In fact, the new program was more theory (content and pedagogy) intensive than the old program (Bulut, 2007; Kartal, 2011; Ucar & Sanalan, 2011). Because it was recommended by CoHE, almost all universities adopted the new program with minor

modifications (Isiksal & Cakiroglu, 2006). Reforms at the K-12 level were not supported by a pre-service teacher education program that integrated mathematics and science.

The uncoordinated strategies of MoNE and CoHE limited the impact of the reforms in twofold. First, according to the Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA), Turkish students continued to underperform peers (Aksit, 2007; Alacaci & Erbas, 2010; Organisation for Economic Co-operation and Development [OECD], 2009b; Zembat, 2010). Second, according to the Teaching and Learning International Survey (TALIS), the need for quality teachers continued to be a major problem (Buyukozturk, Akbaba Altun, & Yildirim, 2010; OECD, 2009a). In response to discouraging findings in cross-national studies, several influential organizations in the country, such as Scientific and Technological Research Council of Turkey (2010) and Turkish Academy of Sciences (2010) called policy making organizations to coordinate their efforts and increase access to Science, Technology, Engineering, and Mathematics (STEM) education by developing effective integrated teacher education programs. Reforms in K-12 and teacher education levels failed to produce effective outcomes.

Research Constructs

In the current study, two constructs are conceptually defined. First, STEM education includes the set of knowledge, skills and beliefs which are collaboratively constructed by students and teachers at the intersection of more than one STEM subject area (Breiner, Harkness, Johnson, & Koehler, 2012). Second, mathematics used in science (MuS) is the mathematical applications that are used in science. Several

examples of MuS at K-12 level were given in an earlier study, including probability in Punnett squares or reading graphs in time-velocity-displacement (Corlu, 2012). The MuS construct conceptualizes STEM education in the K-12 curriculum context.

The purpose of the current study is to describe the attitudes of pre-service mathematics and science teachers in Turkey towards MuS. The specific research questions were: (a) Are the attitudes of teachers studying in an integrated teacher education program statistically higher than the attitudes of teachers studying in a departmentalized teacher education program? (b) Are the attitudes of teachers affected by any interaction of department, program, and gender main effects?

Theoretical Framework

Researchers described the attitude concept in regard to two related theories. The theory of planned behavior, which was an extension of theory of reasoned action (Fishbein & Ajzen, 1975), posited that if individuals evaluated the suggested behavior (attitude) as positive and if they thought they were expected to perform the behavior then they would increase their motivation, which would result in an intention to perform that suggested behavior (Ajzen, 1985, 1988). In both theories, attitude was a concept of belief that represented “a person’s general feeling of favorableness or unfavorableness toward some stimulus object” (Fishbein & Ajzen, 1975, p. 216). Because teacher beliefs were “tacit, often unconsciously held assumptions about students, classrooms, and the academic material to be taught” (Kagan, 1992, p. 65), attitudes of teachers was defined as a mental state of readiness, which was organized through experience (Kulm, 1980).

Attitudes towards STEM education could be described as a mental state of readiness to construct knowledge at the intersection of more than one STEM subject area. Dogan (1999) suggested that when exploring the attitudes of pre-service teachers, it was necessary to consider their attitudes towards both the nature and teaching of the subject area. Some researchers stated that attitudes towards a discipline were usually defined by the instruments used in the study (Aiken, 1970). Because MuS provides STEM education with a context, attitude in the current study was defined by an instrument that measured pre-service teachers' interests in the nature (NMuS) and teaching of MuS (TMuS).

Attitudes towards Mathematics and Science

The attitudes of mathematics and science teachers have been investigated in a number of studies. Researchers stated that poor attitudes of pre-service teachers towards mathematics or science might inhibit both their own learning and teaching their subject area (Battista, 1986; Czerniak & Chiarelott, 1990). Research also showed that teachers' negative attitudes towards mathematics might be transmitted to students (Larson, 1983) or might negatively affect their students' mathematics achievement (Schofield, 1981). Earlier research on teachers' attitudes towards mathematics indicated that attitude had a statistically significant relationship with student achievement despite little practical significance (Aiken, 1976; Pajares, 1992). A mean effect size (Cohen's $d = 0.12$) is estimated across more recent studies on mathematics attitude and achievement (Ma & Kishor, 1997). In Turkey, it was shown that there was no statistically significant difference between male and female pre-service teachers' attitudes towards science

(Bayraktar, 2011; Bilgin & Geban, 2004; Tekbiyik & Ipek, 2007; Turkmen, 2002; Ucar & Sanalan, 2011). In one of the recent studies, researchers found that at the end of their four-year pre-service teacher education program, Turkish science teachers attitudes towards science was statistically significantly less than their attitudes at the beginning (Cohen's $d = 0.60$) (Bayraktar, 2011). In another study, CoHE's new pre-service teacher education program did not improve pre-service teachers' attitudes towards science (Ucar & Sanalan, 2011).

Some researchers explored the attitudes of teachers towards integrated mathematics and science teaching. Several researchers in the U.S. concluded that the attitudes of in-service teachers towards mathematics and science integration were statistically significantly lower than pre-service teachers' attitudes. A possible explanation to this finding was the subject-matter oriented teacher education of the past compared to the pedagogical content knowledge emphasis in the current pre-service teacher education programs (Lehman, 1994; Pang & Good, 2000; Stevens & Wenner, 1996). However, research also indicated that teachers' positive attitudes towards integration of mathematics and science did not automatically transfer into a successful implementation of integrated curriculum (Wicklein & Schell, 1995).

In qualitative investigations of attitudes of pre-service teachers' towards mathematics and science integration, researchers found that integrated teacher education programs enhanced pre-service teachers' understanding of integration and at the end of the program they were able to recognize and appreciate interdisciplinary mathematics and science applications (Koirala & Bowman, 2003; Morrison & Roth-McDuffie, 2009).

In another similar study, an integrated pre-service teacher education program was found to be an effective way to help mathematics and science pre-service teachers recognize the complexity and challenges of STEM education teaching (Berlin & White, 2010).

Methods

Participants

The sample for the current study was purposively drawn from pre-service mathematics and science teachers who were studying at state universities (faculty of education at university A or faculty of education at university B). Both universities were located in a major metropolitan city in Turkey. Participants were in the last semester of their 4-year undergraduate program, planning to graduate as primary school teachers with middle grades specialization (fourth through eighth grade). Further, the participants in the sample met two criteria: (a) they were eligible to graduate at the end of the term; (b) they were enrolled in their last methods courses.

The total sample size was 226: university A mathematics = 50 (Female = 25), university A science = 19 (Female = 12), university B mathematics = 49 (Female = 24), and university B science = 108 (Female = 75). The mean age of the participants across groups were similar ($\text{Mean}_{\text{Total}} = 22.27$; $SD = 0.43$). The methods course instructors awarded trivial extra credit to participants and the response rate was 80%.

Program Comparison

Pre-service teacher education departments at university A (integrated mathematics or integrated science) and university B (departmentalized mathematics or departmentalized science) accepted students who were ranked in the fifth percentile or

above of one and a half million high school graduates (Student Selection and Placement Center, 2007). There were three major differences between the universities: (1) at university A, the integrated program required a balanced coursework in theory (pedagogy and content) and practice (pedagogical content knowledge and integrated teaching courses). At university B, departmentalized programs were theory intensive; (2) at university A, the integrated program required more content courses in pre-service teachers' minor teaching area than departmentalized programs at university B; (3) at university A, integrated program allowed pre-service teachers in both departments to take courses together while at university B departmentalized programs required pre-service teachers to take all their courses separately (Corlu, 2012). Although the two departments in the integrated program at university A were very similar in terms of distribution of coursework, at university B pre-service mathematics teachers were required to take relatively less pedagogical content knowledge courses in their major teaching area than pre-service science teachers. Earlier research showed that CoHE's standard program was similarly theory-intensive (Corlu, 2012; Ucar & Sanalan, 2011) and the current study found that programs at university B were similar to CoHE's standard program. Therefore, pre-service mathematics and science teacher education programs at university A were integrated, while the programs at university B were departmentalized.

Data Collection

The data collection instrument adapted 14 items from Dogan's (1999) attitude survey (DAS), which was selected for four reasons: (a) DAS items were developed with

a consideration of other widely-used surveys, either in attitudes towards mathematics or science (e.g., Aiken, 1970, 1976; Schonfeld, 1989); (b) Dogan developed DAS items with a consideration of mathematics and science curriculum in Turkey; (c) DAS items were specifically designed for Turkish pre-service teachers; (d) score reliability for DAS in a similar context was reported at an acceptable level (Cronbach's $\alpha = .76$) ($N = 344$).

For the current study, the DAS was modified to measure pre-service teachers' attitudes towards the nature (NMuS) and teaching (TMuS) of MuS. Modifications included: (a) the word *mathematics* in DAS was replaced with *mathematics used in science*; (b) a 5-point Likert-scale (strongly disagree = 1, disagree = 2, neutral = 3, agree = 4, and strongly agree = 5) was used instead of a 4-point Likert-scale to expand the range of responses by including a middle choice. The instrument included seven negatively and seven positively worded in addition to the definition and several examples of MuS to ensure that there was a similar understanding of MuS between the researcher and the participants (See Appendix A).

The instrument was administered online and participants were allowed to complete the test anytime in a 24-hour period at their convenience. To ensure there were no missing data, online survey used item validation, which required pre-service teachers to respond to each item. To ensure participant answers were not random, their completion time was monitored. Mean completion time was 4.5 minutes ($SD = 1.8$ minutes). There were no outliers in terms of completion time.

Validity

Face validity was examined. Dogan indicated that the Attitudes toward Mathematics used in Science (AtMuS) instrument used in the current study was aligned with the same intent as that underlying DAS, for the two factors: NMuS and TMuS (*personal communication*, 15 November 2009). See Table 11 for the items included in the instrument.

Table 11
Percentages of Responses for Each Item in AtMuS Instrument

Items	Item names	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
MuS is something you have to do even if it is not enjoyable	NMuS1†	0	2	14	25	59
MuS is interesting	NMuS2	0	16	24	43	17
MuS is abstract and unrelated to reality	NMuS3*†	43	40	6	9	2
I am confident I will teach MuS well	TMuS4	0	3	24	27	45
I don't enjoy working with numbers in MuS	NMuS5*	39	27	28	5	1
MuS is exploratory and creative	NMuS6	2	15	29	35	19
MuS is an enjoyable subject to teach	TMuS7	0	8	34	29	28
I cannot see much value in MuS	NMuS8*	66	22	2	6	3
MuS is one of my favorite subjects to teach	TMuS9	4	17	33	24	22
I like the practical side of MuS	NMuS10	0	1	30	28	41
I don't have sufficient knowledge to teach MuS well	TMuS11*	33	30	32	4	1
MuS is boring	NMuS12*	47	43	5	5	1
I don't have enough interest in MuS to motivate pupils	TMuS13*	38	27	29	4	3
I think that the children I teach will not enjoy MuS	TMuS14*	29	39	31	2	0

Note: * Negatively worded items. † Deleted items.

Score reliability was acceptable for NMuS (Cronbach's $\alpha = .65$) with 8 items and TMuS (Cronbach's $\alpha = .80$) with 6 items (Bryman & Cramer, 1997; Capraro,

2004; Nunnally, 1978). Corrected item-total correlations were below the .3 threshold (Pallant, 2001) for two items (NMuS1 and NMuS3). Both items were dropped from the instrument. Reliability of the scores in NMuS scale with 6 items was estimated with $\alpha = .63$. Inter-tem correlations for NMuS (Mean = .23; range = .07 - .35) and TMuS (Mean = 0.41; range = .22 - .58) indicated NMuS and TMuS were broad constructs of attitudes towards MuS (Clark & Watson, 1995).

A confirmatory factor analysis of the remaining 12 items on two factors (NMuS and TMuS) was conducted using structural equation modeling (SEM) with Analysis of Moment Structures (AMOS) software (Arbuckle & Wothke, 1999) (See Figure 8 for the default model). The numbers on the arrows from the latent variables to observed variables are standardized factor loadings. Several fit indices are also shown on the figure, including statistically significant $\chi^2 = 201.51$ ($p < .001$) with $df = 53$, Comparative Fit Index (CFI) = .785, and Root Mean Square Error of Approximation ($RMSEA$) = .112.

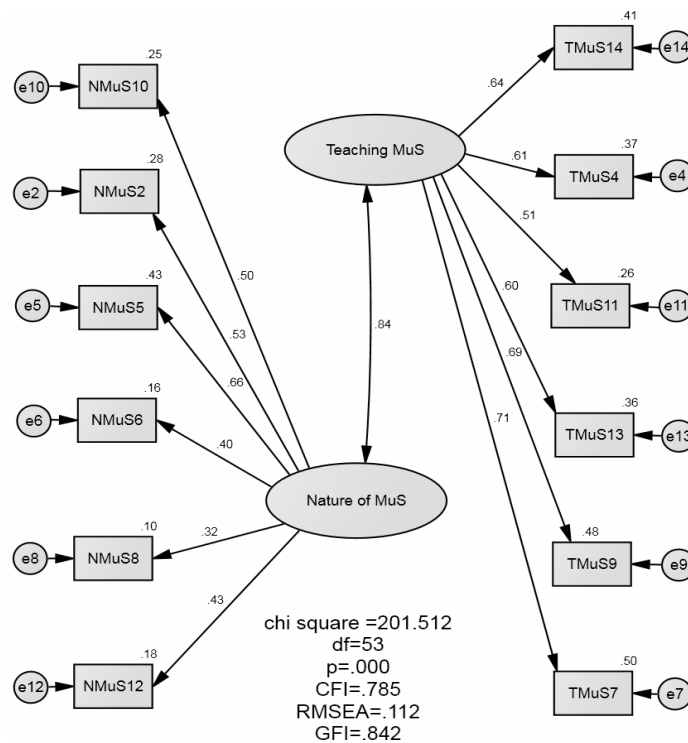


Figure 8. Initial confirmatory factor analysis model with NMuS and TMuS factors.

Investigating the modification indices for a better model fit lead to the revision of the default model. All standardized regression weights in the revised model (See Figure 9) were statistically significant ($p < .01$), except for items TMuS7 and TMuS9. Both items were rather unreliable predictors of TMuS scores. A necessity to reword TMuS7 and TMuS9 emerged as their factor score weights for NMuS were greater than their factor score weights for TMuS. The other modifications from the default model were theory-driven: (1) NMuS8 (*I cannot see much value in MuS*) and NMuS12 (*MuS is boring*) error correlation was based on earlier research, associating mystery-level values with the nature of mathematics and science (Bishop, 2008). Hence, it might be the case that pre-service teachers evaluated the abstract nature of mathematics as boring (2)

TMuS13 (*I don't have enough interest in MuS to motivate pupils*) and TMuS9 (*MuS is one of my favorite subjects to teach*) errors were correlated with the theoretical support from Dweck and Leggett's (1998) model, explaining the relationship between interest and motivation.

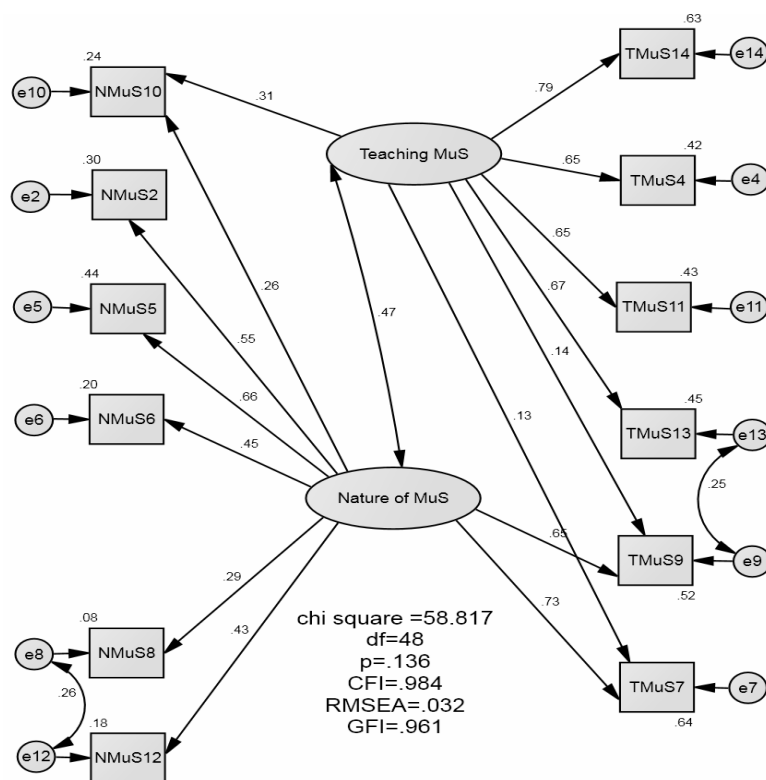


Figure 9. Revised confirmatory factor analysis model with NMuS and TMuS factors.

The sample size was considered large enough to yield robust estimates. In addition, all univariate distributions were evaluated to be normal with respect to the absolute values of skewness and kurtosis (Kline, 2007). Several fit indices were used for the model: (a) $\chi^2 = 58.81$ failed to provide a statistically significant value with $p = .14$

(Barrett, 2007); (b) *CFI* equals .98 was particularly a good evaluator of model fit (Tabachnick & Fidell, 2007) given that threshold value of *CFI* should be above .95; (c) a maximum value of .06 was also met for the *RMSEA* = .03 in the model (Hu & Bentler, 1999). The model reflected an acceptable or excellent fit to data.

Analyses

The data were first examined with respect to univariate normality, Mahalanobis distances for multivariate normality, homogeneity of error variance, and equality of covariance matrices. Assumptions were checked by means of graphical and descriptive statistical measures, such as histogram, scatter-plots, skewness, and kurtosis (Tabachnick & Fidell, 2007). Three outliers were detected and excluded from further analyses. Data were analyzed with a three-way multivariate Analysis of Variance (ANOVA) model with continuous dependent variables; NMuS and TMuS scores and nominal independent variables gender (female = 0, male = 1), department (mathematics = 0, science = 1), and program (integrated = 0, departmentalized = 1).

Results

Table 12 shows the descriptive statistics for NMuS and TMuS continuous variables: NMuS (Mean = 3.99, *SD* = 0.57) and TMuS (Mean = 3.85, *SD* = 0.69).

Table 12
Descriptive Statistics of NMuS and TMuS Scores for Each Group

Variable	Groups	N	Mean	SD
NMuS	Integrated program	69	3.96	0.62
	Departmentalized program	154	4.00	0.55
	Mathematics	99	3.98	0.53
	Science	124	3.99	0.60
	Females	135	3.99	0.56
	Males	88	3.98	0.58
	Total	223	3.99	0.57
TMuS	Integrated program	69	3.88	0.68
	Departmentalized program	154	3.84	0.69
	Mathematics	99	3.77	0.63
	Science	124	3.92	0.72
	Females	135	3.88	0.69
	Males	88	3.80	0.69
	Total	223	3.85	0.69

Pearson's r product moment correlation coefficient between the NMuS and TMuS scores was statistically significant ($r = .53, p < .01$), indicating a moderate correlation between dependent variables (Tabachnick & Fidell, 2007). In three-way multivariate ANOVA, the equality of covariance matrices test was not statistically significant, Box's $M = 17.72, F(21, 12140.75) = 0.80, p = .72$. Sum of squares was partitioned with Type I method sequentially in the gender, program, department, then gender by program, gender by department, department by program, and finally gender by department by program order. The uncontrolled main effect of gender was not statistically significant, Wilks' $\lambda = 1, F(2, 214) = 0.50, p = .61, \text{partial } \eta^2 = 0.005$. Observed power for effects that were not statistically significant were gender (13%), program (11%), department (48%), program by gender (38%), department by gender (40%), and program by department by gender (15%). The three-way multivariate

ANOVA model explained 2.4% of the variance in the NMuS scores, $R^2 = .02$ (*adjusted* $R^2 = -.01$), and 6% of the variance in the TMuS scores, $R^2 = .06$ (*adjusted* $R^2 = .3$). Thus, analysis showed that gender was not a statistically significant predictor of pre-service teachers' MuSITK scores, three-factor term was dropped, and two-factor model was tested. Table 13 shows the parameter estimates for two-way multivariate ANOVA.

Table 13
Parameter Estimates for Two-way Multivariate ANOVA

Variable	Order	Parameters	<i>B</i>	Standard Error	<i>t</i>	<i>p</i>
NMuS	Model 1	Intercept	4.00	0.06	71.58	<.01
		Program	-0.07	0.14	-0.5	0.62
		Department	-0.02	0.1	-0.15	0.88
		Program*Department	0.06	0.18	0.34	0.74
	Model 2	Intercept	4.00	0.06	71.58	<.01
		Department	-0.02	0.10	-0.15	0.88
		Program	-0.07	0.14	-0.5	0.62
		Program*Department	0.06	0.18	0.34	0.74
TMuS	Model 1	Intercept	3.96	0.07	60.31	<.01
		Program	-0.26	0.17	-1.55	0.12
		Department	-0.37	0.12	-3.18	<.01
		Program*Department	0.61	0.22	2.84	<.01
	Model 2	Intercept	3.96	0.07	60.31	<.01
		Department	-0.37	0.12	-3.18	<.01
		Program	-0.26	0.17	-1.55	0.12
		Program*Department	0.61	0.22	2.84	<.01

Note: Departmentalized program and science department were the reference cells in the intercept.

In two-way multivariate ANOVA with department and program factors, equality of covariance matrices (Box's *M*) or Levene's homogeneity of variance tests for TMuS or NMuS factors were not statistically significant. Neither in model 1 (program, department, and program by department order) nor in model 2 (department, program, and program by department order) was there any statistically significant effect of the factors, except for the interaction of program by department was statistically significant

for the TMUS scale, Wilks' $\lambda = 0.96$, $F(2, 218) = 5.04$, $p < 0.01$. When the interaction was investigated for each factor, it was statistically significant for TMuS, $F(1, 219) = 8.05$, $p < .001$, $\eta^2 = 0.03$, Mean Square Error = 0.45. Pre-service mathematics teachers in the departmentalized program (Mean = 3.59) had lower TMuS scores on the average than the pre-service mathematics teachers in the integrated program (Mean = 3.94). The effect size was estimated with Cohen's $d = 0.53$. Pre-service science teachers in the departmentalized program (Mean = 3.96) had higher TMuS scores on the average than the pre-service mathematics teachers in the departmentalized program (Mean = 3.59). The effect size was estimated with Cohen's $d = 0.55$. Estimated $R^2 = .05$ (*adjusted* $R^2 = .04$). The two-way multivariate ANOVA model explained 5% of the variance in TMuS scores. The effects were practically important when compared to previous findings, which showed that Turkish science pre-service teachers' attitudes towards science at the beginning of their pre-service teacher education program were statistically significantly higher than at the end of their program (Cohen's $d = 0.60$) (Bayraktar, 2011) and CoHE's departmentalized pre-service teacher education program did not improve pre-service teachers' attitudes towards science (Ucar & Sanalan, 2011). Graphical representation of the confidence intervals for each group is shown in Figure 10.

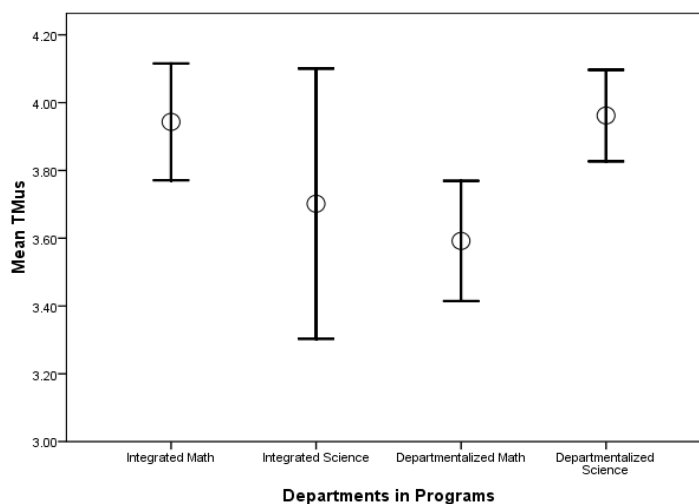


Figure 10. Confidence intervals (95%) for programs by departments in TMuS scale.

Figure 10 shows that pre-service teachers' in the departmentalized mathematics department had statistically significantly lower attitudes towards teaching of MuS, indicating that calculated confidence intervals would encompass the true population 95% of the time (Capraro, 2004).

Discussion

The instrument yielded data, indicating the instrument was useful for investigating pre-service teachers' attitudes towards mathematics and science integration with similar samples. It is important to conduct further studies to examine how the instrument performs with other samples and demographic groups. However, the instrument requires refinement, especially with the wording of two items intended to measure the TMuS dimension of pre-service teachers' attitudes towards mathematics used in science. The current wording fosters variation in response where the items load partially on NMuS. While this is not a fatal flaw, the language should be cleared up to

prevent the interpretation by the respondents that the items measure the attitudes toward the nature of mathematics used in science. Those changes need not invalidate the entire instrument but further work would delineate the practical importance of the two factors and their distinguishing abilities.

The current study highlights the importance of integrated mathematics and science programs for developing positive attitudes toward teaching mathematics and science in a modern integrated curriculum. The findings indicate that the impact of the integrated university curriculum is noteworthy for pre-service mathematics and science teachers' attitudes when compared to pre-service mathematics teachers in the departmentalized program. The integrated university program provides a number of distinct opportunities to pre-service teachers, which may explain this finding. For example, pre-service teachers in the integrated program may benefit from the balanced coursework of content, pedagogy, and pedagogical content knowledge (Carroll, 2007; Sanders, 2009), integrated teaching courses (Berlin & White, 2010; Schleigh, Bossé, & Lee, 2011), or the increased peer stimulation during classroom instruction (Subotnik, Tai, Rickoff, & Almarode, 2010), which have all been shown to positively impact pre-service teacher ability to integrate mathematics and science (Corlu, 2012), which might lead pre-service teachers to be less prone to anxiety for teaching in an integrated curriculum (Bursal, 2010). The excessive focus on mathematics CK coursework in the departmentalized program may have a negative impact on pre-service mathematics teachers' attitudes toward integrating mathematics and science (cf. Blomeke, Suhl, & Kaiser, 2011). Pre-service mathematics teachers in the departmentalized program need

to be provided with at least as many PCK courses as their peers in the science department. Pre-service mathematics and science teachers can be better prepared to adapt to MoNE's reformist curricula with an integrated teacher education program (cf. Ertekin, 2010).

Integrated program emerges as an alternative to CoHE's standard program. Integrated program prepares pre-service teachers equipped with a mental readiness to implement STEM education and adapt to MoNE's reforms. The integrated program may enable universities to better prepare pre-service teachers for the profession.

CHAPTER V

CONCLUSIONS

The Importance of Integrated Teacher Education Programs

In an increasingly knowledge-based economy, nations need well-educated STEM teachers who can raise the current generation with a capacity to innovate. Integrated teacher education programs prepare future teachers equipped with the knowledge, skills, and beliefs to effectively implement STEM education that increases the innovation capacities of students (Cuadra & Moreno, 2005). Pre-service teachers, who graduate from integrated teacher education programs with the integrated teaching knowledge, understand and teach STEM as an interconnected entity with a strong collaborative connection to life. They graduate with the ability to positively affect their students' achievement, beliefs, and attitudes (Tschannen-Moran & McMaster, 2009), and lead more and better prepared students to stay in the STEM pipeline (Burkam & Lee, 2003; Subotnik, Tai, Rickoff, & Almarode, 2010). Integrated teacher education programs educate future teachers to implement STEM education so that they can increase students' innovation capacities (National Research Council, 2011).

STEM teachers need to be prepared to adopt the changes introduced by curriculum reforms at the K-12 level. Integrated teacher education programs prepare pre-service teachers with the necessary skills to implement reforms. In an integrated program, pre-service teachers experience the complexity and challenges of curriculum integration (Berlin & White, 2010; Offer & Mireles, 2009). Pre-service mathematics and

science teachers develop an understanding and appreciation of the nature and teaching of the other subject area by monitoring their peers during micro teaching sessions while they learn to collaborate during integrated teaching courses (Capraro, Capraro, Parker, Kulm, & Raulerson, 2005; Corlu & Corlu, 2012). In an integrated teacher education program, pre-service teachers are educated to become the driving force and genuine supporters of the reforms that aim to transition from the departmentalized model of STEM teaching and learning to an integrated model that promotes innovation (Furner & Kumar, 2007).

Mathematics and Science Relationship

The proposition that posits *mathematics is abstract but science is concrete* is not supported in practice. In contrast to one view, which argues that mathematics and science are epistemologically too different to be integrated (Williams, 2011), both subjects are related to life and dependent on each other to construct new knowledge (Baskan, Alev, & Karal, 2010; Levin, 1992; Ogilve & Monagan, 2007; Pratt, 1985). The relationship of mathematics and science is defined according to different perspectives that emphasize one over the other, such as *mathematics used in science* or *mathematically rigorous science education* or *STEM education*. In this regard, post-modern perspective claim that mathematics and science are indispensable to each other, being supported by an pluralistic understanding of the concrete applications and abstract functionalities that people gave to them (cf. Skovsmose, 2010). This post-modern view helps educators understand STEM education as an integrated entity that raise the current

generation with a capacity to innovate. Therefore, STEM education invalidates the clear-cut distinction of mathematics and science.

STEM education at the K-12 level occur at the intersection of mathematical and scientific content and processes, such as problem solving and quantitative reasoning (Basista & Mathews, 2002; Frykholm & Meyer, 2002; Pang & Good, 2000). Students at the K-12 level experience mathematics extensively across the mathematically rigorous science curriculum (Jones, 1994). Mathematics used in science provide teachers with effective instructional tools (Blum & Niss, 1991). Science teachers use mathematics as a tool or an inscription device (Roth, 1993; Roth & Bowen, 1994) and mathematics teachers use science as an application (Davison, Miller, & Metheny, 1995). Mathematics used in science or mathematically rigorous science education provide educators with an understanding of STEM education that does not create an independent meta-discipline.

Pre-service mathematics and science teachers need to understand the role of mathematics in constructing scientific knowledge (Corlu & Corlu, 2012). Pre-service mathematics and science teachers should perceive mathematics as it contributes to science with its content or processes (Frykholm & Glasson, 2005; NCTM, 2000, 2006). With this point of view, pre-service teachers can develop an appreciation of the mathematical processes to construct knowledge in science (Akkus, 2008). Therefore, pre-service teachers can understand STEM education as an integrated entity that encompasses active exchanges of knowledge between mathematics and science (Corlu, 2011; Ernest, 2000).

Policy Implications

Policy coordination between K-12 and higher education will increase the quality of pre-service teacher education outcomes. This policy coordination can be realized from two perspectives: teacher education programs and a teacher employment system. Teacher education programs developed in tandem with K-12 school curriculum will help pre-service teachers experience teaching environments that resemble K-12 school settings. It can be expected that pre-service mathematics and science teachers, who are educated with an awareness of the realities of K-12 school teaching, will become more self-confident and mentally prepared to implement STEM education (Berlin & White, 2010; Darling-Hammond, 2006). Second, a teacher employment system, collaboratively designed by policy makers at K-12 and higher education levels and based on performance in pre-service teacher education will provide a better assessment of pre-service teachers' readiness to implement STEM education. This will help restore the credibility of mathematics and science teacher education programs. Respectively, pre-service mathematics and science teachers, who believe in the relevance of their education, need not seek alternative methods to learn and practice teaching. Policy-making organizations at K-12 and higher education levels need to develop policies and enact reforms in a coordinated manner (Gur & Celik, 2009) to positively affect the professional development, recruitment, and retention of teachers (Ozturk, 2005).

Teacher education programs should provide pre-service mathematics and science teachers with more opportunities to practice for the profession. A program that emphasizes teaching practice through pedagogical content and integrated teaching

knowledge will better prepare pre-service mathematics and science teachers for the profession. Excessive emphasis on theory in the coursework through subject-area or pedagogy courses widens the gap between the realities of the K-12 level teaching and teacher education at the higher education level. Teacher education programs should graduate teachers who are experts in content and pedagogy rather than graduating content or pedagogy experts who are eligible to become teachers.

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APPENDIX A

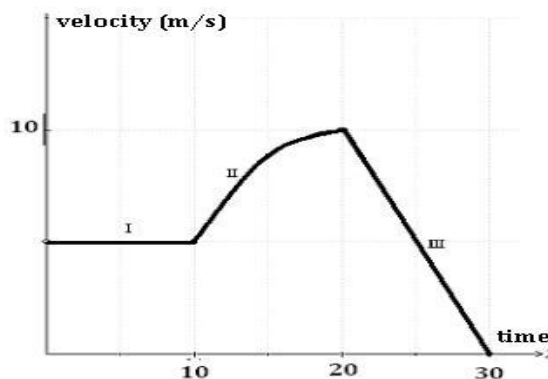
INTEGRATED TEACHING KNOWLEDGE QUESTIONS

Definition

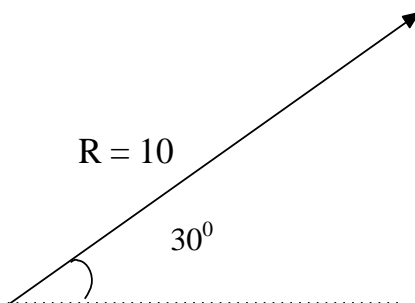
Mathematics Used in Science is defined as the knowledge, skills, and beliefs related to mathematics that is used in and necessary to solve the problems of science. Topics of mathematics used in science usually appear as a preliminary chapter of school science textbooks. You might have also seen mathematics used in science under problem solving exercises in mathematics textbooks? Here are some examples, given below in the form of questions asked to middle school students.

Questions

- 1) If 3 electrons were added twice to X^{-1} ion; what would be the charge of the resulting ion?
- 2) $1 \text{ g/cm}^3 = \dots \text{ kg/m}^3$.
- 3) Explain the movement of the car in terms of its relationship to acceleration according to the velocity-time graph given below.



- 4) Plot the relationship between mass (m) and acceleration (a) on Cartesian coordinates if force (F) is kept constant.
- 5) R and Y indicate two independent genes. If both parents have RrYy genes, find the probability of the child having RrYY.
- 6) Light travels approximately 300,000 km per second. Calculate the distance in meters of a planet which is 2 light years away from earth and show in scientific notation.
- 7) Find the chemical compound that should replace the unknown Y in the given chemical equation $2Y + H_2O \rightarrow CO_3H_2$
- 8) Find the vertical and horizontal components of the resultant R vector as it is shown in the figure.



(Sine $30 = 0.5$; Cosine $30 = \sqrt{3}/2$).

APPENDIX B

INTEGRATED TEACHING KNOWLEDGE SOLUTIONS

1)

$$-1 + 2 \times (-3) \Rightarrow -1 + 2 = 1 \Rightarrow 1 \times (-3) = \underline{\underline{-3}}$$

2)

$$\begin{aligned} 1\text{g} &= 10^{-3}\text{kg} \\ 1\text{cm}^3 &= 10^{-2}\text{m}^3 \end{aligned} \Rightarrow 1\text{g}/\text{cm}^3 = \frac{10^{-3}}{10^{-2}} = 10^{-1}\text{kg}/\text{m}^3$$

The answer is less than 1 because we converted smaller units (g and cm^3) into bigger units (kg and m^3)

3)

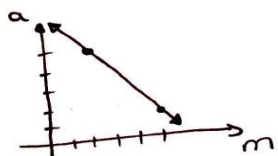
0-10 sec: slope = acceleration = 0 so velocity is constant and equal to 5.

10-20 sec: because of the increasing slope of the curve, the car speeds up with increasing acceleration.

20-30 sec: the car slows down with constant negative acceleration (deceleration)

4)

When F is constant m and a are inversely proportional. ex: $F=10 \Rightarrow$ 1) $m=2$ and $a=5$
2) $m=5$ and $a=2$



It is a line graph because both a and m have exponents of 1.

5)

1) $\frac{\text{Mother}}{Rr} \times \frac{\text{Father}}{Rr} \Rightarrow RR, rr$ and two Rr 's
 Rr probability $\frac{2}{4} \equiv \frac{1}{2}$.

2) $\frac{\text{Mother}}{Yy} \times \frac{\text{Father}}{Yy} \Rightarrow YY, yy$ and two Yy 's
 YY probability $\frac{1}{4}$.

3) Therefore, $RrYY$ probability becomes $\frac{1}{2} + \frac{1}{4} = \frac{3}{4}$.

6)

$$\begin{aligned} 2 \text{ light years} &= 2 \times 3 \times 10^5 \times 365 \times 24 \times 6 \times 10^3 \times 6 \times 10^3 \text{ m} \\ &= 1892160 \times 10^5 \times 10^1 \times 10^1 \times 10^3 \text{ m} = 1892160 \times 10^{15} \\ &= 1.89216 \times 10^9 \text{ m} . \end{aligned}$$

7)

$$2Y + 2H + O = C + 3O + 2H \quad (1)$$

Divide both sides by 2

$$Y + H + \frac{1}{2}O = \frac{1}{2}C + \frac{3}{2}O + H \quad (2)$$

Move H and $\frac{1}{2}O$ to the other side

$$Y = \frac{1}{2}C + 2O + 2H \Rightarrow Y = \frac{1}{2}CO_4H_4 \quad (3)$$

8)

$$\begin{aligned} x(\text{horizontal}) \text{ component} &= 10 \times \sin 30 = 5 \\ y(\text{vertical}) \text{ component} &= 10 \times \cos 30 = \frac{10\sqrt{3}}{2} = 5\sqrt{3} \end{aligned}$$

APPENDIX C

INTEGRATED TEACHING KNOWLEDGE

QUESTIONS & RUBRICS

General Score Rubric

Numerical Value	Descriptions
2	Teacher recognized the student mistake, solved the problem correctly, and provided feedback that addressed the student mistake.
1	Teacher recognized the student mistake, and solved the problem correctly, but did not provide feedback or the feedback was not addressing the student's mistake.
0	Teacher could not recognize the student mistake or could not solve the problem correctly.

Question Specific Rubric Indicators

- 1) Student processed the addition $-1+2$ although the multiplication should have been done first. Order of operations was ignored.

Multiplication/Division should be done first depending on whichever comes first, then the same rule should be applied to addition/subtraction
- 2) Student made a mistake while dividing two exponential numbers. When converting smaller units into bigger units, the answer may be bigger than one.

If you did not ignore cubing the conversion factor, you would have seen the answer was 10^3 .
- 3) 10-20 sec: Student wrote the slope of the curve was increasing so the car speeded up with increasing acceleration.

You should have drawn more than one tangent line on the curve to see the slope thus the acceleration was decreasing.

- 4) Student plotted a linear relationship. Graph is not linear because m (independent) and a (dependent) are two inversely proportional variables.

You should have plotted at least 3 points to have an accurate picture of the graph.

- 5) Student added the probabilities of two genes.

The probability of two independent events in mathematics is found by multiplying. Therefore, the result should have been $1/8$.

- 6) Exponentials were multiplied. Powers should have been added, instead.

When multiplying exponential numbers of the same base, the powers should be added. As for scientific notation, you should have increased the power of ten as many decimal places as you decreased 1892160.

- 7) In the second equation, the student transposed H and $1/2O$ to the other side of the equation without changing their signs.

Change signs when taking the unknowns to the other side or you should have divided by the coefficient of Y after you subtracted H and $1/2O$ from the other side. This would let you isolate the unknown with one division.

- 8) For the x component, student multiplied with sine 30 instead of cosine 60.

According to the angle, multiply R with sine (opposite/hypotenuse) to find the horizontal component. Then multiply R with cosine (adjacent/hypotenuse) to find the vertical component.

APPENDIX D

INTERVIEW GUIDE

Preface

The interview time will be prearranged so that participants can know in advance when they will be interviewed. Interviews will be conducted online, it will be confirmed that the interviewees have good broadband connection. An alternate time will be predetermined if the connection turns out weak. Eight-hour time difference between the location of the researcher and the interviewees' will be considered.

Subjects will be provided with a copy of their responses to the MuSTEB, so that the interviewees remember their responses. In addition, eight examples of mathematics used in science will be sent via email prior to the interview to remind them the definition of MuS. The researcher will have a document that includes interviewees' responses and the preliminary results from the quantitative analysis so that the interview can focus on the items in which informants were at extreme with respect to the means in each item.

The approval of the consent form, stating that they could be available for an online post-survey interview, will be instated. The reason, why the recording of the interview with an audio recorder was necessary, will also be explained as it eases the interviewer's job to recall the information for further analysis.

After the goals of the interview and the reasons why the interviewees were chosen are explained, informants will be reminded to stop and ask for any clarification during the interview.

Semi-structured Interview Questions

Some of the questions that will guide the interview are:

- 1) Could you tell me a bit about academic background before coming to the mathematics/science education department at your university?
- 2) What motivated you choose your current department?
- 3) How do you compare mathematics and science in general?
- 4) How do you compare mathematics and science teaching?
- 5) What do you think mathematics used in science entails?

At this point, the researcher will remind the definition of the term to the interviewee, as it was given in the survey: “Mathematics Used in Science is defined as the knowledge, skills, and beliefs related to mathematics that is used in and necessary to solve the problems of science. Topics of mathematics used in science usually appear as a preliminary chapter of school science textbooks. Do you remember your science textbook at school? You might have also seen mathematics used in science under problem solving exercises in mathematics textbooks, do you remember?”

- 6) Did you witness any incident that your mentor teachers used mathematics used in science in the classroom?
- 7) How confident are you with teaching mathematics used in science?
- 8) What difficulties do you foresee in teaching mathematics used in science?
- 9) Interviewees’ specific responses to MuSTEB questions in which they expressed extreme responses with respect to the overall trend.

Closure

Participants will be asked if they have any questions about the interview, or they have something else to add. They will be reminded that they will receive a follow-up email to authenticate the researchers' report about the interview, and will be asked if they could respond. They will also be asked if they could provide a sample of their work in the method course, such as lesson plans, assignments, or research articles.

The confidentiality of the interview and the member check procedure will be reinstated, and lastly, they will be thanked for their participation.

Member check

A member check procedure will check the authenticity of the initial report about each participant's responses. The correspondence will be established via email.

APPENDIX E
TRANSLATED QUOTATIONS

Interviewee	Indicator	Original input
Atakan	1	Matematiğe girmek için üniversite sınavına bir daha girdim.
Atakan	2	Üniversite matematiği daha çok çalışma gerektiriyor.
Atakan	3	Matematiğin yeri ayrı tabii.
Bengu	4	Hayat diğerlerinden daha iyi olmakla ilgili. Fark yaratmak gerekiyor.
Bengu	5	Fizikçilere karşı yarıştırmamın sebebini anlamıyorum.
Bengu	6	Annemden çok yararlandım.
Cem	7	Bütün okul hayatım, yani sosyal hayatım falan hep okul sonrasında göre, biraz devlette bir işim olup olmayacağına bağlı geleceğim.
Davut	8	Beş yıl! Öğretmen olmak için çok çok uzun.
Efe	9	Bunların hepsini şimdiden sınıfta zaten yapıyoruz.
Efe	10	Somut gerçeklerle uğraşır.
Ferdi	11	Diğer derslerde baya zahmet çektim.
Ferdi	12	Bir düşünme biçimi
Bengu	13	Bilimsel verilerin matematiksel yorumlarından ibaret bence.
Bengu	14	Tüm bilimlerin kaynağında matematik var.

Bengu	15	Yerçekiminde, hız ya da kimyasal reaksiyonlar hepsi zaten doğada doğal olarak varlar. Matematiksel data ile bir bilime dönüşüyorlar.
Atakan	16	Yoksa fen büyücülükten ibaret kalır.
Bengu	17	Son gelişmelerin ayrıntılarıyla ilgili fazla bir bilgim yok.
Bengu	18	Okulda çok iyi hocalarım vardı.
Cem	19	Çoğunlukla fen öğretmenlerimin derste matematik göstermeleri gerekti, çünkü gerekir dersin içeriği icabı ama aslında matematik dersinde işlenmemişti daha o konular.
Cem	20	İşimi daha iyi bir şekilde yapmak isterim, ama net değil, fen bilimleri müfredatının hangi matematik konularını gerektirdiğini bilmiyorum.
Bengu	21	Fen bilimlerinde kullanılan matematiği öğretirken kendime güveniyorum çünkü öğretmenlik deneyimi derslerinde, sınıfta kend; kendimize öğretmenlik yaparken fen dersinin nasıl öğretiltiğini de görüyorum.
Bengu	22	Gerçek bir sınıfta hiç öğretmenlik tecrübem yok ama. Yani gerçek bir sınıfta (FKM) nasıl işlenir bilmiyorum.
Efe	23	Fen bilimleri öğretmenleri matematik öğretebilmeliler, konular gerektirirdiği zaman ama.

Efe	24	Matematik öğretmenleri fen bilimleri öğretmenlerini desteklemeli, örneğin gerekli konuları paylaşabilir ya da doğru başvuru kaynaklarına yönlendirebilirler.
Ferdi	25a	Matematiği nasıl öğreteceğimize yoğunlaşıyoruz.
Ferdi	25b	Matematikselse beceriler üzerinde odaklanarak.
Ferdi	26	Matematik ve gerçek hayat arasında bir ilişki kurmalıyım, ama hayat sadece fen değil.
Cem	27	Şimdilerde mesela açı ölçmeyi yanı pergelle öğretirken hangi yöntemler izlemem gerektiğini bilmiyorum ya da çarpma - bölme de bir problemleri olsa onlara nasıl anlatacağımı bilmiyorum. Bununla ilgili hiçbir eğitim almadım ki.
Davut	28	Onlara yardımcı olurken matematik anlatma yöntemlerimi kullanıyorum.
Cem	29	Açıkçası ben sadece bildiğimiz test sorularını öğretiyorum, matematiği nasıl öğreteceğimi tam olarak bilmiyorum.
Davut	30a	Matematiğini anlatmak onun (fizik profesörlerinin) görevi değil mi?
Davut	30b	Lisedeki matematik öğretmenlerimiz yalnızca üniversiteye nasıl gireceğimiz konusunda yardımcı olurlardı.
Ferdi	31	Sorumlu olduğum bir kısım temel matematik konularının olduğu kabul ediyorum.
Ferdi	32	Fen öğretmenleri matematik öğretmenlerinin anlattıklarına

		göre, temel konularda, ona göre derslerinde birşeyler yapabilirler.
Cem	33	Fen bilimleri müfredatında öğretilcek bunca farklı konu varken, bir eşitlikte x'i nasıl yalnız bırakılacağını öğretmek, buna zaman harcamak imkansız geliyor bana.
Atakan	34	KPSS'nin matematiğimi körelttiğini düşünüyorum. Lisede matematiği algılamada da sonuca ulaşmada da daha iyiydim. O dönemlerdeki matematiği özlüyorum. Belki (şimdi) KPSS'de testlerindeki matematiğe teslim olmuş vaziyetteyim.
Cem	35	Sınav fen bilimleri ile ilgili hiçbir şey içermiyor yahut matematik ve fizik nasıl birlikte öğretilmeli diye. Çoğunlukla genel yeteneği ölçer, ikinci bir üniversite sınavı gibi.
Efe	36	Herkes aynı soruları çözüyormuş.
Efe	37	Madem fen bilimlerinde kullanılan matematikle ilgili bir soru bulmak mümkün değil, o halde neden bununla vakit kaybedelim. Hatta, onu geçelim, asıl pure fen bile yokken öğretmenlik derslerine neden dikkat edeyim?
Davut	38	Özel okullarda fen bilimlerinde kullanılan matematiği anlatabilirim, her tür öğrenci sorusuna cevap verebilirim sanıyorum. Evet, bu konuda kendime güveniyorum.
Bengu	39	Özel okullar basit öğretme yöntemleri olan tecrübeli öğretmenlerden öte, yenilikçi öğretim yöntemleri olan

		öğretmenleri tercih ediyorlar.
Efe	40a	Uluslararası Bakalorya mesela, öyle bir okulda çalışmayı çok isterim.
Efe	40b	Bu mükemmel olur, ki aranan bir öğretmen olabilirim böylece.
Cem	41	Bu şekilde, ihtisas gerektiren özel bir okulda, ciddi emin değilim yapıp yapamayacağımdan.

VITA

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