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Minnesota Teachers' Understanding, Training, Perception of STEM Education and Its Implementation

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by

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Abstract

According to the CRS Report for Congress (Library of Congress, 2008), “there is a growing concern that the United States is not preparing a sufficient number of students to enter in the professions of science and engineering.” This growing concern has motivated the creation of a discipline based on the integration of science, technology, engineering and mathematics known as STEM. The supporters of STEM education believe that this program has more benefits than the traditional system, an obsolete system that fails to capture students’ interest in STEM subjects (Sanders, 2009).

Unfortunately, there are barriers in successfully implementing STEM programs in K-12 education, including minimal STEM curriculum for teachers to use in integrating STEM approaches in their classrooms, a lack of efficient training to provide STEM teacher preparedness, and minimal, continuous STEM professional development programs (Nadelson et al., 2013).

The study examined Minnesota teachers’ understanding, training and perception of STEM education and its implementation. Additionally, the study examined how teachers perceived the need for continuous professional development in the effective implementation of STEM. Based on the literature and data collected in the study, the study acquired a positive inclination in research respondents’ understanding of the purpose of STEM, their confidence in understanding, teaching and implementing STEM, how they rated the value of the STEM, development on STEM. The study also identified that more professional development programs inspiring STEM instruction should be designed to develop teachers’ understanding and implementation of STEM integration.

Dedication

This dissertation is dedicated to my father who always encouraged me to set my sights high. He advised me to be a lifelong learner and to reach the highest degree in my field of study. Unfortunately, he passed away soon after I enrolled in my doctoral program. Today, I pass on this same wisdom to my children, students and others.

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To my family, I thank you for your unwavering love and support in this journey. You were always there offering a helping hand and reassuring words. You allowed me to reach my life's dream, which was to earn a doctoral degree. This work would not have been possible without you.

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Chapter 1: Introduction

There is a concern that the United States of America is not planning to train an adequate number of students who are qualified to pursue careers in the disciplines of science, technology, engineering, and mathematics (National Summit on Competitiveness, 2005). This concern is a challenge to America's competitiveness in a global economy. In the report *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Future* (National Académies, 2006), it was asserted that the United States is losing its position as a world leader in technology-based economy because its students are failing to keep up with other competing countries in STEM fields. According to the CRS Report for Congress (Library of Congress, 2008) "there is growing concern that United States is not preparing a sufficient number of students in the areas of STEM" (p. 1).

This growing concern about the nations' students has energized attention to the creation of a discipline based on the integration of science, technology, engineering, and mathematics. The interdisciplinary integration among these discrete disciplines as one entity is called STEM (Morrison, 2006). STEM education is designed to offer students an opportunity to make sense of the world as a whole, rather than in pieces and bits. "STEM education is an interdisciplinary approach to learning in which rigorous academic concepts are coupled with real world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise, enabling the development of STEM literacy and with it the ability to compete in the new economy" (Tsupros, Kohler, & Hallinen, 2009).

The role of the federal government became inevitable in supporting the competitiveness of the United States in these disciplines (GPO, 2007, p. 1). A congressional report offered four recommendations to meet the nation's current and pressing needs, and to enlarge the pipeline of future STEM programs. These recommendations were to 1) increase United States' talent pool by improving K-12 mathematics and science education; 2) support and increase our nation's commitment to long-term research; 3) recruit and retain top students, scientists, and engineers from both the United States and abroad; 4) make sure that the United States is the first in the world for innovation (National Summit on Competitiveness, 2005). In 2007, the Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act (America COMPETES Act) was passed to expand existing STEM education programs and establish new programs. In recent years, several pieces of legislations have been introduced to improve STEM education in the United States. All these bills were influenced by the business community and academic and scientific organizations (The Education Commission of the States, Keeping America Competitive: Five Strategies to Improve Mathematics and Science Education, July) (Coble & Allen, 2005). The Obama administration reauthorized the America COMPETES Act in 2010 and established an office under the National Science and Technology Council that embedded STEM Education activities in federal agencies.

The supporters of STEM education believe that this program has more benefits than the traditional system, an obsolete system that fails to capture students' interest in STEM subjects (Sanders, 2009). Claiming the attributes of STEM, Morrison (2006) noted that a STEM educated student is a problem solver, innovator, inventor, self-reliant, logical thinker, and is technologically literate. Other benefits of STEM as integrated curriculum include it is student centered; it helps students involved in planning their learning; and it improves higher order thinking skills (Smith & Karr-Kidwell, 2000). The separation of STEM from other programs continues to occur in many schools. “As a result, there is little thoughtfully planned and implemented STEM curriculum in secondary schools” (Lantz, 2009). Few guidelines exist guiding teachers use of STEM in their classrooms (Wang, Moore, Roehrig, & Park, 2011). Herschbach (2011), writes, “It is hard to discern what exactly is meant by STEM. Practically, any kind of educational intervention that is even remotely associated with science, technology, engineering or math is referred to as a STEM innovation.”

Many educators still believe that STEM subjects are interrelated to each other and integrating them could help students acquire more knowledge (Berry, Chalmers, & Chandra, 2012). However, shifting from the traditional method of learning to this new paradigm requires school change to support STEM integration. This change involves substantial curriculum reformulation, teacher and educational leader initiatives, and school policy initiatives (Moore & Smith, 2014). Since the federal government is the driving force behind the STEM initiatives in United States, the Government Accountability Office (GAO) reported in 2004 that there were 207 federal education programs planned to improve the quality of STEM education (Library of Congress, 2008). Over the past years, many states have developed STEM networks. The Minnesota STEM NETWORK is one of the 12 such statewide networks throughout the United States (www.scimatnmn.org).

STEM in Minnesota

Minnesota is one of the states that has been implementing STEM initiatives in their K-12 school districts, though it is in the early stages. However, Minnesota is not one of the 42 states and the District of Columbia that has adopted the Common Core, which according to some researchers, is expected to reduce the variations in mathematics curriculum in the nation, strengthen the STEM pipeline and expose all students to international benchmark standards (Schmidt, 2011). Instead, Minnesota has established its own academic standards for mathematics. This standard has two advantages: it improves mathematical achievement on international assessments, and it is rigorous and simplifies integration with other STEM disciplines. As a result of its' rigorous mathematics standards, Minnesota became one of two states that participated in the 2007 TIMSS as test "countries" and outperformed the U.S. average in both fourth and eighth grade and posted competitive scores internationally (Mullis, Martin, & Foy , 2008; SciMathMn, 2008).

While STEM is not widely implemented in Minnesota, it is among the states that made an effort to improve STEM education through the addition of engineering standards (Kuenzi, Mathews & Mangan, 2006; National Governors Association, 2007). In 2009, Minnesota added engineering concepts to its academic standards for K-12 science education (Moore, Stohlmann, McClelland, & Roehrig, 2011).

Like many other states, there is no common STEM curriculum in Minnesota schools. According to 2011 P-20 STEM Achievement Gap, Minnesota does not have standards in all STEM disciplines. In addition, professional development programs are limited; those related to specific engineering curriculum projects like "Engineering in Elementary", and "Project Lead the way" are sometimes accompanied by professional development. Although Minnesota's Department of Education has funded several professional development workshops for teachers to learn about STEM, a majority of the teachers are ill prepared or lack the knowledge and experience to teach STEM (Moore et al., 2011).

In 2010, some school districts in Minnesota began adding a STEM standard to their elementary standards. Schibeci and Hickey (2000) reported that those elementary teachers would be required to learn more than the ordinary content knowledge to adapt to these changes. According to 2011 P-20 STEM Achievement Gap, creating effective professional development training becomes inevitable in building confidence among teachers involved in STEM teaching.

Statement of the Problem

There is lack of common understanding of STEM among Minnesota educators. According to researchers, there is a correlation between teachers' preparations to teach and their students' performance, educators in general are more hesitant about new knowledge such as STEM in which they are not adequately prepared to teach (Crismond, 2013; Czneriak, 2007). Additionally, a study performed by Brown, Brown, Reardon, and Merritt (2011) in Illinois concluded that STEM integration was lacking coherence to the educator as there was no clear vision of how STEM is implemented.

Purpose of the Study

The quantitative study examined Minnesota teachers' understanding, training and perceptions of STEM education and its implementation. Since no studies about STEM teachers' perceptions within the state of Minnesota were found in the literature, the results of the study ascertained how Minnesota teachers rated the value of STEM training they received, and their confidence and efficacy for teaching STEM as there is no common definition and curriculum of STEM nationwide. Additionally, the study was designed to examine how teachers perceived the need for continuous professional development in the effective implementation of STEM, and the challenges teachers shared in implementing STEM. Although STEM educators understand the importance of STEM, many questions remain unanswered.

Research Questions

1) How did select Minnesota STEM teachers report their understanding of the purpose of STEM?
2) How prepared and confident were select Minnesota STEM teachers in teaching/ implementing STEM?
3) How much training did select Minnesota STEM teachers report they received on STEM?
4) How did select Minnesota STEM teachers report the value of the STEM training they received?
5) How did select Minnesota STEM teachers report they would benefit from further staff development on STEM?

Significance of the Study

As the beliefs and perceptions of STEM educators become clear, the study may help to highlight the need to better define and implement STEM with a uniform standard. According to Merrill (2009), STEM is defined as "a standard-based, meta-discipline residing at the school level where all teachers, especially science, technology, engineering, and mathematics (STEM) teachers teach an integrated approach to teaching and learning, where discipline-specific content is not divided, but addressed as one dynamic, fluid study" (p. 49). Thus, a STEM education with uniform national curriculum standards is necessary to be implemented so students in all schools regardless of size and location will engage in high quality science, technology, engineering, and mathematics at school level disciplines. Such standards will serve as a national roadmap for teacher preparation.

Predicated on the notion that good leadership is one of the backbones of school success (Waters, Marzano, & McNulty, 2003), the study promotes the importance of strong STEM leadership that create schools with positive climate and student achievement.

Délimitations

The study was conducted using analysis of survey participants' data. The use of multiple choice survey questions limited the answer options for the targeted population.

The delimitations were:

a) STEM schools in Minnesota were part of the study.

b) Only STEM educators were asked to complete the survey.

c) The study was limited to a select sample of Minnesota school districts that operated STEM programs at the time of study.

d) The study sample was limited to select school districts in the Minneapolis – St. Paul metropolitan area and St. Cloud area school district.

e) The study was limited by the need to employ the internet to gather responses from respondents.

f) The study was limited by the accuracy of data reported by the respondents.

g) The study was limited in not being generalizable to other Minnesota or other state operating STEM programs.

Definitions and Acronym of Technical Terms

STEM. STEM is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy (Tsupros et al., 2009)

Engineering in elementary. Is a research-based, standard-based, and classroom-tested curriculum designed to integrate engineering and technology concepts and skills into elementary school science topics and mathematics learning, as well as literacy and social studies (Lachapelle, & Cunningham, 2007).

Project Lead the Way. Leading provider of rigorous and innovative science, technology, engineering, and mathematics education curricular programs used in middle and high schools throughout the United States (www.pltw.org).

Professional development. According to Learning Forward (2012), formerly known as NSDC (National Staff Development Council), effective professional development is "a comprehensive, sustained and intensive approach to improving teachers' and principals' effectiveness in raising student achievement" (Definition of Professional Development, para 3).

TIMSS. Trends in International Mathematics and Science Study is International assessment of the mathematics and science knowledge of fourth and eighth grade students (https://nces.ed.gov/timss).

Organization of the Study

This study is organized into five chapters. Chapter 1 presents an introduction of the study, Minnesota teachers' perceptions on implementation of STEM and its definition. Chapter 2 presents a review of the related literature. Chapter 3 outlines a description of the methods in conducting the study, and the instrument used in gathering the data. Chapter 4 presents the analysis of the data, and chapter 5 contains the results, conclusion and recommendations of the study.

Chapter 2: Review of Literature

Chapter 2 presents a review of literature related to Minnesota STEM educators' perception of STEM education and its implementation. Main themes of this chapter include:

- Introduction
- STEM History
- STEM Initiatives
- Challenges of Integrated STEM
- STEM Teacher Preparation and Professional Development
- School Climate
- Summary

Introduction

In the 21st century, United States leadership needs to change the way it perceives and values K-12 education (Wise, 2007). United States schools are not showing any readiness to change in an ever-changing global society; students follow their daily school habitual much the same way as their grandparents once did (Wallis & Steptoe, 2006). According to President Barack Obama's executive report, Prepare and Inspire: K-12 education in Science, Technology, Engineering and Math (STEM) Education for America's Future, the President's Council of Advisors on Science and Technology emphasized the need to produce students with strong foundations in science, technology, engineering and mathematics (Holdren, Lander, & Varmus, 2010). In an economy driven by innovation and knowledge, American citizens require the skills they need to compete (OECD Publishing, 2010). Similarly, in his 2011 State of the Union address, President Obama said, we need to "out-innovate" our competitors, and that "In America, innovation does not change our lives. It is how we make our living." William R. Brody, President of Johns Hopkins University, and Co-chair of the National Initiative Advisory Committee, stated about the university's teaching mission, "We need to teach students to learn how to learn…we have to focus on the thinking process." He further stated, "We must think about new curriculum for a multidisciplinary approach to teach aspects of innovation" (Innovate America, 2005). This multidisciplinary curriculum approach results in the emergence of STEM, an acronym of Science, Technology, Engineering, and Mathematics (Johnson, Breiner, Harkness, & Koehler, 2012).

According to the report, *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Future* (Augustine, 2005), the United States of America is lagging behind the highest performing nations on international assessments in the STEM fields. According to the National Assessment of Educational Progress, 75% of American eighth graders are not proficient in mathematics when they compete globally with other eighth graders (Schmidt, 2011). Additionally, Trends in International Mathematics and Science Study (TIMSS) developed an international benchmark which revealed that only ten percent of American eighth graders met the science standard compared with 32% in Singapore and 25% in China (Gonzales et al., 2008). Another warning is that the top students in United States schools "scored below their peers in 29 countries on mathematics literacy, and below 12 countries on science literacy" (National Science Board, 2010, p. 8).

President Barack Obama stated in his 2011 State of the Union address that the United States of America was again experiencing another "Sputnik Moment," a moment in which the USA is strongly challenged by its international competitors. The significance and increased demand for STEM education has grabbed the attention of other prominent figures in the business fields. Michael J. Burns, Chairman, President and CEO of Dana Incorporated (2004-2008), urged government and business leaders to focus on improving K-12 education and specifically expressed concern that American students in middle and high school students were not performing well in STEM relative to their peers in other developed countries (Innovate America, 2005). According to Bureau of Labor Statistics, 80% of fastest-growing jobs are STEM related jobs and due to shortage of talents within the country are applied and filled by talents from abroad or by international students who remain in the United States after earning their degrees (NAS, NAE, & IOM, 2007).

A previous National Research Committee found (NRC, 2011):

> The primary driver of the future economy and concomitant creation of jobs will be innovation, largely derived from advances in science and engineering … 4 percent of the nation's workforce is composed of scientists and engineers; this group disproportionately creates jobs for the other 96 percent. (p. 4)

Thus, in an ever-changing society where technological advancement has dominated global markets, the United States must scheme and prepare its workforce to be competitive (NAS, NAE, & IOM, 2007).

The review of literature revealed that in the history of United of States education the focus on STEM is not a new idea. Some American educators in the past, who became aware that real world problems were not isolated within the traditional curricular domains, also applied the idea of curriculum integration (Czemiak, Weber, Sandmann, & Ahern, 1999; Jacobs, 1989).

STEM History

The National Science Foundation (NSF) first identified STEM as an educational term in the early 2000's (Salinger & Zuga, 2009). However, education involving STEM first began in the America's Colonial Era. In 1749, Benjamin Franklin, author of the article, "Proposals Relating to the Education of Youth in Pennsylvania," presented his vision for the future of education in the Americas that emphasized that such trade skills as grafting, planting, inoculating, commerce, manufacturing, trades, force and effect of engines and machines, and mechanics should to be taught (Franklin, 1970).

In 1824, Rensselaer Polytechnic Institute, the first technological university in the English-speaking world to teach crafts or non-fine arts to the sons and daughters of the tenants of the Van Rensselaer feudal landholding, was established (Salinger & Zuga, 2009). By the year 1857, educators from ten different states gathered to talk about public education and the quality of instruction in schools (Holcomb, 2006). They later established the National Educators Association (NEA). The Committee of Ten, established In July 1892, at the annual meeting of NEA in Saratoga Spring, New York, was designed to create a smoother transition from high school to college. This committee focused on the importance of science and science-related subjects. (Retrieved from http://www.nea.org/home/12172.htm).

Eliakim Moore, the president of the American Mathematical Society delivered a speech on December 29, 1902, emphasizing the importance of mathematics and the manner in which it should be integrated with other subjects. He stated, "Mathematics should be directly connected with matter of thoroughly concrete character." This speech was the first time that integration of subjects taught in school was publicly mentioned (Archibald, 1980).

Three years later, in 1905, a commission known as the Douglas Commission was appointed by the Massachusetts Senate and House of Representatives to study the needs of the state in industrial and technical education. The commission's report later encouraged further studies that led to the formation of vocational education in Massachusetts Public Schools (McClure, Chrisman, & Mock, 1985). As McCarthy (1950) related:

> It may be remembered that the Douglas Commission was created not only because of the inadequacy of manual training programs in the public schools, but because three land-grant colleges failed to serve the needs of agriculture or industry of the workers' level.

From 1917 to 1921, Ellsworth Collings directed an experimental project at a rural school in McDonald County, Missouri about curriculum development. The students participated in the project and determined the topics they would study. The students from that experimental school later outscored the students of the neighboring schools on standardized tests. The experimental project was named the Project Method. Professor William Kilpatrick, who was the doctoral advisor of Collings, later used the findings of the Project Method (1918), and made progressive ideas accessible to students at Teachers' College. Kilpatrick is considered as the father of curricular integration (DeBoer, 1991; Rury, 2002).

Progressive schools started using integrated curriculum design in the 1920s (Kilebard, 1987). John Dewey published his famous study, *The Way Out of Educational Confusion* (1931), arguing in favor of the reorganization of the subjects based on his lengthy research into how students learn. He advocated for the integration of subjects throughout the 1930s (Dewey, 1931). The United States entrance into World War II in 1941 affected all individuals and institutions including educational institutions. Although the standard in public education generally improved, the war had a negative effect on STEM education causing progress in this area to halt (DeBoer, 1991) since funds allocated toward school programs were directed toward war resources.

In 1957 when the Russians successfully launched the first satellite, Sputnik, into space, the United States Congress enacted the National Defense Education Act of 1958 to provide funds to assist in reforming public educations at all levels. The United States' reaction to the launch of Sputnik and the ongoing criticism of the American educational system once again caused the rebirth of STEM education as vital to the protection of the nation (Passow, 1957).

With the arrival of the first modern computer, STEM education was fundamentally advanced. As early as 1974, Micro Instrumentation Telemetry Systems (MITS) produced a "build-it-yourself" computer kit called Altair (Freiberger & Swaine, 2000).

In 1980, the International Congress on Mathematical Education (ICME) met at Berkeley, California, discussing the New Math program and its failure to meet the needs of education. At this conference, ideas for the "Back to Basics" approach in mathematics were developed (Malaty, 1988).

Howard Gardner's research on multiple intelligences had a profound impact on thinking and practice in education, since its introduction in 1983. The theory affected instructional practices, provided platforms to reach diverse audiences of learners and proposed alternative routes to instructional pedagogy on STEM disciplines (Sulaiman & Sulaiman, 2010).

The National Commission on Excellence produced a report, *A Nation at Risk* (1983), which created much debate among United States K-12 educational and political institutions. The report expressed:

> Our nation is at risk. Our once challenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competition throughout the world. This report is concerned with only one of the many causes and dimensions of the problem, and is the one that undergirds American prosperity, security, and civility. We report to the American people that while we can take justifiable pride in what our schools and colleges have historically accomplished, contributed to the United States and the well-being of its people, the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a nation and a people. What was unimaginable a generation ago has begun to occur—others are matching and surpassing our educational attainments. (p. 8)

Boston College conducted a study, known as the Third International Mathematics and Science Study (TIMSS), which assessed the state of science and mathematics education in 41 countries throughout the world. More than a half million students of multiple grade levels were tested. The study ranked the United States at the middle of about 40 countries. The results revealed the depth of the fall of the United States in Science and Mathematics Education, exposing the fact that many U.S. students were not prepared for the demands of today's workforce (Woodward, 2004).

In 2002, the *No Child Left Behind* (NCLB) Act, the purpose of which was to support higher student achievement, was signed into law. The law increased accountability for states, school districts, and individual schools, and gave options to parents whose children were enrolled in failing schools. The NCLB also had great influence on science and mathematics curriculum (Act, 2001).

The STEM Education Coordination Act of 2009 was enacted to fulfill the National Science foundation Board's recommendation to establish a committee to coordinate STEM education activities and programs sponsored by all federal agencies in the United States (Gallant, 2010). More than 50 years after the launch of Sputnik there remains a thrust to improve STEM (Kanematsu, 2016). There are numerous studies that support the implementation of STEM programs in order to secure a better future for American education and insure that the nation's competitiveness is directly related to its success in K-12 STEM education, needed to generate future scientists, engineers, and inventors (PCAST, 2010). A previous NRC (National Research Committee) report found:

> The primary driver of the future economy and concomitant creation of jobs will be innovation, largely derived from advances in science and engineering…… 4 percent of the nation's workforce is composed of scientists and engineers; this group disproportionately creates jobs for the other 96 percent (Augustine, 2010, p. 4)

The Minnesota STEM Network ("the Network") was organized and established by SciMathMn in 2010 to implement a strategic plan in advancing and improving STEM education across the state (SciMathMN, 2008).

Although the journey of STEM began earlier, the momentum of the United States' STEM initiatives increased in recent years to assist in creating K-16 academically strong students to compete globally (Johnson et al., 2012).

STEM Initiatives

Over the past decade, the federal budget investment in STEM has increased (Kuenzi, 2008). In 2007, President George Bush signed into a law the Americas COMPETES Act. This

Act was instituted, "to invest in innovation through research and development, and to improve the competitiveness of the United States" (GPO, 2007, p. 1). President Obama reauthorized the COMPETES Act in 2010 and created a 5-year federal STEM education strategic plan (Congress, 2010). Between 2008 and 2010, the federal government allocated $32.7 billion for STEM initiatives. In another initiative, President Obama’s Race to the Top, the United States federal budget included $4.3 billion for STEM education reform (Johnson, 2013).

According to National Research Council (2011), The STEM reform movement was driven by three main goals: 1. Increase the number of students pursuing higher degrees and careers in STEM; 2. Enlarge the participation in the STEM workforce, and 3. STEM literacy for all.

STEM is viewed as a new curriculum that integrates the standards and objectives of Science, Engineering, Math and Technology fields, which represents a significant departure from the methodology for which instruction has been delivered in American schools in the past (Johnson, 2013). The subjects that have been taught separately would be now integrated showing the functional interrelationship within and between them (Kuenzi, 2008; McNeil, 1990). Integrated STEM education is more than curriculum integration (Czerniak & Johnson, 2007), but an instructional approach integrating the teaching of the four subjects of STEM using scientific inquiry, engineering and engineering design, mathematical thinking and reasoning, and 21st century interdisciplinary themes and skills (Bryan, Moore, Johnson, & Roehrig, 2015). Some researchers explain STEM as an interdisciplinary approach bridging discrete disciplines (Morrison, 2006; Tsupros et al., 2009). Others contend that STEM education with its greater complexities is larger than any interdisciplinary approach and should be called trans-disciplinary

(Kaufmann, Moss, & Osborn, 2003; Lantz, 2009). The National Governors Association's (NGA) Innovation America: Building a Science, Technology, Engineering, and Math (STEM) agenda, described STEM as follows:

> STEM literacy is an interdisciplinary area of study that bridges the four areas of science, technology, engineering, and mathematics. STEM literacy does not simply mean achieving literacy in these four strands or silos. Consequently, a STEM classroom shifts students away from learning discrete bits and pieces of phenomenon and rote procedures and towards investigating and questioning the interrelated facets of the world. (NGA, 2007)

According to Bryan et al. (2015), integrated STEM is defined as "The teaching and learning of the content and practices of disciplinary knowledge which include science and/or mathematics through the integration of the practices of engineering and engineering design of relevant technologies." The integrated STEM education has more benefits than the traditional system, an obsolete system that fails to capture students' interests (Gallant, 2010). Curriculum integration reflects the idea that real world problems are not as separated as the typical school subjects are separated (Czermiak et al., 1999). Hirst (1974) pointed out that isolated subjects taught in schools alienate learners from real world experiences. Teaching STEM by integrating its components is not a new method. As Moore (1903) stated in his presidential address to the American Mathematical Society in 1902:

> Engineers tell us that in the schools algebra is taught in one water-tight component, geometry in another, and physics in another, and that the student to appreciate (if ever) only very late the absolutely close connection between these different subjects, and then,

> if he credits the fraternity of teachers with knowing the closeness of this relation, he blames them most heartily for their unaccountably stupid way of teaching him. (p. 415)

Senge (1990), addressing the traditional concepts of solving problems, wrote:

> From a very early age, we are taught to break apart problems, to fragment the world. This apparently makes complex tasks and subjects more manageable, but we pay a hidden, enormous price. We can no longer see the consequences of our actions; we lose our intrinsic sense of connection to a larger whole. When we try to see the big picture, we try to reassemble the fragments in our minds, to list and organize all the pieces. (p. 3)

"Research indicates that using an interdisciplinary or integrated curriculum provides opportunities for more relevant, less fragmented, and more stimulating experiences for learners" (Furner & Kumar, 2007, p. 186). Suggesting the attributes of a STEM student, Morrison (2006) mentioned that a STEM educated student is a problem solver, innovator, inventor, self-reliant, logical thinker, and technologically literate. Other benefits include a student centered approach, which helps students become more involved in planning their learning, improving higher order thinking skills (Smith & Karr-Kidwell, 2000).

A case study on integrated mathematics, science and technology course of "at risk" and/or non-college bound students revealed that students' motivation increased, their school absences compared with previous years reduced, and students' self-esteem improved (Wicklein & Shell, 1995), because teachers of integrated STEM demonstrate deep and flexible subject matter knowledge, pedagogical content knowledge connected to the STEM education disciplines and skills to integrate contents (Bryan et al., 2015).

Challenges of Integrated STEM

According to Ejiwale (2013), there are some barriers in implementing STEM successfully in K-12 education. The barriers are:

- Minimal STEM teacher preparation, minimal STEM professional development programs and shortage in supply of qualified STEM teachers (Asghar, Ellington, Rice, Johnson, & Prime, 2012). “Teachers will need considerable support to build their capacity to deliver integrated STEM instruction” (Stohlmann, Moore, & Roehrig, 2012).
- Lack of administrative support and encouragement from the school system and shortage in funding sources (Ertmer et al., 2009).
- Poor preparation and inspiration of students (According to 2010 PCAST report, due to lack of poor preparation and inspiration, few students pursue STEM fields).
- Lack of research collaboration across STEM fields, i.e., no collaboration between STEM educators (Asghar et al., 2012).
- Lack of common curriculum (Although there is a new STEM road map for K-12 now, it is not yet common for all).
- Poor content delivery and assessment (Standardized tests still measure disciplinary knowledge) (Czerniak, Weber, Sandmann & Ahern, 1999).
- Poor Condition of laboratory facilities and instructional media.
- Lack of hands-on instruction (Kyere, 2017).
- Lack of appropriate assessment tools for STEM instructions (Katzenmeyer & Lawrenze, 2006).

For STEM education to achieve its goals and objectives, the barriers to STEM education listed above, and others will need to be addressed (Ejiwale, 2013).

Although sufficient research work about the implementation of curriculum integration has been published, there is no common conceptualization of STEM among its stakeholders (Breiner, Harkness, Johnson, & Koehler, 2012). Therefore, it is very important to move towards a common understanding in order to conduct research in a more effective manner. (Johnson, 2013).

Furthermore, the present global society needs STEM education and research (Hoachlander, 2014/2015), and the potential to obtain STEM as a distinct field of study is in its early stages (Honey, Pearson, & Schweingruber, 2014). Nevertheless, Herschbach (2011) outlined three important conditions needed for the integration of STEM curriculum.

- An indiscernible curriculum that blends the components of STEM, and showing as well the interrelationships between subjects.
- Teaching students the organizational, substantive and syntactical structures of what they are learning.
- Students should be taught how the knowledge they learned is applied (Herschbach, 2009; McNiel, 1999).

STEM is currently a nationwide movement and educators are required to meet students' interests and achievements in the domains of STEM (Nadelson et al., 2013). According to the congressional report *Rising above the Gathering Storm*, school leaders are called upon to recruit and maintain qualified teachers in STEM fields. Therefore, a call for quality professional development programs for teachers has become an urgent need (Marx & Harris, 2006).

STEM Teacher Preparation and Professional Development

The quality of teachers' knowledge has the greatest impact on student learning (Darling-Hammond, 2000; Mujis & Reynolds, 2000; Wenglinsky, 2000). Excellent instruction requires deep content and pedagogical knowledge to positively impact learners (Coe, Aloisi, Higgins, & Major, 2014). According to Elmore (2008), the targets for professional development programs are 1) to organize teachers around a specific curricula like STEM and teaching practices; 2) to have "hit–and–run" workshops designed to enlighten teachers and administrations about new concepts or new requirements; 3) to provide off-site workshops planned for teachers and administrators to award them academic credits. There is clear evidence from current research that professional development programs are most likely effective in improving student learning if they increase teachers' understanding of their content and present strategies on how students learn that content (Cohen & Hill, 2000). The teaching methods of teachers are built upon their prior knowledge (Marzano, 2004), their own beliefs and ideas, and their previous experience in education. Most teachers are the products of educational systems based on disciplines taught in silos. In their study, Nadelson et al. (2013) found that professional development significantly increased teachers' knowledge, confidence and efficacy in teaching STEM. Moore and Smith (2014), stressing the importance of professional development in STEM wrote,

> Teachers and administrators need professional learning experiences that prepare them to work within and develop STEM integration learning environments for K-12 students. Most instructors, teachers, and administrators have not learned disciplinary content using STEM contexts, nor have they taught in this manner, and therefore new models of teaching must be developed if STEM integration is to lead to meaningful STEM learning.

> Programs should be developed at local and state levels to promote this change in practice.
>
> School change is needed to support STEM integration. (p. 7)

Therefore, more professional development programs inspiring STEM instruction should be designed to develop teachers' understanding and implementation of STEM integration (Nadelson et al., 2013).

According to the National Research Council's report (2010), nearly 10%-20% of middle and high school mathematics and science teachers were neither certified in the subjects they teach nor did they have majors in a related field. Professional associations and experts offered many documents promoting the knowledge and skills teachers needed, as well as the learning opportunities new teachers required in their preparation (Darling-Hammond & Bransford, 2005; Levine 2006; Panel, 2010). However, the content preparation of new teachers is the heart of discussion among the researchers on teacher preparation, but there is little empirical research related to this topic.

Universities that have teacher preparation programs lack a common core curriculum for STEM programs, but some states are redesigning their teacher preparation programs to build more content knowledge and inquiry skills. "Currently, more than three-fourth of beginning teachers are involved in some kind of formal induction, or new teacher support program" (American Association of State Colleges and Universities, 2006). The teacher induction activities can include mentoring, coaching, and workshops with different durations, intensity and other supports. The programs may also differ from one another based on the purpose, participants, and support providers (Ingersoll & Smith, 2004). Although "Existing studies on induction…do not answer the question of which components of induction have the strongest potential to improve the effectiveness and retention of beginning teachers" (Lopez, Lash, Schaffner, Shields, & Wagner, 2004, p. 33), Ingersoll and Smith (2004) found that novice teachers participating in induction programs who are mentored by and/or collaborated with teachers of the same content area would most likely remain in the profession, and their current teaching positions longer.

In many ways, researchers agree on the characteristics of high-quality professional development (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009) such as full collaboration between educators, alignment to specific content areas and focus on student learning. The National Staff Development Council (2001) and the National Research Council (1996) have both published professional development guidelines for teachers. Because evidence from research supporting the effectiveness of professional development characteristics reveal that the effectiveness of one-day workshops is not strong (Guskey, 2003), effective professional development must provide a longer timeframe for the participants to make significant changes (Cohen & Hill, 2001).

Effective STEM programs reference the importance of teacher preparation and education (NRC, 2011). STEM professional development is "often short, fragmented, ineffective, and not designed to address the specific need of individual teachers" (NRC, 2011, pp. 20-21). The report, *Engineering in K-12 Education*, by the National Academy of Engineering and National Research Council (Katehi, Pearson & Feder, 2009) provided quality picture of K-12 engineering education. Although there was no common curriculum developed for K-12 engineering courses, the engineering content area that was integrated with K-12 disciplines was engineering design, a process that engineers used to solve problems and to develop products.

According to the 2011-2012 Criteria for Accrediting Engineering Programs, as stated by ABET (Accreditation Board for Engineering and Technology), engineering design "is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs" (p. 4). Engineering design is a pedagogical strategy that bridges engineering, science and mathematics concepts and is helpful in teaching problem solving strategies (Wang et al., 2011).

College students apply the engineering design in all the engineering courses in their four-year engineering degree program (Wang et al., 2011). Conversely, in order to apply an engineering design to K-12 education, the construct must be simplified to fit the different purposes for different programs within K-12 education (Wang et al., 2011). For instance, three engineering programs, *Engineering is Elementary (EiE)* curricula by the Boston Museum of Science, which focuses on elementary students' learning, *Project Lead the Way*, which focuses on middle and high school students' learning, and *In the Middle of Engineering* for middle school engineering, all employ the engineering designs. The EiE involves a five-step engineering design cycle: ask, imagine, plan, create, and improve (Museum of Science - Boston, 2010). The benefits of introducing engineering designs into the mathematics and science curricula are to increase students' interest in STEM subjects and careers in STEM fields (Apedoe, Reynolds, Ellefson, & Schumn, 2008; Cantrell, Pekcan, Itani, & Velasquez-Bryant, 2006).

Achieving ongoing support for the STEM initiative and improving the preparation and training of STEM teachers have taken precedence. Therefore, it is crucial to focus improvement efforts on initial preparation through induction and ongoing professional development (Wilson, 2011).

The Minnesota Department of Education funded several professional development programs in 2009 for teachers to understand the goals of STEM. One of the programs was the secondary STEM integration teacher-training module that provided a STEM integration experience for STEM teachers in grade 6-12. Since the participants were science and mathematics teachers, the new Minnesota science curriculum was presented at the same time. Teachers received instruction on how to integrate engineering with science and mathematics (Wang et al., 2011). The overall goal of the STEM integration professional development program was to increase the teachers' understanding of the subjects they taught and to use STEM integration in their classes. The professional development program was comprised of five days of training that was extended throughout 2009-2010 (Wang et al., 2011). The facilitators of the training used hands-on activities to integrate engineering with the other three subjects (mathematics, science and technology). These activities provided learning experiences that could later be used by the teachers in their classrooms. The training topics included:

- How engineering and engineering design can be taught as a regular school course.
- Discovering and analyzing how mathematics can be taught within the engineering design cycle lessons.
- Model-Eliciting activities (MEAs) using mathematical approaches (Lesh & Doerr, 2003).
- How technology integration could enrich other STEM disciplines.

- Organizing, managing and encouraging deliberations on STEM concepts amongst students.

Though more refinement is needed in continuing teachers' professional training, the sessions provided by the MDE have had a significantly positive impact on teachers' attitudes toward STEM as well as the attitudes and knowledge of their students (Wang et al., 2011). Finally, as successful professional development do have an effect on student achievement, it should be regularly evaluated (Elmore, 2008). Recent research also emphasized that professional training for teachers cannot alone improve student achievement without achieving positive climate in the schools (Cohen, McCabe, Michelli, & Pickeral, 2009). Continuously

School Climate

The National School Climate Council (2007) defined school climate as "norms, values, and expectations that support people feeling socially, emotionally and physically safe" (p. 4). Researchers emphasized that teacher quality alone cannot improve student achievement, but school leadership, and a positive climate are other factors that contribute to meaningful change (NRC, 2011).

Researchers have related principal behaviors to school climate. Fullan (2002) asserted that "Only principals who are equipped to handle a complex, rapidly changing environment can implement the reforms that lead to sustained improvement in student achievement" (p. 16).

According to Schmidt (2011), principals can play an important role in improving students' achievements by determining clearly the mission of the school, for instance, STEM school mission, and establishing an atmosphere favorable to learning. Even though there has been little research on instructional leadership's effects on achievement in STEM, some studies found that instructional leaders must be able to envision the change needed, share the STEM initiative with the teachers, students and parents, empower them to share the decision and create an effective school culture that can improve student learning in STEM (Schmidt, 2011). Marzano, Waters, and McNulty (2005), stated, "The research of the last 35 years provides strong guidance on specific leadership behaviors for school administration and that those behaviors have well documented effects on student achievements" (p. 7).

A study of six STEM schools illustrated that establishing a school culture will help to create a sense of community, and will help faculty and students feel comfortable (Bruce-Davis et al., 2014).

Finally, it is crucial to focus on the overall improvement of a school as leadership is not individual endeavor but collective responsibilities (Leithwood & Mascall, 2008). However, it is also important to remember that it is unlikely that positive results will be achieved without focusing on improving the organizational climate of the school (Angus et al., 2009).

Summary

The study examines Minnesota teachers' perceptions in understanding the purpose of STEM and its implementation.

The report *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Future* (National Académies 2006) raised a warning that the United States was losing its position as a world technology-based economic leader due to the failure of its students to measure up to other competing countries students in STEM fields (Schmidt, 2011). One of the main responses to the report was a call for school reform and increased awareness of STEM literacy in the United States (National Research Council, 1996; Steen, 2001).

"Research indicates that using an interdisciplinary or integrated curriculum provides opportunities for more relevant, less fragmented, and more stimulating experiences for learners" (Furner & Kumar, 2007, p. 186). Morrison (2006) stated that a STEM educated student is a problem solver, innovator, inventor, self-reliant, logical thinker, and technologically literate.

STEM education offers benefits including a student centered approach, which asserts students to become more involved in planning their learning and improves higher order thinking skills (Smith & Karr-Kidwell, 2000).

Achieving ongoing support for the STEM initiative and improving the preparation and training of STEM teachers have taken precedence. Therefore, it is crucial to focus improvement efforts on initial preparation through induction and ongoing professional development (Wilson, 2011). In this regard, Minnesota Department of Education funded several professional development programs for teachers to understand STEM. One of the programs was the secondary STEM integration teacher-training module that provided a STEM integration experience for STEM teachers in grades 6-12 (Wang et al., 2011).

As STEM initiatives have been pursued, constraints and challenges have threatened to discontinue the movement. Consequently, for STEM education to become a reality, all these challenges and misconceptions must be addressed and corrected. School leadership, staff collaboration, and a positive climate have significant impacts on improvement efforts.

Chapter 3: Methodology

Introduction

STEM is viewed as an instructional approach that integrates the standard of science, mathematics, engineering and technology fields using 21st century interdisciplinary themes and skills (Bryan et al., 2015).

Over the past decade, investments in STEM initiatives from both federal and state governments and foundations have increased due to a growing concern that the United States is not producing a sufficient number of qualified students to pursue careers in science, technology, engineering and mathematics (The national Summit on Competitiveness, *Statement of the National Summit on Competitiveness: Investing in U.S. Innovation, December 2005*). Unfortunately, there are barriers in successfully implementing STEM programs in K-12 education, including minimal STEM curriculum for teachers to use to integrate STEM approaches in their classrooms, a lack of efficient training to provide STEM teacher preparedness, and minimal, continuous STEM professional development programs (Nadelson et al., 2013).

Researchers have reported that, “There is a serious lack of instruments of demonstrated validity and reliability to measure important outcomes of STEM education interventions, including teacher knowledge and skills, classroom practice, and student conceptual understanding in mathematics and science” (Katzenmeyer & Lawrenze, 2006, p. 7). Consequently, more research needs to be conducted examining Minnesota teachers’ understanding of STEM, implementation of STEM integration, and desire for further STEM training.

Purpose

The purpose of the quantitative study was to examine Minnesota teachers' understanding, training and perceptions of STEM education and its implementation. Since no studies with regard to Minnesota STEM teachers' perceptions were found in the literature and there is no common definition and curriculum for teaching STEM nationwide, the findings of the study intended to reveal how Minnesota teachers rated their confidence and efficacy in teaching STEM and the value of the STEM training they received.

Further, the study examined how teachers perceived the need for continuous professional development in order to insure effective implementation of STEM and the challenges teachers experienced in implementing STEM.

Research Questions

1) How did select Minnesota STEM teachers report their understanding of the purpose of STEM?
2) How prepared and confident were select Minnesota STEM teachers in teaching/implementing STEM?
3) How much training did select Minnesota STEM teachers report they received on STEM?
4) How did select Minnesota STEM teachers report the value of the STEM training they received?
5) How much did select Minnesota STEM teachers report they would benefit from further staff development on STEM?

Participants

The study intended to survey select elementary, middle and high school teachers involved in teaching in STEM programs located in select Minnesota districts and schools which operate STEM programs.

The study participants were K-12 teachers in STEM programs in five schools districts located in the state of Minnesota. Participating school districts and schools were identified through an examination of a listing of Minnesota STEM programs maintained by the Minnesota Department of Education and through personal investigation by the researcher.

In September 2018, a consent letter (see Appendix B) was emailed to superintendents of districts with STEM programs. The acceptance of at least seven districts were anticipated but acceptance emails were received from six school districts. In the end, only five districts fully accepted to participate in this study.

When the acceptance to participate in the study was confirmed by the participating school districts, the Statistical center of St. Cloud State University emailed the survey instrument questions and a letter of consent to the participating teachers in all the participating STEM schools. A copy of the letter sent to the teachers is found in Appendix C. Eighty-three teachers participated in the study, but 63 educators fully completed the survey and responded to all of the instrument questions.

Instrumentation

A web-based survey instrument, Survey Monkey, was developed by the researcher to serve as the study's research tool for the purpose of data gathering. The survey (Appendix C) consists of 16 instrument questions.

The 16 instrument questions were developed by the researcher and were designed to collect the demographic data of the research participants and data regarding the participants' confidence in their understanding of the purpose of STEM, their preparation in teaching STEM and their perception in implementing STEM.

Participants were asked to respond to questions using a 5-point Likert-type scale. The scale's responses were as follows: (1) strongly disagree, (2) disagree, (3) neither agree or disagree, (4) agree, and (5) strongly agree.

Instrument questions 1, 2 and 3 were aimed at collecting demographic data such as the participants' current employment status as an elementary, middle school, or high school teacher; their years of teaching experience; and how long they have taught in their present school's STEM program.

The remaining thirteen instrument questions were non-demographic questions focused on: 1) participants' perceptions and understanding of the purpose of STEM, 2) participants' confidence in and preparation for teaching in a STEM classroom, 3) participants' perceptions on the professional development they received on STEM programming, and 4) participants' perceptions on their need for future professional development on STEM programming.

The 13 non-demographic instrument questions were aligned to the research questions of the study. Instrument questions 4, 5, 6, 7, and 8 were aligned to research question 1. Instrument questions 9 and 10 were aligned to research question 2. Instrument questions 11, 12 and 13 were aligned to research question 3. Instrument question 14 was aligned to research question 4, and lastly, instrument questions 15 and 16 were aligned to research question 5.

Human Subject Approval

The researcher completed St. Cloud State University's Institutional Review Board (IRB) training on January 15, 2017.

In order to secure approval of the research study involving human subjects, the researcher submitted an application to St. Cloud State University's Institutional Review Board (IRB) Office on February 26, 2018. Approval from the IRB to proceed with the conduct of the purposed study was received on December 7, 2018 (see Appendix A).

Data Collection and Analysis

Upon receipt of the IRB's approval of the study design and the successful completion of the researcher's preliminary defense, the Center for Statistics at St. Cloud State University assisted the researcher in formatting and distributing the study's final survey instrument through the internet employing Survey Monkey.

Select school districts' superintendents with STEM schools were contacted by telephone, to secure consent for the participation of school district STEM schools and teachers in the study. An authorization letter and copy of the research survey was emailed to the superintendents and principals of the participating STEM schools. A copy of the letter sent to the superintendents and principals is found in Appendix B.

The survey was distributed by email to participating STEM teachers. Respondents were notified that their participation in the survey is voluntary. An estimated completion time of the study survey was determined to be 15 minutes.

A window of 2 weeks was established for the completion of the survey. Two weeks after launching the survey, a follow-up notification was distributed to respondents encouraging them, if they had not done so, to complete the study survey. The reminder notification cited the importance of the respondents participating and specified the manner in which the information gathered would assist school districts intending to initiate new STEM programs in Minnesota.

Following the receipt of the results from the web-based Survey Monkey, the Center for Statistics at St. Cloud State University compiled the study data and ascertained level of statistical significance. The Statistical Package for the Social Sciences (SPSS) was used for the purpose of data analysis.

Research Design

A quantitative (non-experimental) design was selected for use in the study. According to Haq (2015), quantitative social research is focused on collecting numerical data and analyzing it using statistical methods to explain a phenomenon" (p. 5).

A web-based survey (Survey Monkey) was designed to provide select Minnesota STEM teachers an opportunity to offer their quantitative perceptions of their STEM program's preparation and experiences.

Employing frequency, percentage, and select tests of statistical significance, the study examined Minnesota educators' confidence in their understanding of the purpose of STEM, their confidence in teaching and implementing STEM, the extent and quality of the STEM staff development training they received, the value of their STEM staff development training and their advice to teachers who were about to teach in a STEM program for the first time.

Procedure and Timeline

A draft of the study instrument was administered to a St. Cloud State University Doctoral cohort on June, 2017. The purpose of the administration of the instrument was to secure feedback on the readability and clarity of the instrument questions and the approximate time of survey administration. Based on the feedback received, revisions of the instrument were undertaken and completed.

Data collection was started in the second week of January 2019 and completed on February 23, 2019.

Chapter 4: Results

The new learning paradigm known as STEM has reignited the need to offer students an opportunity to make sense of the world as a whole rather than in pieces and bits. The supporters of STEM education believe that this program is more beneficial than the traditional system, and as noted by Morrison (2006), STEM educated students will be problem solvers, innovators, inventors, self-reliant logical thinkers, and technologically literate.

Study Overview

The study examined select Minnesota teachers' understanding, training and perceptions of STEM education and its implementation. Since studies about teachers' perceptions of STEM within the state of Minnesota were not found in the literature and there is no common definition and curriculum for STEM nationwide, the results of the study were focused on ascertaining how Minnesota teachers rated the value of the STEM training they received and their confidence and efficacy in teaching STEM. Additionally, the study examined how teachers perceived the need for continuous professional development for the effective implementation of STEM and the challenges teachers shared in implementing STEM.

The following five research questions were developed to guide this study:

1) How did select Minnesota STEM teachers report their understanding of the purpose of STEM?
2) How prepared and confident were select Minnesota STEM teachers in teaching/implementing STEM?
3) How much training did select Minnesota STEM teachers report they received on STEM?

4) How did select Minnesota STEM teachers report the value of the STEM training they received?
5) How did select Minnesota STEM teachers report they would benefit from further staff development on STEM?

The study survey was distributed to an estimated 120 teachers employed in STEM schools in five Minnesota school districts. The instrument consisted of 16 questions, based on the literature. Thirteen of the instrument questions matched each of the research questions that were developed to measure Minnesota teachers' understanding, training and perception of STEM, and the remaining three were demographic questions. Eighty-three STEM educators agreed to participate in the study and responded to some of the survey instrument questions, but only 63 teachers answered all of the survey instrument questions. The results of the survey were presented using data tables that provide descriptive analyses.

Chapter 4 reports the study findings by demographic results and findings for each research questions using tools and descriptive statistics.

Demographic Results

Demographic information was collected from each of the survey respondents requesting their experience in non-STEM teaching, their experience in STEM teaching, and their school setting. Seventy-seven STEM educators responded to the demographic instrument questions. Descriptive statistics were used to summarize the following data.

Table 1 reports respondents' years of experience in teaching. Survey responses revealed that 38 respondents or 49.4% had more than 10 years of teaching experience, while 18 respondents or 24.7% served between 5 to 10 years as teachers. Only 13 respondents or 16.9% had been teaching for less than 3 years.

Table 1

Years of Experience in Teaching

Years of Experience	Frequency	Percent
10 +	38	49.4
5 - 10	18	24.7
3 - 5	7	9.1
< 3	13	16.9
Total	77	100.0

Note: Responses to "How many years have you taught?"

Table 2 presents the respondents' years of experience as STEM teachers. Thirty-five respondents or 45.5% reported that they had been STEM teachers at least 5 years, and 25 respondents or 32.5% related they had been teaching in a STEM program between 1 and 5 years. Seventeen respondents or 22.1% stated that they were new STEM teachers.

Table 2

Years of Experience as STEM Teacher

Years of Experience	Frequency	Percent
5 +	35	45.5
3 – 5	18	23.4
1 - 3	7	9.1
< 1	17	22.1
Total	77	100.0

Note: Responses to "How many years of experience do you have as a STEM teacher?"

Table 3 designated information collected on survey respondents' educational settings. Of those, 64 respondents or 83.1% worked at an elementary STEM school settings, and 11 respondents or 14.3% worked at middle school settings. Only one respondent was employed in a high school STEM setting, and another one at both elementary and middle school settings.

Table 3

Respondents' STEM School Settings (Elementary, Middle School, Secondary)

	Frequency	Percent
A. Elementary Setting	64	83.1
B. Middle school Setting	11	14.3
C. High School Setting	1	1.3
D. A and B	1	1.3
Total	77	100.0

Note: Responses to "What school setting do you work?"

Survey Findings: Research Question 1

- How did select Minnesota STEM teachers report their understanding of the purpose of STEM?

The first research question of the study sought to determine if there was a common understanding of STEM among Minnesota STEM educators**.**

Table 4 reports the levels of understanding of the purpose of STEM education among the respondents. Twenty-five respondents or 39.7% reported they strongly believed there was an agreed upon understanding of the purpose of STEM education, while 26 respondents or 31.3% somewhat believed there was an agreed upon understanding of the purpose of STEM education. Twelve respondents or 19.1% reported there was no or little agreement on the understanding of the purpose of STEM education.

Table 4

Degree of Agreed-upon Understanding of STEM Education among Teachers

	Frequency	**Percent**
Very Much	25	39.7
Somewhat	26	41.3
Little	10	15.9
None	2	3.2
Total	63	100.0

Note: Responses to "To what degree is there an agreed-upon understanding of the purpose of STEM education among your colleague teachers?"

Table 5 reveals respondents' beliefs regarding whether or not there is a difference in teaching approaches and instructional strategies between STEM teaching and non-STEM teaching. Thirteen respondents or 20.6% believed there was a significant difference between the two approaches, while 39 respondents or 61.9% believed there was somewhat of a difference between STEM and non-STEM teaching. Eleven respondents or 17.5% stated they believed there was little difference between STEM and non-STEM teaching.

Table 5

Respondents' Beliefs in the Difference between the STEM and Non-STEM Teaching Approaches and Instructional Strategies

	Frequency	**Percent**
Very Much	13	20.6
Somewhat	39	61.9
Little	11	17.5
None	0	0
Total	63	100.0

Note: Responses to "To what extent do you believe the teaching approaches and instructional strategies with STEM teaching differ from Non-STEM teaching?

Since STEM is viewed in the literature as a new curriculum that integrates the standards and objectives of the fields of Science, Engineering, Mathematics and Technology, Table 6 presents the respondents' beliefs about whether or not there is a difference between the curriculum employed in STEM and non-STEM teaching. Sixteen respondents or 25.4% believed there is little or no difference between the curriculums involved in STEM and non-STEM teaching. Forty-seven respondents or 74.6% expressed a belief there was very much or somewhat of a difference between the curricula used in STEM or non-STEM teaching.

Table 6

Respondents' Beliefs in the Difference between the Curriculum Employed in STEM and Non-STEM Teaching

	Frequency	**Percent**
Very Much	5	7.9
Somewhat	42	66.7
Little	15	23.8
None	1	1.6
Total	63	100.0

Note: Responses to "To what extent do you believe the curriculum in STEM classrooms is different from the curriculum in Non-STEM teaching?

Table 7 reports the extent to which respondents' teaching and instructional methodologies changed as a result of teaching in STEM classrooms. Fifty-one respondents or 80.9% reported their teaching and instructional methodologies had changed very much or somewhat since teaching in a STEM setting. Twelve or 19.0% stated that their teaching and instructional methodologies had changed little. No respondents reported their teaching and instructional methodologies had not changed at all as a result of teaching in a STEM classroom.

Table 7

Extent of Respondents Change in Teaching and Instructional Methodologies after Teaching STEM

	Frequency	**Percent**
Very Much	20	31.7
Somewhat	31	49.2
Little	12	19.0
None	0	0
Total	63	100.0

Note: Responses to "To what extent have your teaching and instructional methodologies changed by teaching in STEM classroom?

To further understand the implementation of STEM teaching, the researcher examined the integration of engineering and technology practices or content in the classroom with science and mathematics. In this regard, Table 8 reveals the extent to which respondents had implemented the practices and content of engineering and technology. Twenty-three or 36.5% of the respondents reported they addressed engineering and technology content very much in their classrooms, while 28 respondents or 44.4% stated they somewhat implemented engineering and technology practices in their classrooms. Twelve respondents or 19.1% related they slightly had implemented engineering and technology practices little or none in their classrooms.

Table 8

Extent to which the Practices or Content of Engineering & Technology were Implemented in Respondents' Classrooms

	Frequency	Percent
Very Much	23	36.5
Somewhat	28	44.4
Little	11	17.5
None	1	1.6
Total	63	100.0

Note: Responses to "To what extent are the practices or content of Engineering & Technology addressed in your classrooms?

Survey Findings: Research Question 2

- How prepared and confident were select Minnesota STEM teachers in teaching/implementing STEM?

Since STEM is an instructional approach that integrates the teaching of four subjects (Science, Technology, Engineering, and Mathematics), STEM educators need to have a significant amount of confidence when undertaking this challenging task. The second research question sought to reveal selected educators' confidence in understanding the purpose of STEM and also their confidence in implementing STEM in their classrooms.

Table 9 reports respondents' confidence in understanding the purpose of STEM when they first taught in a STEM classroom. Six or 9.5% of the respondents were very confident in understanding the purpose of the STEM program, while 28 or 44.4% of the respondents were somewhat confident in understanding the purpose of STEM. Twenty-nine respondents or 46.1% reported that they had little or no confidence in understanding the purpose of the STEM program.

Table 9

Respondents' Confidence in Understanding the Purpose of the STEM Program

	Frequency	Percent
Very Much	6	9.5
Somewhat	28	44.4
Little	27	42.9
None	2	.2
Total	63	100.0

Note: Responses to "At the time you first taught in a STEM classroom, how confident were you that you understand the purpose of the STEM program?

Table 10 reports the extent to which respondents were confident in teaching and implementing STEM at the time they first taught in a STEM classroom. Nine or 14.3% of the respondents reported they had much confidence in teaching and implementing STEM when they first taught in a STEM classroom, while 23 respondents or 36.5% stated that they were somewhat confident. Thirty-one of the respondents or 49.2% stated they had little or no confidence in teaching and implementing STEM during their first time in a STEM classroom.

Table 10

Respondents' Confidence in Teaching and Implementing STEM

	Frequency	Percent
Very Much	9	14.3
Somewhat	23	36.5
Little	28	44.4
None	3	4.8
Total	63	75.9

Note: Responses to "At the time you first taught in a STEM classroom, how confident were you to teach and implement STEM in your classroom?

Survey Findings: Research Question 3

- How much training did select Minnesota STEM teachers report they received on STEM?

In their study, Nadelson et al. (2013) found that professional development significantly increased teachers' knowledge, confidence and efficacy in teaching STEM. The third research question sought to reveal the availability of professional development on teaching in the STEM program for teachers. Tables 11, 12, and 13 reveal the frequency results for teachers' responses to instrument questions that match research question 3.

Table 11 shows the amount of professional development on the purpose, strategies and/or curriculum of STEM that respondents received prior to teaching in a STEM classroom. Twenty-five or 39.7% of the respondents stated they received little or no training on the purpose, approaches, strategies and/or curriculum of STEM prior to teaching in STEM classroom, while 25 respondents or 39.7% related they somewhat received such training. Thirteen or 20.6% of the participants reported they received very much training on the purpose and approaches of STEM prior to teaching.

Table 11

Professional Development received by Respondents prior to Teaching STEM

	Frequency	Percent
Very Much	13	20.6
Somewhat	25	39.7
Little	18	28.6
None	7	11.1
Total	63	100.0

Note: Responses to "How much professional development did you receive on the purpose, approaches, strategies and/or curriculum prior to teaching in a STEM classroom?

Table 12 displays the amount of staff development respondents reported they received on the purpose, approaches, strategies and/or curriculum subsequent to their beginning to teach in a STEM classroom. Twenty or 31.7% of the respondents stated they had received very much staff development training on the purpose, approaches, strategies and/or curriculum of STEM since they began teaching in STEM classrooms, while 23 respondents or 36.5% were somewhat further trained after beginning to teach in a STEM classroom. However, 20 respondents or 31.7% stated they received little or no training on the purpose, approaches, strategies, and/or curriculum of STEM since they began teaching in STEM classrooms.

Table 12

Respondents' Professional Development received after teaching STEM

	Frequency	**Percent**
Very Much	20	31.7
Somewhat	23	36.5
Little	15	23.8
None	5	7.9
Total	63	100.0

Note: Responses to "How much professional development have you received on the purpose, approaches, strategies and/or curriculum since you began teaching in a STEM classroom?

Table 13 illustrates the organizations that provided the staff development training on STEM that respondents received. Two respondents or 3.2% stated the STEM training they received had been provided by the Minnesota Department of Education, while 28 respondents or 45.2% indicated their school districts provided the training. Thirty-two respondents or 51.6% stated other institutions had provided the STEM trainings they received.

Table 13

Providers of Respondents' Staff Development Training

	Frequency	Percent
Minnesota Department of Education	2	3.2
Your School District	28	45.2
Others	32	51.6
Total	62	100.0

Note: Responses to "Who provided the staff development training on STEM?

Survey Findings: Research Question 4

- How did select Minnesota STEM teachers report the value of the STEM training they received?

Research question 4 sought to determine respondents' ratings of the value of the professional development they received on STEM instruction since professional development programs were believed to be effective in increasing teachers' understanding and strategies of STEM content.

Table 14 reported respondents' ratings of the value of the STEM staff development they received. Twenty respondents or 32.3% rated the value of the STEM staff development as above average, while 33 or 53.2% of the respondents rated their STEM staff development as average. Nine respondents or 14.5% rated their STEM training as below average or of no value.

Table 14

Respondents Rating the Value of Staff Development on STEM They Received

	Frequency	**Percent**
Above Average	20	32.3
Average	23	53.2
Below Average	7	11.3
None	2	3.2
Total	62	100.0

Note: Responses to "How do you rate the value of staff development you received on STEM?

Survey Findings: Research Question 5

- How did select Minnesota STEM teachers report they would benefit from further staff development on STEM?

Survey questions 15 and 16, aligned to research question 5, intended to identify the extent to which STEM teachers believed they would had benefitted from additional staff development on STEM, and to the type of further staff development on STEM that would have been of value to them.

Table 15 reports the degree to which respondents believed they would have benefited from additional staff development on STEM. Thirty-six respondents or 57.1% believed they would had benefited very much from additional staff development on STEM, while 24 or 38.1% of the respondents believed they would have benefited somewhat by having further STEM training. Three respondents or 4.8% believed that they would have benefited little from additional training on STEM.

Table 15

Belief on Additional Staff Development on STEM

	Frequency	Percent
Very Much	36	57.1
Somewhat	24	38.1
Little	3	4.8
Total	63	100.0

Note: Responses to "How much do you belief you would benefit from additional staff development on STEM?

Table 16 displays the types of STEM training respondents believed would be valuable to them. Thirty-seven or 59.7% of the respondents reported that further staff development on integrating the teaching of the four subjects of STEM would be of value to them. Ten or 16.1% of the respondents preferred more training on STEM teaching methodologies. Nine or 14.5% of the respondents stated that further staff development on the STEM curriculum would be of value to them, and only one or 1.6% of the respondents reported that professional development on the purpose of STEM would be valuable.

Table 16

Types of Further STEM Development

	Frequency	Percent
Integration	37	59.7
Teaching Methodologies	10	16.1
Curriculum	9	14.5
Others	5	8.1
Purpose of STEM	1	1.6
Total	62	100.0

Note: Responses to "What type of further staff development on STEM would be of value to you?

Summary

Chapter 4 described the findings and the analysis of the study's five research questions which were intended to examine Minnesota teachers' understanding, training and perception of STEM education and its implementation. Survey participants responded to 16 survey questions using a Likert Scale. The chapter provided several findings on STEM teachers' perceptions of their involvement with their schools' STEM programs which resulted in the formulation of conclusions and recommendations in Chapter 5.

Chapter 5: Conclusions and Recommendations

Study Overview

The report, "Rising above the Gathering Storm: Energizing and Employing America for Brighter Future" (National Academies, 2006), was a call for school reform and increased awareness of STEM literacy in the United States (Steen, 2001). According to Furner and Kumar (2007), research indicated that this new paradigm would provide a more inspiring experience for students. In order to fulfill that goals, achieving ongoing support for the STEM initiative and improving the preparation and training of STEM teachers have taken precedence. It has become crucial to focus improvement efforts on initial preparation through induction and ongoing professional development (Wilson, 2011).

According to research, educators in general are more hesitant about new knowledge, such as STEM, which they are not adequately prepared to teach (Crismond, 2013; Czneriak & Johnson, 2007). Furthermore, the present global society needs STEM education and research (Hoachlander, 2014/2015), and the potential to obtain STEM as a distinct field of study is in its early stages (Honey et al., 2014).

The chapter furnishes a summary of the conclusions from the data findings presented in Chapter 4, discussions, limitations and recommendations for practice and for future research.

Purpose of the Study

The study examined Minnesota teachers' understanding, training and perceptions of STEM education and its implementation. Since no studies about STEM teachers' perceptions within the state of Minnesota were found in the literature, the results of the study ascertained how Minnesota teachers rated the value of the STEM training they received, and determined their confidence and efficacy for teaching STEM as there is no common definition and curriculum of STEM nationwide. Additionally, the study examined how teachers perceived the need for continuous professional development in the effective implementation of STEM, and the challenges teachers shared in implementing STEM.

Research Questions

1) How did select Minnesota STEM teachers report their understanding of the purpose of STEM?
2) How prepared and confident were select Minnesota STEM teachers in teaching/implementing STEM?
3) How much training did select Minnesota STEM teachers report they received on STEM?
4) How did select Minnesota STEM teachers report the value of the STEM training they received?
5) How did select Minnesota STEM teachers report they would benefit from further staff development on STEM?

In order to gather data on the respondents' understanding, perceptions of STEM education, training and its implementation, the researcher created online survey questions that were aligned to the aforementioned research questions.

Research Findings: Question 1

How did select Minnesota STEM teachers report their understanding of the purpose of STEM? The researcher examined the instrument questions, 4, 5, 6, 7, and 8, aligned to research question 1, and received the following results:

- The frequency results of instrument question 4 revealed that 25 or 39.7% of the respondents reported they strongly believed there was an agreed upon understanding of the purpose of STEM education, 26 or 31.3% somewhat believed this and 12 or 19.1% reported there was little or no agreement on the understanding of the purpose of STEM education.
- Instrument question 5's frequency results established that 13 or 20.6% of the respondents believed there was very much of a difference between STEM and non-STEM teaching approaches and instructional strategies, while 39 or 61.9% believed that there was somewhat of a difference between the two approaches.
- Instrument question 6 responses revealed that 47 or 74.6% of the respondents expressed a belief that there was very much or somewhat of a difference between the curriculums employed in STEM and non-STEM teaching. On the other hand, 16 or 25.4% of the respondents, more than one in four respondents, believed there was little or no difference between the curriculums involved in STEM and non-STEM teaching.
- The results of instrument question 7 disclosed that 51 or 80.9% of the respondents reported their teaching and instructional methodologies had changed very much or somewhat since teaching in a STEM setting.
- The frequency results of instrument question 8 revealed that 33 or 36.5% of the respondents reported they addressed engineering and technology contents very much in their classrooms, while 44.4% stated they somewhat implemented engineering and technology practices in their classroom. Those respondents who revealed they did not

implement engineering and technology practices in their classrooms or implemented it very little totaled 12 or 19.1%.

In the literature, STEM is viewed as a new curriculum that integrates the standards and objectives of the fields of science, engineering, math and technology, which represents a significant departure from the methodology for which instruction has been delivered in American schools in the past (Johnson, 2013). In accordance with the literature, the study found a positive trend in select Minnesota STEM teachers' understanding of the purpose of STEM, believing there was a difference between STEM and non-STEM curriculum and teaching and instructional approaches as well as addressing engineering and technology in their classrooms with their average responses varying, typically, between very much and somewhat.

Research Findings: Question 2

How prepared and confident were select Minnesota STEM teachers in teaching/implementing STEM? Instrument questions 9 and 10 aligned to research question 2, which requested respondents reveal their confidence in understanding the purpose of the STEM program and their confidence in teaching and implementing STEM. The results of instrument questions 9 and 10 include the following:

- In instrument question 9, 34 or 53.9% of the respondents were very much or somewhat confident in their understanding of the purpose of the STEM program, while 29 or 43.1% of the respondents reported they had little or no confidence in their understanding of the purpose of the STEM program.
- The frequency results of instrument question 10 disclosed that 32 or 50.8% of the respondents reported they felt very much or somewhat confident in teaching and

implementing STEM at the time they first taught in a STEM classroom, while 31 or 49.2% shared they had little or no confidence in teaching and implementing STEM during their first time in a STEM classroom.

In the literature, there is a correlation between teachers' preparations and their confidence in teaching and their students' performances. Educators, in general, are more hesitant about new knowledge, such as STEM, in which they are not adequately prepared to teach (Crismond, 2013; Czernriak, 2007). The study found that nearly half of the respondents (n = 31) had little or no confidence in understanding the purpose of the STEM program and in teaching and implementing it when they first started teaching STEM.

Research Findings: Question 3

How much training did select Minnesota STEM teachers report they received on STEM? Instrument questions 11, 12, and 13 match research question 3 and revealed the following results:

- According to responses on instrument question 11, 25 or 39.7% of the respondents affirmed they had received little or no training on the purpose, approaches, strategies and/or curriculum of STEM prior to teaching in STEM classroom. Those who stated they somewhat received such training totaled 25 or 39.7%, while 13 or 20.6% of the participants stated they received very much training on the purpose and approaches of STEM prior to teaching.
- The frequency results from instrument question 12 revealed that 20 or 31.7% of the respondents stated they had received very much staff development training on the purpose, strategies and/or curriculum of STEM since they began teaching in STEM

classrooms, while 23 or 36.5% of the respondents received further staff development trained after beginning to teach STEM and 20 or 31.7% stated somewhat they received little or no staff development since they began teaching in STEM classrooms.

- The results of instrument question 13 revealed that two or 3.2% of the respondents affirmed the STEM staff development training they received had been provided by the Minnesota Department of Education, while 28 or 45.2% of respondents stated their school districts delivered the training and 32 or 51.6% of the respondents related that other institutions had provided them with STEM training they received.

When speaking of the importance of professional development in STEM, Moore and Smith (2014) stated, “Most instructors, teachers, and administrators have not learned disciplinary content using STEM contexts nor have they taught in this manner, and therefore new models of teaching must be developed if STEM integration is to lead to meaningful STEM learning.” In a study conducted by Nadelson et al. (2013), the author affirmed the importance of professional development and its significant effect on teachers’ knowledge, confidence and efficacy in teaching STEM.

The study’s results highlighted that the professional development respondents received prior to teaching STEM or after they had begun teaching in STEM classrooms were not believed to be sufficient. Although the Minnesota Department of Education funded several STEM professional development programs, the respondents affirmed that the STEM staff development training in which they had least participated was provided by the Minnesota Department of Education.

Research Findings: Question 4

How did select Minnesota STEM teachers report (rate) the value of the STEM training they received?

Instrument question 14, aligned to research question 4, revealed the following frequency results:

- The respondents who rated the value of the STEM staff development they received as above average totaled 20 or 32.3%, while 33 or 53.2% of respondents rated their STEM staff development as average and nine or 14.5% of the respondents rated their STEM training as below average value.

According to the literature, 43 or 85.5% of the research participants agreed that the STEM program was more valuable or impactful than the traditional system as it allowed students to apply science, technology, engineering, and mathematics in contexts that made connections between school, community, work, and the global enterprise, enabling the development of STEM literacy and with it the ability to compete in the new economy" (Tsupros et al., 2009).

Research Findings: Question 5

How did select Minnesota STEM teachers report (state) they would benefit from further staff development on STEM?

The researcher examined instrument questions 15 and 16, which are aligned to research question 5, and revealed the following results:

- Over one in two, 36 or 57.1% of the respondents very much believed they would have benefited from additional staff development on STEM, while 24 or 38.1% of the respondents somewhat believed they would benefit from having further STEM training and three or 4.8% of the respondents believed they would only benefit a little from additional training on STEM.

- Thirty-seven or 59.7% of the respondents reported that further staff development on integrating the teaching of the four components of STEM would be of value to them, while 16.0% of the respondents preferred more training on STEM teaching technologies. Nine or 14.5% of the respondents affirmed that they would appreciate further staff development on STEM curriculum, and one or 1.6% of the respondents stated that additional professional development on the purpose of STEM would be valuable.

According to National Research Council (2011), effective STEM programs reference the importance of teacher preparation and education. In relation to that, greater than 50% of the study respondents indicated that more professional training on STEM would be beneficial for them. Since STEM education is designed to offer students an opportunity to make sense of the world as a whole because of its interdisciplinary approach (Tsurpos et al., 2009), research participants reported that, as STEM teachers, professional training on integrating the four components of STEM would have been more advantageous.

Discussions

Although the study revealed a positive inclination in research respondents' understanding of the purpose of STEM, their confidence in teaching and implementing STEM, how they rated the value of the STEM staff development they received, and how they would have benefited from additional staff development on STEM, there is no clear STEM educational purpose found in the study. This was consistent with the literature which stated that there is no common conceptualization of STEM among its stakeholders (Breiner et al., 2012).

The challenges found in the study regarding the creation, implementation and maintenance of a STEM program were as follows: In regard to the degree of understanding of the purpose of STEM education, nearly one in five respondents reported they had little or no agreement on the understanding of STEM's purpose, while 11 or 17.5% of the respondents believed there was little difference between STEM and non-STEM teaching approaches. Further, one in four respondents believed there was little or no difference between the curriculums involved in STEM and non-STEM teaching, while nearly 20.0% of respondents reported their teaching and instructional methodologies had not changed as a result of teaching in a STEM setting. Similarly, nearly one in five respondents reported they implemented very little or no engineering and technology practices in their classrooms.

Regarding preparation and confidence in teaching and implementing STEM, nearly 50% of the respondents reported they had little or no confidence in their understanding of the purpose of the STEM program, while one out of two research respondents shared they had little or no confidence in teaching and implementing STEM during their first time in a STEM classroom.

Of the many professional development sessions in which respondents participated over the years, 25 or 39.7% of the respondents stated they had received little or no STEM training prior to teaching STEM, while 20 or 31.7% of the respondents received little or no STEM professional development since they began teaching in STEM settings.

When asked to rate the value of the STEM training they received and how they would benefit from further staff development on STEM, 9 or 14.5% of the respondents rated their

STEM training as below average in value to them, while 3 or 4.8% of the respondents believed they would only benefit a little from additional training on STEM.

Since there is a correlation between teachers' preparations, their confidence in teaching and their students' performances, the researcher recommends a clear vision for teacher education programs to make efforts in preparing STEM teachers.

The researcher believes it is important for school districts operating STEM programs to establish a common or agreed upon understanding of STEM, address the barriers to STEM education found in the literature, and ensure the quality and training of STEM educators to meet students' interests and the achievements expected in the domains of STEM (Nadelson et al, 2013).

The researcher also recommends the implementation of STEM programs at the elementary school level to take advantage of the curiosity of young learners (Maltese & Tai, 2010) and provide elementary teachers with continuous STEM professional development to be able to teach STEM effectively. This would establish an understanding by all students and teachers, K-12, of the school districts' purposes in offering STEM programming.

Since STEM is viewed as a new curriculum, the researcher recommends the construction of a common state curriculum for STEM. The researcher also advises the collaboration between STEM teachers and STEM professionals to better prepare students for careers in STEM

Limitations

Defining limitations of a study, Price and Murnan (2004) wrote:

> The limitations of the study are those characteristics of design or methodology that impacted or influenced the interpretation of the findings from your research. They are the

constraints on generalizability, applications to practice, and/or utility of findings that are the result of the ways in which you initially chose to design the study and/or the method used to establish internal and external validity.

According to Saunders, Lewis, and Thornhill (2009), a research study was determined by the research methodology used. With this observation in mind, the limitations of the study are as follows:

- The study was designed to survey Minnesota STEM teachers. Unfortunately, only five Minnesota school districts agreed to participate in the study. This was largely believed to be because the IRB office of St. Cloud State University required the researcher to secure approvals from participating school districts prior to the university approving the study. In many instances, school district leaders refused to agree to participate in a study which had not previously been approved by the university.
- Since the completion of the study survey was voluntary, the number of STEM teachers who participated in the study from the five participating school districts was 85. Subsequently, only 63 respondents fully completed their surveys
- The study was distributed to teachers after their school districts' winter breaks. This time in the school year is challenging for teachers as it coincides with the time for administering first semester examinations. The timing of survey distribution may have negatively affected the number of study respondents.
- The reliability of the on-line survey delivery system.

- The results of the study may not be generalizable to other populations in Minnesota or other states.

Recommendations for Practice

Based on the literature review and the findings of the study of selected Minnesota STEM teachers' understanding, training, and perceptions of STEM education and its implementation, it is believed that there were correlations between STEM teachers' knowledge of, confidence in, and efficacy in teaching STEM content and its implementation. The following recommendations will provide leadership at all levels of school districts to clarify and build support for STEM education and provide support to STEM educators.

- It is recommended that continuous professional development in STEM should be offered by school district leaders to enhance teachers' content knowledge, confidence and the efficacy in teaching STEM (Nadelson et al., 2013). As nearly 50% of the research participants reported they had little or no confidence in their understanding of the purpose of the STEM program, regular professional development in STEM would seem essential for addressing these conditions.
- Curricula that integrate STEM are rare for K-12 education. It is recommended that school districts develop a unified curriculum for STEM programs to strength teachers' content knowledge and STEM teaching skills.
- It is recommended that school districts involve new STEM teachers in well designed, formal induction or a new STEM teacher support program to assist them in succeeding in STEM settings.

Recommendations for Further Research

The following recommendations are tendered for further research:

- It is recommended that further research be conducted on all Minnesota STEM schools to examine how the STEM program is effectively executed in their schools and how their STEM teachers are effectively trained in implementing STEM.
- It is also recommended a comprehensive study on the impact of STEM on student achievement be conducted.
- It is recommended a study be conducted of a sample of the highest quality STEM programs in the state of Minnesota in order to provide advice to school districts which intend to design and implement STEM programs.
- It is recommended a qualitative study be conducted in which STEM teachers are interviewed to ascertain how curriculum and instruction differ in STEM and non-STEM classrooms.

Summary

The study sought to examine how selected Minnesota STEM teachers rated their confidence and efficacy in teaching STEM, their understanding of the purpose and value of STEM programs and their perceived need for continuous professional development in the effective implementation of STEM. Based on the literature and data collected in the study, the study acquired a positive inclination in research respondents' understanding of the purpose of STEM, their confidence in understanding, teaching and implementing STEM, how they rated the value of the STEM staff development they received, and how they would have benefited from additional staff development on STEM. The study also identified that more professional development programs inspiring STEM instruction should be designed to develop teachers' understanding and implementation of STEM integration.

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Appendix A: IRB Approval Letter

ST. CLOUD STATE UNIVERSITY

EDUCATION FOR LIFE.

Institutional Review Board (IRB)

720 4th Avenue South AS 210, St. Cloud, MN 56301-4498

Name: Abdulcadir Mohamud

Email: moab1202@stcloudstate.edu

IRB PROTOCOL DETERMINATION:
Expedited Review-1

Project Title: Minnesota Techer's understanding, training, perception of STEM Education and its implementation

Advisor Roger Worner

The Institutional Review Board has reviewed your protocol to conduct research involving human subjects. Your project has been: **APPROVED**

Approval granted for those schools who provided authorization documentation. P.I. should submit any additional authorizations to the IRB if received.

Please note the following important information concerning IRB projects:

- The principal investigator assumes the responsibilities for the protection of participants in this project. Any adverse events must be reported to the IRB as soon as possible (ex. research related injuries, harmful outcomes, significant withdrawal of subject population, etc.).

- For expedited or full board review, the principal investigator must submit a Continuing Review/Final Report form in advance of the expiration date indicated on this letter to report conclusion of the research or request an extension.

-Exempt review only requires the submission of a Continuing Review/Final Report form in advance of the expiration date indicated in this letter if an extension of time is needed.

- Approved consent forms display the official IRB stamp which documents approval and expiration dates. If a renewal is requested and approved, new consent forms will be officially stamped and reflect the new approval and expiration dates.

- The principal investigator must seek approval for any changes to the study (ex. research design, consent process, survey/interview instruments, funding source, etc.). The IRB reserves the right to review the research at any time.

If we can be of further assistance, feel free to contact the IRB at 320-308-4932 or email ResearchNow@stcloudstate.edu and please reference the SCSU IRB number when corresponding.

IRB Chair:

Dr. Benjamin Witts
Associate Professor- Applied Behavior Analysis
Department of Community Psychology,Counseling, and Family Therapy

IRB Institutional Official:

Dr. Latha Ramakrishnan
Interim Associate Provost for Research
Dean of Graduate Studies

OFFICE USE ONLY

SCSU IRB# **1781 - 2257**	**Type:** Expedited Review-1	**Today's Date:** 12/7/2018
1st Year Approval Date: 12/7/2018	**2nd Year Approval Date:**	**3rd Year Approval Date:**
1st Year Expiration Date: 12/6/2019	**2nd Year Expiration Date:**	**3rd Year Expiration Date:**

Appendix B: Letter to Superintendents

LETTER TO SUPERINTENDENTS FOR PERMISSION TO PARTICIPATE IN STUDY

Abdulcadir Mohamud
18 Battle Creek Ct
St. Paul, Minnesota
MN 55119

Dear _______________________,

As a requirement of the degree of Doctor of Educational Administration and Leadership through St. Cloud State University, I am writing a dissertation on **Minnesota Teacher's understanding, training, perception of STEM Education and its implementation**. This survey intends to examine Minnesota teachers' understanding, training and perception of STEM education and its implementation. The study will help to highlight the need to better define and implement STEM with a uniform standard in Minnesota schools and school districts. As the educational realm focuses more heavily on STEM instruction, it is essential that knowledge acquired through the study will be applicable to schools in Minnesota.

This letter is to request your assistance with this quantitative research which I am hopeful will be of interest to educators, administrators, staff development coordinators, and universities with teacher preparation programs. Your system's participation will be in the form of an on-line anonymous survey lasting approximately fifteen to twenty minutes in length. Pending IRB approval, I anticipate the survey will occur during the month of October, 2018.

I recognize professional educators' time is valuable and believe their input into this research is valuable and will be beneficial to Minnesota school systems.

If you have questions or concerns, please contact me at 651-367-9308 or my advisor Dr. Roger Worner at 612-719-5857. Thank you for your consideration of participation in this research study.

Sincerely,

Abdulcadir Mohamud

Appendix C: Consent to Participate Letter

Minnesota Teacher's understanding, training, perception of STEM Education and its implementation.

CONSENT TO PARTICIPATE IN STUDY

Background Information and Purpose There is currently a lack of studies in the literature that pertain to Minnesota STEM teachers' understanding, training, perception of STEM education and its implementation. This study is designed to provide insight into elementary, middle and high school teachers' perceptions of STEM Education and its implementation.

Procedures The study intends to survey select elementary, middle and high school teachers teaching in STEM programs in select Minnesota Metro area districts and schools which operate STEM programs. If you agree to participate in this research study, you will be asked to complete a survey. This survey will take approximately fifteen to twenty minutes to complete.

Risks There are no risks to participating in this study.

Benefits The study will help to highlight the need to better define and implement STEM with a uniform standard and will support schools and school districts in the implementation process. As the educational realm focuses more heavily on STEM instruction, it is essential that knowledge acquired through the study will be applicable to schools in Minnesota.

Confidentiality The confidentiality of the information gathered during your participation in this study will be maintained. All data will be kept in a file cabinet in a locked office.

Research Results Following the receipt of the results from the web-based Survey Monkey, the Center for Statistics at St. Cloud State University will compile the study data and ascertain level of statistical significance.

Contact Information Principal Investigator: Abdulcadir Mohamud (Graduate Student) at moab1202@stcloudstate.edu Faculty Advisor: Dr. Roger Worner at rbworner@stcloudstate.edu

Voluntary Participation/Withdrawal

Completion of the study is voluntary. You may stop at any time.

Acceptance to Participate

Your completion of the survey designates your consent to participate in the study and that you are at least 18 years of age.

Appendix D: Instrument Questions

<u>Direction for completing the following section:</u>
Respond to each of the questions (4–15) below by placing “X” in the box that best reflects your level of agreement. Please fill in only one box per question.

1. How many years have you taught?

< 3 years	3 – 5 years	5 – 10 years	➢ 10 years

2. How many years of experience do you have as a STEM teacher?

< 1 year	1 – 3 years	3 – 5 years	➢ 5 years

3. Which school setting do you work with?

A. elementary setting	B. Middle school setting	C. High school setting	A and B	B and C

4. To what degree is there an agreed-upon understanding of the purpose of STEM education among your colleague teachers?

None	little	somewhat	very much

5. To what extent do you believe the teaching approaches and instructional strategies with STEM teaching differ from non-STEM teaching?

None	little	somewhat	very much

6. To what extent do you believe curriculum in STEM classrooms is different from the curriculum in non-STEM teaching?

None	little	somewhat	very much

7. To what extent have your teaching and instructional methodologies changed by teaching in a STEM classroom?

none	little	somewhat	very much

8. To what extent are the practices or content of engineering and technology addressed in your classroom?

none	little	somewhat	very much

9. At the time you first taught in a STEM classroom, how **confident** were you that you **understood the purpose** of the STEM program?

not at all	a little	somewhat	very much

10. At the time you first taught in a STEM classroom, how **confident** were you to **teach and implement** STEM in your classroom?

not at all	a little	somewhat	very much

11. At the time you first taught in a STEM classroom, how **prepared** were you to **teach and implement** STEM in your classroom?

none	a little	somewhat	very much

12. How much professional (staff) development did you receive on the purpose, approaches, strategies and/or curriculum **prior** to teaching in a STEM classroom?

none	a little	some	a great deal

13. How much staff development have you received on the purpose, approaches, strategies and/or curriculum of STEM **since** you first began teaching in a STEM classroom?

none	a little	some	a great deal

14. How do you rate the value of staff development you received on STEM?

received none	below average	average	above average

15. How much do you believe you would benefit from additional staff development on STEM?

none	little	somewhat	very much

16. Who provided the staff development training on STEM?

Minnesota Department of Education	Your school district	others