Fall 12-2017

A Mixed-Methods Evaluation of Project Lead the Way Engineering Curriculum Goals within Missouri High Schools

Brian Eugene Smith
Lindenwood University

A Mixed-Methods Evaluation of Project Lead the Way Engineering Curriculum Goals within Missouri High Schools

by

Brian Eugene Smith

December 2017

A Dissertation submitted to the Education Faculty of Lindenwood University

in partial fulfillment of the requirements for the

degree of

Doctor of Education

School of Education

A Mixed-Methods Evaluation of Project Lead the Way

Engineering Curriculum Goals within Missouri High Schools

by

Brian Eugene Smith

This dissertation has been approved in partial fulfillment of the requirements for the

degree of

Doctor of Education

At Lindenwood University by the School of Education

Dr. Lynda Leavitt, Dissertation Chair — 12/1/2017 Date

Dr. Terry Stewart, Committee Member — 12/1/2017 Date

Dr. Timothy McInnis, Committee Member — 12/01/2017 Date

Declaration of Originality

I do hereby declare and attest to the fact that this is an original study based solely upon my own scholarly work here at Lindenwood University and that I have not submitted it for any other college or university course or degree here or elsewhere.

Full Legal Name: Brian Eugene Smith

Signature: Date: 12/1/2017

Acknowledgments

I would like to express my gratitude to my dissertation chair, Dr. Lynda Leavitt. Her support and unwavering commitment to assist me in completing this process has been invaluable. I would also like to thank my committee members Dr. Terry Stewart and Dr. Tim McInnis for their time, effort, and feedback regarding the finished product. Further, a sincere thank you to Dr. Kevin Winslow and Dr. Sherrie Wisdom for their statistical assistance and to Dr. John Long for his continuous encouragement as my program mentor. Each of them played a part in this process, and I am appreciative to each of them for the time invested in me.

I would also like to thank the Project Lead the Way (PLTW) engineering community in the state of Missouri for their feedback and to the Missouri Department of Elementary and Secondary Education for providing statistical information regarding the state of PLTW Engineering assessment. I am particularly thankful to the study participants who took the time to volunteer for an interview; each of them provided insightful feedback and helped make this study meaningful.

Lastly, I owe a debt of gratitude to my wife, Angela, for her ongoing support and dedication to this process. She sacrificed tremendously, in both time and finances, for me to achieve this goal. I would also like to thank my three sons, Micah, Benjamin, and Luke, for their unconditional love and support. Towards the end of this process, my family became the main reason why I completed this dissertation. This is for you.

Abstract

Within the confines of this study, the researcher investigated Project Lead the Way (PLTW) Engineering curriculum goals within Missouri high schools. The study measured Missouri PLTW teachers' perceptions of various elements of the curriculum as well as state and national PLTW End of Course student assessment data to determine if a relationship existed between teachers' perceptions of curriculum implementation and student performance, as measured through Missouri End of Course exams in various secondary engineering classes. In addition, the researcher conducted voluntary interviews with teachers, state administrators, and national representatives of PLTW to inquire about experiences with the PLTW Engineering curriculum.

Qualitatively, Missouri PLTW Engineering teachers expressed varied levels of satisfaction through a survey generated by the researcher, based upon national curriculum goals established by PLTW. Within the study, teachers' perceptions reported students' abilities to identify, formulate, and solve engineering problems were greater than students' abilities to design and conduct experiments, as well as to demonstrate knowledge of and responsibility for engineering issues, including ethical and professional responsibilities. The researcher attributed this perception to students' lack of professional experience and to PLTW curriculum not providing enough opportunities for students to gain real-world relevant experience using the content and strategies learned during instructional class time.

The intention of this study was to provide a framework to review and evaluate curriculum goals established by PLTW, Inc. Originally, the researcher looked at national goals for the program to determine the outcomes of PLTW's educational programming.

However, much of the data was post-secondary related and the researcher wanted to maintain the quantitative nature of the study. Nonetheless, research could expand upon the framework to study any state in the nation through either a mixed-methods approach or the use of a quantitative study approach. The researcher recommends further research be conducted either by PLTW, Inc., through state PLTW affiliates or by other individuals to determine future outcomes of educational curriculum offered by PLTW. This could include engineering, biomedical science, computer science, middle school curriculum offered through Gateway to Technology (GTT), or through elementary curriculum offered through Launch.

Table of Contents

List of Tables

Chapter One: Introduction

Our nation faced a significant shortage of college graduates in engineering. Kimmel, Carpinelli, and Rockland (2007) noted, "Interest in science and math is fading in American children, resulting in fewer students seeking education and professions in engineering" (p. 1). The state of American engineering was in disarray, as Van Overschelde (2013) referenced within U.S. Congress House Resolution No. 6429, which ultimately led to the STEM Jobs Act in November 2012 and granted roughly 55,000 employment visas to individuals from other nations. The individuals were professionally certified or possessed advanced degrees in STEM-related fields from U.S. educational institutions (p. 3), and a high employment demand existed for these individuals. Given the state of STEM education, specifically engineering education, the need to develop a new generation of engineers for our country appeared necessary and critical to the U.S. economy. Secondary education engineering curriculum, program implementation, and instruction in engineering appeared timely and relevant (Bottoms & Anthony, 2005; Bottoms & Uhn, 2007; Fadali, Robinson, & McNichols, 2000; Jeffers, Safferman, & Safferman, 2004; PLTW California, 2017). This study focused on the need for STEM education, specifically through Project Lead the Way (PLTW) engineering within the state of Missouri and the teaching of PLTW Engineering curriculum to secondary students. Chapter One details the study's background, context, and rationale, as well as introduces the research questions and null hypotheses of this mixed-methods study. The researcher also addresses limitations of the study and defines the terminology used within the study.

Background of the Study

The need for STEM education, specifically secondary engineering education, led the researcher to conduct an evaluation of PLTW Engineering curriculum goals within the state of Missouri. The researcher examined the nationally stated curriculum goals of the PLTW Engineering program and measured the efficacy of the curriculum goals through multiple methods, including Missouri PLTW student assessment data defined by PLTW EOC examinations, through Missouri PLTW secondary teacher survey data, and through interviews conducted with instructional and administrative leaders of PLTW involved in management and program implementation. The nationally stated PLTW overview included 11 curriculum goals (Table 1).

The primary goal of this researcher was to determine if Missouri high schools met or exceeded the stated national curriculum goals of PLTW, Inc., through: 1) an evaluation of Missouri PLTW assessment data, 2) PLTW teacher survey responses, and 3) feedback from program representative interviews. The proposed study included survey data from Missouri high school instructors (N = 329) who implemented PLTW at the time of this study. The data collection included a PLTW high school teacher survey instrument on the instructional perspective of PLTW curriculum goals, interviews of state and national PLTW representatives, and secondary PLTW EOC engineering assessment data available through the Missouri Department of Elementary and Secondary Education (MODESE, n.d.a).

Definition of Terms

College attrition rates: “The diminution in numbers of students resulting from lower student retention” (Hagedorn, 2006, p. 6).

Table 1

Established Goals of PLTW Engineering

Goal Number	Goal
1	Demonstrate an ability to identify, formulate, and solve engineering problems.
2	Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
3	Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
4	Demonstrate an ability to apply knowledge of mathematics, science, and engineering
5	Demonstrate an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
6	Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
7	Demonstrate an understanding of professional and ethical responsibility.
8	Demonstrate an ability to function on multidisciplinary teams.
9	Demonstrate an ability to communicate effectively.
10	Gain knowledge of contemporary issues.
11	Recognize the need for, and develop an ability to engage in life-long learning.

Note: (Cahill, personal communication, July 2, 2015).

Engineering: "The art of applying scientific and mathematical principles, experience, judgment, and common sense to make things which benefit people. Engineering is the process of producing a technical product or system to meet a specific need" (MODESE, n.d.b, p. 3).

Engineering design: "A systematic, intelligent process in which designers generate, evaluate and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints" (Dym, Agogino, Eris, Frey, & Leifer, 2005, p. 104).

Engineering design process: Burghardt & Hacker (2004) defined the engineering process.

> The iterative process for creation and manipulation of the human-made world. The process combines knowledge and skills from a variety of fields with the application of values and understanding of societal needs to create systems, components, or processes to meet human needs. Initialized by problem definition, followed by clarity of the specifications the designed product must meet, the open-ended engineering design process optimizes competing needs and constraints, and . . . uses modeling and analysis to drive the creation of new engineered solutions to serve humankind. (p. 9)

Engineering literacy: "The ability to use scientific knowledge and processes to understand the natural world as well as the ability to participate in decisions which affect it" (National Governor's Association Center for Best Practices, 2008, p. 2).

Engineering technology programs: "The school subject which teaches about the processes used to design, create and maintain the human-made world through the integration of technical, mathematical, and scientific knowledge and skills" (MODESE, n.d.a, p. 5).

Equitable and inclusive opportunities: For the purpose of this study, opportunities for underrepresented groups in engineering, such as women and minorities.

Ethnic origin: For the purpose of this study, nationality of the individual studied.

Gender origin: Defined as either male or female.

High School: For the purpose of this study, an educational institution that serves students in grades nine through 12.

Mathematical literacy: "The ability of students to analyze, reason, and communicate ideas effectively as they pose, formulate, solve, and interpret solutions to mathematical problems in a variety of situations" (National Governor's Association Center for Best Practices, 2008, p. 2).

Missouri Career Paths: "These clusters of occupations which require different levels of education and training. People working in a career path share interests, abilities, and talents. Career Paths helped students identify a career focus without a commitment to a specific occupation" (MODESE, n.d.b, p. 3).

Missouri Department of Elementary and Secondary Education: The state institution, which oversaw Pre-kindergarten through 12th grade public education in the State of Missouri.

Project Lead the Way Engineering: An educational program offered through Project Lead the Way, Inc., which applied science, technology, engineering, and mathematics (STEM) to solve complex, open-ended problems in a real-world context.

Students focused on the process of defining and solving a problem through hands-on experiences (Project Lead the Way [PLTW] Missouri, 2014).

PLTW Pathway to Engineering: “Is a four-year high school sequence taught in conjunction with traditional math and science courses? PTE’s eight courses, including Principles of Engineering and Civil Engineering and Architecture, provide students with an in-depth, hands-on knowledge of engineering and technology-based careers” (Bertram, 2013, para. 18).

Scientific Literacy: “The ability to use scientific knowledge and processes to understand the natural world as well as the ability to participate in decisions which affect it” (National Governor’s Association Center for Best Practices, 2008, p. 2).

STEM: Acronym for Science, Technology, Engineering, and Mathematics. STEM incorporated hands-on activities in the various areas of STEM to generate content interest of students (Boynton & Hossain, 2010).

Technology: The National Academy of Engineering (2010) defined technology as a field that:

> comprises the entire system of people and organizations, knowledge, processes, and devices that go into creating and operating technological artifacts, as well as the artifacts themselves. Throughout history, humans have created technology to satisfy their wants and needs. Much of modern technology is a product of science and engineering, and technological tools are used in both fields. (p. 17)

Technology and Engineering: “The school subject which teaches about the processes used to design, create, and maintain the human-made world through the integration of technical, mathematical, and scientific knowledge and skills" (MODESE, n.d.b, p. 5).

Technological Literacy: "Students should know how to use technologies, understand how new technologies are developed, and have the skills to analyze how new technologies affect us, our nation, and the world" (National Governor's Association Center for Best Practices, 2008, p. 2).

Statement of Issue

On March 13, 2013, before the U.S. House Committee on Science, Space, and Technology, Subcommittee on Research, Bertram (2013), Project Lead the Way President and CEO stated, "By 2018, the United States will have more than 1.2 million unfilled STEM jobs" (para. 4). Jackson (2004) supported this stance and stated,

> There is a quiet crisis building in the United States — a crisis that could jeopardize the nation's pre-eminence and well-being. The crisis has been mounting gradually, but inexorably, over several decades. If permitted to continue unmitigated, it could reverse the global leadership Americans currently enjoy. The crisis stems from the gap between the nation's growing need for scientists, engineers, and other technically skilled workers, and its production of them. (p. 1)

Engineering was an interdisciplinary field where mathematics and science made connections (Katehi, Pearson, & Feder, 2009) and programs such as PLTW supported secondary school-aged students in learning of engineering education. Lewis (2005) stated, "Some education leaders believe that the incorporation of engineering in technology education will lead to greater technological literacy and promote engineering as a career choice" (p. 1).

Rationale

In *One Nation Under Taught: Solving America's Science, Technology, Engineering, and Math Crisis*, Bertram (2014) wrote, "We are simply not healthy today" (p. 9) concerning the status of science, technology, engineering, and mathematics (STEM) education. Within this comment, Bertram (2014) referred to both the state of our national economy and the state of our educational system, and used this opportunity to connect the health of the economy to the health of the workforce for future high school and college graduates. Ditzler, President of Monmouth College, stated, "Too many students are graduating with a weak background in science and math . . . we need to make sure our graduates know the basics and many don't" (as cited in Bertram, 2014, p. 10).

Several educational programs, lumped under the STEM acronym, were created to counteract the perceived and proven results of the tepid state of the national STEM economy -- including PLTW, Robotics Education through Active Learning (REAL), and other career and technical programs designed to provide applicable and practical opportunities for secondary students (Association for Career and Technology Education [ACTE], 2009; Dortch, 2014; MODESE, n.d.b). In STEM-related areas, the field of engineering found itself in an important, yet unenviable position. In comparison to other STEM areas, science, technology, and mathematics had national standards (Common Core State Standards Initiative [CCSSI], 2016; International Society for Technology, 2013; Next Generation Science Standards [NGSS], 2013); however, no specific national engineering standards existed at the elementary or secondary level (National Academy of Engineering [NAE], 2010).

With no national standards in place, a gap existed in educational programming and in “increasing the visibility of technology and engineering in the standard K-12 curriculum” (Hanover Research-District Administrative Practices, 2011, p. 7). Hanover Research-District Administrative Practices (2011) further defined the concept of STEM literacy to include engineering literacy and described STEM literacy as “the understanding of how technologies are developed via the engineering design process using project-based lessons in a manner that integrates across multiple subjects” (p. 8). In the researcher’s experience, as a secondary public school administrator at the time of this study, the concept of engineering literacy and, to a larger degree, engineering, received little support in secondary educational institutions due to the lack of established national or state standards. Despite the lack of engineering standards, a U.S. Department of Commerce report stated, “Science, technology, engineering, and mathematics workers drive our nation’s innovation and competitiveness by generating new ideas, new companies, and new industries” (as cited in Langdon, McKittrick, Beede, Khan, & Doms, 2011, p. 3). Wigal and Betro (2012) noted, “Engineering is crucial to moving our nation into the 21st century and to enhancing our national security and global competitiveness” (para. 1). The national economy supported the development and expansion needs of the STEM-related workforce, where “STEM-related jobs were expected to grow approximately 20% from 2008-2018. . . a rate that is almost twice the growth rate of non-STEM-related jobs” (Langdon et al., 2011, p. 1).

Secondary education engineering programs had a void to fill, and programs such as PLTW supported the growth of engineering education. Secondary engineering programs also provided future support for the recruitment of professional engineers in the United States. According to Pinelli and Haynie (2010), "The addition of engineering in secondary curriculum will help feed the engineering pipeline by exposing students to engineering content during their middle school and high school years" (p. 53). Pinelli and Haynie (2010) proposed implementation of engineering curriculum could accomplish the following curricular concepts:

> Work as a contributing member of or lead a team, use appropriate written and/or visual mediums to communicate with a wide variety of audiences, participate in public speaking, listen to the needs and ideas of others, understand the potential impact their ideas and products may have on society, use problem solving methods and skills, manage time, resources and projects, participate in researching ideas and concepts including data collection and analysis, go beyond the classroom for answers, and be better prepared for success in two- and four-year college programs. (p. 3)

Purpose of the Dissertation

This dissertation reports the result of investigation of PLTW Engineering curriculum goals in the state of Missouri and the perceived success of curriculum implementation in Missouri high school classrooms. The purpose of this dissertation received further clarification through PLTW Engineering assessment data and survey information from then-current Missouri high school PLTW Engineering teachers, as well as state and national PLTW leaders. This dissertation remained grounded in the need for the development of secondary engineering programs designed to promote the field of engineering, increase the amount of U.S. engineers, and create STEM employment opportunities, specifically in the engineering realm, within the United States.

STEM fields remained critical to the economic well-being of the United States (Chen & Soldner, 2013). However, the United States was “facing fierce competition from abroad in producing and retaining STEM talent” (Chen & Soldner, 2013, p. 1). Due to the increasing global competitiveness for jobs, programs like engineering education reacted with the creation and development of educational programming to encourage secondary students to pursue careers in STEM-related areas, such as engineering.

Specifically, PLTW Engineering, since its inception in 1986, outlined curriculum goals to encourage high school graduates to pursue two and four-year degrees in high-needs career paths, such as engineering (PLTW California, 2017). The engineering education experience offered through PLTW provided secondary students access to specific skill sets and tools associated with and used in engineering fields, as well as opportunity for application of STEM-related concepts. The national curriculum goals of PLTW Engineering, if successful, created an increasing population of students in STEM-related areas, as well as increased levels of college graduates who pursued related careers with a significant STEM focus (Holt, 2011; McMullin & Reeve, 2014; Ontiveros & Alvarez, 2012; Van Overschelde, 2013).

To address opportunities within STEM education, MODESE listed STEM as one of sixteen career clusters available to guide students in the state of Missouri (MODESE Division of Career Education, n.d.). These career clusters provided students of Missouri secondary institutions information about potential careers and educational training required to pursue defined career paths. MODESE (n.d.a) included engineering as a career pathway and STEM as a career cluster. Despite the declaration and commitment from the state of Missouri and the state education department to recognize engineering as a specific career pathway, there were no national engineering standards (Bybee, 2011) at the time of this study and no organization or entity conducted any statewide PLTW evaluations within the state of Missouri. As of January 2015 electronic correspondence with Hogan, Director of Engineering and Technology from MODESE, affirmed no initiated or completed program evaluations of Missouri PLTW Engineering existed, based upon national curriculum goals. This study added to the field of STEM and engineering education through a mixed-methods evaluation of PLTW Engineering curriculum goals within high schools in the state of Missouri.

Context

Research showed nationally developed standards aligned to science (NGSS, 2013), technology (International Society for Technology, 2013) and mathematics (CCSSI, 2016.), but not engineering (Bybee, 2011). From the researcher's perspective, the lack of national engineering standards led secondary schools to seek comprehensive engineering programs to fill the void within the engineering curriculum, especially in secondary educational settings. Organizations like PLTW provided the opportunity for schools to purchase desired curriculum, resources, and assessment materials and created a career pathway for students who may have personal interests in the field of engineering beyond secondary school experiences. The Division of Career Education through MODESE (n.d.a) recognized, "technology and engineering must be an essential component of both general education and career education" (p. 7). Further, a significant need for students to pursue STEM-related fields existed because of elevated levels of attrition rates (Chen & Soldner, 2013). Reasons for increased attrition rates included "students' demographic backgrounds, precollege academic preparation, postsecondary enrollment characteristics and STEM course selection and performance" (Chen & Soldner, 2013, p. 47). A *St. Louis Post-Dispatch* article from 2013 further suggested, "While demand is good news for engineering and science students, interest in these careers will not keep pace with demand" (Schrader, 2013, para. 2).

Therefore, the researcher concluded the need to conduct a curriculum evaluation of the PLTW Engineering program within the state of Missouri to determine if the stated curriculum goals of PLTW Engineering classes achieved a positive perception of the implementation of PLTW curriculum goals by PLTW Missouri secondary teachers. The researcher used teacher survey data measuring satisfaction levels of PLTW curriculum goals. Additionally, the researcher conducted interviews with instructional and administrative leaders who had practical experience within PLTW curriculum development and program implementation. Further, the researcher sought to determine student success in the PLTW program through submitted statewide data requests to MODESE. Data requests provided access to statewide student assessment data for each PLTW Engineering course offered in the state of Missouri. The researcher used this data to determine achievement levels of students in the PLTW Engineering curriculum.

This study initiated from the researcher's experience with PLTW Engineering and course implementation within the researcher's school district. The researcher's district implemented PLTW Engineering during the school year of 2010-2011 (Smith, B., personal knowledge, 2010). The curriculum replaced an industrial arts curriculum in existence since the inception of the school in 1959. During this time of transition, a section of the school community became upset with the school's decision to change the curriculum programming, citing shared experiences of parents and students within the industrial arts curriculum as a lead reason to keep the industrial arts program and not move forward with PLTW Engineering. (Smith, B., personal knowledge, 2017). Despite the negative perceptions and concerns for change in certain sections within the community, the school district implemented the PLTW Engineering program in 2010 and received national accreditation through PLTW as a Project Lead the Way Engineering School in 2013 (Yates, 2013). Verification of the implementation process occurred through a formal site visit conducted by state leadership officials of Missouri PLTW Engineering. The school further added PLTW Biomedical Sciences in 2014-2015 and PLTW Computer Science in 2015-2016 (PLTW Missouri, 2016c). The researcher became interested in the process of whether the PLTW Engineering program met its nationally stated curriculum goals within the state of Missouri as part of his role as a secondary principal. The researcher constructed a mixed methods research design with quantitative and qualitative data collection components and analysis of the mixed methodology.

This study contributed to the professional literature regarding engineering education and specifically, PLTW Engineering curriculum goals. The researcher believed a curriculum evaluation completed at the state level, using both secondary assessment data and qualitative data collected by the researcher provided a comprehensive methodology to the study. Further, the study developed a teacher survey instrument for others to replicate future evaluations of PLTW Engineering, PLTW

Gateway to Technology (middle school engineering program), PLTW Launch (elementary school engineering program), and other types of PLTW educational programming within a state or geographic area. This study 'closed the gap' in the literature on national curriculum goals of PLTW Engineering and provided guidance to measure program success in the field of PLTW Engineering.

Hypotheses

Hypothesis 1: There is a relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering problems, in all PLTW coursework and students' scores on national PLTW End of Course assessments.

Hypothesis 2: There is a relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering needs and students' scores on national PLTW End of Course assessments

Hypothesis 3: There is a relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation of mathematics, science, and engineering knowledge and students' scores on national PLTW End of Course assessments.

Research Questions

RQ1: How do Missouri PLTW Engineering teachers perceive curriculum implementation on identifying, formulating, and solving engineering problems?

RQ2: How do Missouri PLTW Engineering teachers perceive curriculum implementation on engineering experiments?

RQ3: How do Missouri PLTW Engineering teachers perceive curriculum implementation on techniques, skills, and tools for engineering practice?

RQ4: How do Missouri PLTW Engineering teachers perceive curriculum implementation on the impact of engineering solutions in a global, economic, environmental, and societal context?

RQ5: How do Missouri PLTW Engineering teachers perceive curriculum implementation on opportunities to demonstrate and understand professional responsibility?

RQ6: How do Missouri PLTW Engineering teachers perceive curriculum implementation on the understanding and demonstration of ethical responsibility?

RQ7: How do Missouri PLTW Engineering teachers perceive curriculum implementation to function on multidisciplinary teams in the classroom setting?

RQ8: How do Missouri PLTW Engineering teachers perceive curriculum implementation to communicate effectively in the classroom setting?

RQ9: How do Missouri PLTW Engineering teachers perceive curriculum implementation to recognize the need for and develop an ability to engage in lifelong learning?

Limitations

The researcher identified limitations as part of the study. The limited nature of participation in this study occurred due to the specific type of teaching and administrative experiences required by the research as part of the study. The population selection used purposive sampling, where "researchers intentionally select participants who are informed about or have experience with the central concept(s) being investigated" (Fraenkel, Wallen, & Hyun, 2012, p. 562). The study included 66 total participants; 61 teachers and five state or national-level leaders of PLTW Engineering. Although 60 to

70 participants were enough for study purposes, the small sample size may not have provided a portrayal of the complete population invited to participate in the study (N = 329).

The researcher's professional responsibility was a potential limitation to the study. At the time of data collection, the researcher was a high school principal whose school implemented Project Lead the Way Engineering programming in the state of Missouri. The researcher did have direct supervision of one of the study's 329 potential respondents and one of the study's 61 teacher respondents. However, the researcher did not have any prior PLTW teaching experience or program administration experience, which had potential to lead to undue influence of any other survey respondent. The researcher used a collegiate email account to administer the teacher survey and used the email account to conduct correspondence in the establishment of interviews and in the request and communication of data from MODESE.

The researcher considered sample demographics to be a potential limitation of the study. At no time during the development or conducting of the teacher survey did the researcher ask for demographic information of any potential participant. The researcher committed to the protection of the anonymity of participants within the study. Demographic information could have revealed further topics for future study considerations, such as gender imbalance in engineering teaching positions, etc., but likely would have identified specific study participants, due to any recognition of gender associated with the study. Additionally, certain PLTW EOC program sizes created limitations as part of the study. In Missouri, classes such as Aerospace Engineering (AE), Biotechnical Engineering (BE), and Computer Integrated Manufacturing (CIM) had limited numbers of school districts offering the specific course as part of the PLTW sequence. Therefore, certain data was limited, especially in the previously mentioned classes.

Further, the researcher looked at 10 internal validity threat factors to determine which, if any, had any level of effect, creating limitations within the research. These factors included subject characteristics of research participants, mortality, location, instrumentation, testing, history, maturation, subject attitude, regression, and implementation (Fraenkel, et al., 2012). The researcher attempted to control validity threats to the research through standardizing processes of collection of information from research participants and through the choice of methodology for the study to create an unambiguous research opportunity (Fraenkel, et al., 2012).

Summary

Galama and Hosek (2008) noted a "concern about the U.S. maintaining its leadership position given the current educational trends" (para. 1). Given this concern, the purpose of this study was to use mixed methods to measure PLTW Engineering curriculum in the state of Missouri and the perceived implementation and achievement success in Missouri high school classrooms, as supported by PLTW Engineering assessment data and survey information from then-current Missouri high school PLTW Engineering teachers. The researcher also collected qualitative data during phone interviews of PLTW state and national representatives.

Chapter One details the background, context rationale for this study and includes the study research questions, hypotheses, and a discussion of the study's limitations and professional terminology used in the text. Chapter Two reviews the existing professional literature on the topic of STEM education and PLTW Engineering. Chapter Two further highlights the status of the history of STEM education, the role of Career and Technical Education (CTE) in the field of STEM education, the lack of development of standards in the engineering education field, and the varied research of students, teachers, parents, and professionals with involvement in PLTW Engineering. The researcher also discussed the state of PLTW assessment and the use of evaluation instruments to measure student success in PLTW Engineering. Chapter Three establishes the methodology of the study through nine research questions and three null hypotheses. The survey instrument provided ample information regarding the participants of the study. Chapter Four reports the results obtained from the analyzed data and discussed the findings of the mixed-methods study. Chapter Five provides opportunities for further discussion and reflection regarding the research questions and hypotheses of the study.

Chapter Two: The Literature Review

In February 2012, a report from the President's Council of Advisors on Science and Technology (PCAST) stated, "Projections point to a need for approximately one million more STEM professionals than the U.S. will produce at the current rate over the next decade if the country is to retain its historical preeminence in science and technology" (p. 1). Two years later, ACT, Inc., (2014) released an annual report on the condition of science, technology, engineering, and mathematics (STEM) in the United States, which stated approximately 900,000 members of the nationwide high school graduating class of 2014 expressed an interest in STEM-related fields (p. 3). Despite this positive student perspective on the state of STEM interest within recent graduates, Bertram (2014) declared, "The current STEM workforce is about 7.4 million employees, with an estimated 8.6 million employees needed by 2018 — and that is just a minimum projection" (p. 5). Using this statistic, the researcher concluded the workforce needed approximately 1.2 million more jobs to fulfill a stable nationwide STEM work force populated by recent college and high school graduates. Jackson (2007) previously described the need for engineers as "a quiet crisis" and this crisis had the potential to no longer position the United States as a world economic superpower, due to "the gap between the nation's growing need for scientists, engineers, and other technically skilled workers, and its production of them" (p. 1).

According to the Association for Career and Technical Education (2009), "The demand for U.S. STEM professionals is expanding rapidly, but the supply of STEM talent is not increasing to meeting the growing need" (p. 2). Several variables affected the then-current population of STEM professionals. Engineers close to retirement

(National Research Council, 2010; National Science Board, 2006; Selingo, 2008) were more likely to have a diminishing impact on the nationwide engineering population. A lack of interest by students in STEM-related careers also led to a lack of awareness, fewer role models, diminished skills, and a lack of content aptitude (National Science Board, 2010). The below-average international achievement performance in mathematics and science (NAE, 2010; National Academy of Sciences, 2007) were also blamed for the lack of interest in engineering. Further, a lack of technological foundational skills for Americans (Diaz & Cox, 2012; Pearson & Young, 2002) led to diminished interest of students to pursue STEM-related fields.

Older generations continued to retire a significant percentage of the STEM-related work force, as “twenty-six percent of people with science and engineering degrees currently working are fifty years or older” (ACTE, 2009, p. 2). Retirement of the aging engineering population contradicted the fact that STEM interest remained high in the nationwide high school class of 2014. The expressed (but non-measured) interest amongst students measured at approximately 49% (ACT Inc., 2014, p. 3). However, within the same group of individuals, only 17% of students had a measured interest in STEM, representing only about one-third of the general interest indicated in STEM-related careers (ACT Inc., 2014, p. 3). The statistic translated to approximately 450,000 individuals who expressed an interest in engineering and technology, but amounted to only approximately 153,000 individuals who began pursuit of a college degree in engineering and technology (ACT Inc., 2014, p. 3). Further, 2010 National Assessment of Education Progress (NAEP) results showed, “only 26 percent of American high school seniors scored at or above the proficiency level in math . . . and 36 percent had failing scores" (as cited in Bertram, 2014, p. 4). The factors of retirement, lack of interest, and lack of foundational skills contributed to the creation of a significant gap in the U.S. educational STEM system, one which should have prepared students for success in science, technology, engineering, and mathematics subjects. Instead, the researcher believed this STEM gap created elementary and secondary students who lost interest and skills in STEM-related areas, which led to fewer individuals interested in STEM careers.

The History of STEM Education

Historically, the introduction of the acronym STEM occurred within the National Science Foundation (NSF). STEM referred to science, technology, engineering, and mathematics. Tai (2012) described the emergence of STEM from the original concept of mathematically gifted students who needed acceleration, rigor and increased depth of learning to serve student learning needs. STEM opportunities also provided students the ability to earn college credit and use integrated skills through successful completion of the accelerated curriculum; however, no official or professionally recognized definition of STEM existed to merge various organizations' thoughts and beliefs regarding STEM education. Nonetheless, PCAST (2012) stated, "STEM goals are designed to increase America's global competitiveness in science and technology innovation, as well as to improve the STEM understanding of U.S. citizens" (p. 1). STEM was further described as "a broad reform movement in the area of science, technology, engineering, and mathematics that seeks to cultivate a STEM-proficient workforce and a STEM-literate citizenry to increase the United States' competitiveness in the global economy" (Hanover Research-District Administrative Practices, 2011). PCAST established four overarching goals to promote STEM fields, including: "1) to ensure a STEM-capable citizenry, 2) to build a STEM-proficient workforce, 3) to cultivate future STEM experts and 4) to close the achievement and participation gap" (p. 1). Katehi, Pearson, and Feder (2009) also referred to "cultivating soft skills such as scientific inquiry and problem-solving skills" (p. 7) amongst then-current and future STEM students. Thornberg (2008) discussed the application of certain STEM subjects such as mathematics and science used for assessment purposes, like the NAEP. However, other content subjects such as engineering and technology did not find a place within national or international assessments, such as the NAEP. Despite the inconsistency of student assessment in STEM content subjects, STEM occupations "are some of the most in-demand and highest paying jobs" (Missouri Economic Research and Information Center [MERIC], 2014b, p. 1). Further, "The demand for STEM-related occupations . . . outpaces non-STEM occupations as well" (MERIC, 2014b, p. 2). Meyrick (2011) described STEM students as "learning and building skills that can be applied to a variety of situations, including making room for student innovation and original design" (p. 2). Wigal and Betro (2012) described the then-current state of STEM education as one of "high needs with low resources" (para. 24).

Career and Technical Education (CTE) Role in STEM Education

Cole, High, & Weinland noted, "Career and technical education (CTE) has entered into a period of redefinition and reassessment of improving rigor and relevance to the 21st century knowledge and skills" (2013, p. 86). ACTE (2009) categorized the variety and depth of CTE programs and initiatives offered as STEM content, where students developed a deeper understanding of career pathways and career clusters. These STEM programs and initiatives gained support through federal legislation passed in 2006 and included part of the Carl D. Perkins Vocational and Applied Technology Education Act of 1998, also known as Perkins IV (Dortch, 2014). According to Dortch (2014), members of the Congressional Research Service described the intent of Perkins IV to "develop the academic and career and technical skills of secondary and postsecondary education students who elect to enroll in CTE programs, particularly programs which prepare students for high-skill, high-wage, or high-demand occupations in current or emerging professions" (p. 4). Perkins IV also characterized CTE as "activities that offer a sequence of courses that provides individuals with coherent and rigorous content aligned with challenging academic standards and relevant technical knowledge and skills needed to prepare for further education and careers in current or emerging professions" (p. 4). According to Stone, Alfeld, Pearson, Lewis, and Jensen (2006), CTE significantly increased the rate of STEM programs in secondary schools throughout the United States. The CTE programs supported "a deeper understanding of STEM career pathways to facilitate student transitions into these areas, build interest in STEM and STEM-related careers by making math and science content more relevant and tangible to students through integration" (Cole, et al., 2013, p. 88). In a survey conducted by Massachusetts Institute of Technology (MIT), students enrolled in newly created CTE programs indicated a willingness and curiosity towards STEM career paths and professions (University of Massachusetts Donahue Institute, 2011). Cole, et al. (2013) further stated:

> Through definitive (career and technical) programs, students can explore and then enter into a career pathway with knowledge and skills that theoretically will provide a better preparatory foundation between secondary and postsecondary education and into a high-skill, high-wage, high-demand job opportunity. (p. 89)

State of Pre-Engineering Education

Brophy, Klein, Portsmore and Rogers (2008) stated, "Engineering as a profession faces the challenge of making the use of technology ubiquitous and transparent in society, while at the same time raising young learners' interests and understanding of how technology works" (p. 1). Organizations, such as the American Society for Engineering Education (ASEE) focused on the state of pre-engineering through the concept of the "social good of engineering as a discipline" (Douglas, Iversen, & Kalyandurg, 2004, p. 4). Despite some level of focus on pre-engineering, Duderstadt (2005) cited numerous studies (Augustine, 2005; Clough, 2004; Duderstadt, 2005; Vest, 2003), which concluded, "Stagnant federal investments in basic engineering research, key to technical innovation, are no longer adequate to meet the challenge of an increasingly competitive global economy" (2005, p. 4). Duderstadt's (2005) stance regarding engineering practice, research, and education reform highlighted the need to expand pre-engineering opportunities for students.

Several engineering programs existed to support students at the elementary and secondary levels. Among these programs, Engineering is Elementary (EiE), funded by the NSF, integrated reading, science, and engineering into the elementary levels. Cunningham, Lachapelle, and Lindgren-Streicher (2005) stated research studies showed, "Children who use EiE make statistically significant gains on their understanding of engineering and technology concepts, when their post-tests are compared to pre-tests" (p. 377). LEGO Engineering, initiated through the Tufts Center for Engineering Educational Outreach, worked with the LEGO organization with a focus on the Mindstorm toy line. Tufts' research addressed the learning of teachers and the impact of teachers on student learning in engineering (Hynes, 2008; Rogers & Portsmore, 2004). The work of Cejka (2005) indicated several different approaches to teaching engineering, including the use of Mindstorm tools, as well as a focus on content specialization of teachers. Secondary engineering programs also included the Infinity Project, conceived in 1999 at Southern Methodist University. This project, in partnership with Texas Instruments, the U.S. Department of Education, the NSF, and the Texas Instruments Foundation, gained additional support through the Institute for Engineering Education. The purpose of the Infinity Project was to teach students how to design technology and highlighted STEM philosophy, which "in today's digital world, we believe students should be exposed to fundamental elements of technology so they will become competent, functioning, well-rounded citizens of the information age" (Infinity Project, 2007, para.1).

Additional programs included the Vanderbilt Instruction in Biomedical Engineering for Secondary Science, created in 1999, which established units of instruction to support the learning of students in engineering, physics, anatomy, and physiology. The program received support through the NSF's Vanderbilt-Northwestern-Texas-Harvard/MIT Engineering Research Center. The National Research Council, as a leader in addressing the National Science Education Standards, cited a program, Vanderbilt Instruction in Biomedical Engineering for Secondary Science, known as VIBES (Vanderbilt Instruction in Biomedical Engineering for Secondary Science [VIBES], 2008). Research findings suggested VIBES units were successful in multiple educational settings (Klein & Geist, 2006).

Introduction of PLTW Engineering

Among several engineering programs designed for elementary and secondary education students, PLTW was designed in New York by Blais, in 1997, with a mission to “Inspire students and address the shortage of engineering students at the college level” (Bertram, 2014, p. 52). Bertram (2014) also acknowledged the Liebich Family, the Kern Family Foundation, as well as numerous organizations with affiliations in science, technology, engineering, and mathematics (STEM), who supported PLTW in its infancy. PLTW established itself a 501 (c) (3) non-profit organization as “the only STEM organization endorsed by the Aerospace Industries Association” (Bertram, 2014, p. 52). PLTW had three types of engineering programs to address the STEM learning needs of students in grades K-12: Launch for elementary, Gateway to Technology (GTT) for middle level, and Engineering for high school. As of 2013, PLTW was considered “the nation’s leading provider of rigorous and innovative STEM education curricular programs used in schools . . . with more than 4,700 participating schools and impacts 500,000 students in all 50 states, including the District of Columbia” (Bertram, 2013, para. 2).

Purpose of PLTW Engineering

Bertram (2014) reiterated a quote heard often in curriculum development, especially within STEM-related subject areas, “In America, we teach subjects in isolation and tend to teach a mile wide and an inch deep” (p. 53). PLTW proposed an alternative to the isolation of STEM-related engineering curriculum which was, according to Kimmel et al. (2007), “Exposing K-12 students to engineering at an early age is key to creating a successful educational pipeline that will eventually lead to a higher education institution”

(p. 1). McMullin and Reeve (2014) described the purpose of PLTW as, “one of the purposes of PLTW is to provide a complete curriculum with a scope and sequence for students to follow in secondary pre-engineering” (as cited in McMullin & Reeve, 2014, p. 3). In 2009, members of the National Academy of Engineering noted the United States “implemented secondary pre-engineering programs in over 4,000 schools in 50 states” (p. 2). In the study, McMullin and Reeve cited over 30 pre-engineering programs used in K-12 education, including PLTW. PLTW was identified as one of the largest pre-engineering programs in North America (2014, p. 3).

PLTW, as described in their mission statement, “exists to prepare students for the global economy through its world-class curriculum, high-quality professional development, and an engaged network of educators, students, universities, and professionals” (PLTW, 2014, para. 3). Numerous public, private, and charter schools throughout the nation implemented PLTW to fulfill the needs of students for pre-engineering curriculum at the K-12 level, as identified by the National Academy of Engineering and the National Research Council. Even though no national engineering standards adopted by national engineering organizations existed, PLTW created curriculum, activities, and teacher professional development opportunities to address the perceived lack of quality of pre-engineering curriculum in the United States.

The Development of Standards in Pre-Engineering Education

One consistent concept, specific to engineering educational programming, and in general, curriculum research, was the reference to a set of standards for a subject area where the standards indicated what to teach. Many high schools with STEM types of curriculum programs adopted standards as set forth by the organization which created the engineering curriculum. Yet the National Research Council (2010) stated there were no national engineering standards established at the K-12 level; therefore, curriculum writers and curriculum providers responded to this declaration with a continued push to develop additional materials, themes and processes to support the teaching of engineering in the K-12 format. Despite not formally possessing standards in the field of engineering, Grayson (1980) indicated the Society for the Promotion of Engineering Education (SPEE) worked on creating standards specifically for engineering — in 1894, the same year that SPEE was founded. In the 120 years previous to this writing, pre-engineering curriculum at the secondary level lacked cohesion and organizational communication between engineers, engineering curriculum developers, post-secondary schools of engineering, and secondary schools.

Educational standards “have been found to drive innovation in education and can engender the implementation of assessments, teacher training, curriculum, and textbooks” (Carr, Bennett, & Strobel, 2012, p. 4). Brophy, et al. (2008) stated, “What gets taught in PK-12 classrooms is often a function of what gets emphasized in national and state content standards” (p.1). In engineering, Rutherford (2009) and organizations such as the National Academy of Engineering (2010) supported an integrated approach to standards development in K-12 engineering. Bybee (2009) suggested literacy standards for engineering as part of an overall STEM curriculum. Rutherford (2009) proposed integration of engineering into all areas of content and the implementation of a database of all developed engineering curriculum created nationwide; while the National Academy of Engineering recommended further funding for design and research. Despite the intentions of these researchers and organizations at the time, no further movement occurred regarding development of national engineering standards for implementation at the secondary level.

Carr, et al. (2012) researched each state within the United States and discovered 11 states had explicit state engineering standards in either K-12 or high school levels (p. 3). Fifteen states had explicit engineering standards using the International Technology and Engineering Educators Association (ITEEA) engineering standards — while four states had explicit engineering standards using PLTW standards as their own (p. 12). Six states mentioned engineering standards within the context of technology design, three states mentioned engineering standards within a component of technology, two states mentioned engineering components within their statewide curriculum and nine states had no established engineering standards at all (Carr, et al., 2012). Further, when engineering offerings were analyzed to determine where engineering content could be found within a variety of curriculums, the subject of engineering or concepts of engineering could not be found anywhere within any curriculum of 12 then-current states in the U.S. (Carr, et al., 2012). As the Committee on Standards for K-12 Engineering Education through the National Research Council stated, “It is commonly understood that effective standards must be coherently reflected in assessments, curricula, instructional practices, and teacher professional development” (National Research Council, 2010, p. 30). If engineering standards, assessments, curriculum resources, and professional development did not exist for teachers to teach engineering at the secondary level in roughly 20% of the nation’s states, the researcher discovered a general lack of engineering standards at the secondary level throughout the United States.

Although standards would be helpful specifically in the development of engineering curriculum, standards alone would not address the implementation of a STEM curriculum or separately, curriculums of STEM content. As Meyrick (2011) stated, "Merely writing engineering standards into curriculum will not necessarily improve or increase how it is being taught" (p. 4). Bybee (2009) further stated, "Developing standards may be easy; overcoming the barriers related to implementation presents the most difficult challenges and assuming a 'build them and they will come' posture would be a fatal mistake" (p. 15). There were two perspectives to the establishment and implementation of engineering standards: stand-alone engineering standards and the integration of engineering standards (Carr, et al., 2012). The National Academy of Engineering (NAE) standards committee "recommended infusion of engineering into existing standards... that is, integration of engineering with other subjects through concept mapping" (Carr, et al., 2012, p. 5). The NAE (2010) standards committee also suggested, "Standards for K-12 engineering education could help create an identity for engineering as a separate and important discipline in the overall curriculum on par with more established disciplines" (NAE, 2010, p. 19). Despite the inconsistency of the NAE standards committee, work for the integration of engineering standards and the creation of separate stand-alone engineering standards both displayed continued development.

Researchers such as Bybee (2009), Rutherford (2009), and the NAE (2010) standards committee suggested integration of engineering standards into an overall STEM curriculum. Bybee (2009) believed the evolution of literacy standards for STEM would weave engineering into an established STEM curriculum. Rutherford (2009) recommended taking engineering concepts and putting them into a database for nationwide access. Several studies suggested the integration of pre-engineering activities led to a greater interest of students in the concept of STEM (Brophy et al., 2008; Katehi et al., 2009; Schunn, 2009). The NAE (2010) standards committee addressed the integration of engineering into STEM by advocating for continued design, research and analysis of other engineering curriculum and programs established to teach engineering. Meyrick (2011) concluded, “The advantage of integrating STEM curriculum into all content areas is that it provides students with informal practice creatively solving problems long before the need to decide on a course of study for college” (p. 4). Meyrick (2011) further suggested, “Teaching . . . engineering in the integrated format also allows for other content areas to find natural places to integrate” (p. 2). The standards committee of the NAE supported the view of integration. Reasons for this support included the lack of experience of teachers to teach engineering, a general lack of quantity of interested teachers to teach engineering, the inconclusiveness of the implementation of engineering standards within the curriculum, and difficulty in creating a perceived new content area with new standards (Carr, et al., 2012). Researchers indicated difficulties existed in creating a standards-based, stand-alone engineering curriculum for secondary students to experience, instead opting for the approach of integration when referring to engineering curriculum and standards.

Despite researchers’ claims, a standards-based and stand-alone engineering curriculum remained difficult to create and implement. The NAE (2010) standards committee, stated, “Standards for K-12 engineering education could help create an identity for engineering as a separate and important discipline in the overall curriculum”

(p. 19). The state of Massachusetts used the stand-alone approach and established engineering standards statewide in 2001. These engineering standards addressed topics such as engineering and technology "from material properties and use of primitive tools through sophisticated design problems and knowledge of such evolving technologies as bioengineering and the thermal systems" (Carr, et al., 2012, p. 6). Carr, et al. (2012), also stated, "To date, Massachusetts . . . has led the field of standards design for K-12 engineering" and included one-fourth of a year of engineering and technology education through the science curriculum to teach every elementary school student components of engineering in Massachusetts (p. 41). Beyond Massachusetts, public schools in states such as Arkansas, Florida, Maryland, New Hampshire, and Texas required engineering coursework for their students (Meyers-Sharp, 2004).

Curriculum and Program Goals of PLTW Engineering

PLTW pre-engineering courses at the secondary level included two foundational courses, Introduction to Engineering (IED) and Principles of Engineering (POE), as well as other specialization courses, such as Digital Electronics (DE), Aerospace Engineering (AE), Biotechnical Engineering (BE), Civil Engineering and Architecture (CEA), and Computer Integrated Manufacturing (CIM). In addition, one capstone course provided students culminating engineering activities to prepare for the potential of post-secondary engineering interest titled Engineering Design and Development (EDD). The engineering curriculum of PLTW (2014) "emphasizes the nature of engineering and presents an engineering track . . . it teaches students and teachers how to engage in the field of engineering" (para. 3). The PLTW Engineering goals, as part of its curriculum philosophy, are included in Table 2.

Table 2

PLTW Engineering Curriculum Philosophy Goals

Curriculum Goal Number	Goal
1	Work as a contributing member of or lead a team.
2	Use appropriate written and/or visual mediums to communicate with a wide variety of audiences.
3	Participate in public speaking.
4	Listen to the needs and ideas of others.
5	Understand the potential impact their ideas and products may have on society.
6	Use problem solving methods and skills.
7	Manage time, resources and projects.
8	Participate in researching ideas and concepts including data collection and analysis.
9	Go beyond the classroom for answers.
10	Be better prepared for success in two- and four-year college programs.

Note: PLTW Engineering curriculum philosophy goals obtained via McMullin and Reeve, 2014, p. 3

PLTW students, as described by Bertram (2013), “create, design, build, collaborate, and solve problems while applying core concepts from math, and other academic areas. The hands-on, project-based engineering courses engage students on multiple levels, exposing them to areas of study that they typically do not pursue” (para. 5).

PLTW Engineering included nation-wide goals: “(1) Every student in America will have access to PLTW programs and (2) PLTW will increase the pipeline of students prepared for the global economy” (as cited in Bertram, 2013, para. 21). PLTW administrators measured these goals and noted, as of 2013, PLTW incorporated educational programs in 2,189 school districts across the nation (Bertram, 2013, para. 21) and enrolled more than 500,000 students in PLTW classes (para. 22). Bertram (2014) stated, “PLTW measures student knowledge, skills, and habits of mind through nationally administered End of Course (EOC) Assessments and project-based assessments. Data are collected and analyzed to evaluate program effectiveness and to provide direction to PLTW on how to improve” (p. 64).

The Current State of PLTW Literature

The literature review, specific to PLTW, limited itself to research conducted after 1997, due to the timeline of the creation of the program. McMullin and Reeve (2014) stated, “Research on PLTW is limited, and the research that has been conducted makes it clear that more research needs to be done, especially on a state-by-state basis, to discover and evaluate the elements of successful pre-engineering programs” (p. 5). Rethwisch (2014) further elaborated on the state of research, “There has been sparse research to-date that has rigorously measured the impact of PLTW on mathematics and science achievement” (p. 1). Research studies regarding PLTW limited the focus to students, teachers, principals, parents, and programs (Tai, 2012). Rethwisch (2014) also indicated, “There is a need for evaluations to be conducted on a large, state-wide level” (p. 3). The research of Daugherty, Zeng, Westrick, Custer, and Merrill (2007) highlighted the need for additional research specifically focused on improvements to engineering curriculum across all grade levels. Ontiveros and Alvarez (2012) summarized the state of research as, “A great effort is being placed on bringing exposure of engineering to K-12 students and creating awareness for all groups, including underrepresented students” (p. 3). Research which specifically highlighted PLTW curriculum generally addressed concepts, such as elementary and secondary student career activities, student interest in STEM career fields, and K-12 educational experiences in STEM-related areas (PLTW, 2016e).

PLTW Student Research

PLTW student studies mainly focused on academic achievement and student persistence. Tai (2012) indicated 16 of these research studies existed (p. 2). Amongst these findings, Kelley (2008) looked at problem-solving behaviors in students. Schenk, Rethwisch, Chapman, Laanan, Starobin, and Zhang (2011) completed a PLTW statewide study in Iowa focused on whether PLTW students performed better in science and mathematics due to their secondary school participation in PLTW. Tran and Nathan (2010) also studied the connection of PLTW to science and mathematics, with limited participation within the study. Bottoms and Uhn (2007) studied NAEP-referenced exam scores and the completion of four years of mathematics and determined PLTW students scored higher in comparison to career and technical education (CTE) students. Heywood and White (2011) found participation in PLTW Engineering led to positive outcomes on students’ reading and mathematics abilities, but PLTW Engineering did not have a positive outcome on student performance beyond those two areas. Other student studies included the self-efficacy in African-American students (Martin, 2011) and female engineering participation and achievement (Paslov, 2007). PLTW studies completed with students as the primary focus “reported positive impacts on students’ achievement as measured by standardized tests" (Tai, 2012, p. 3), and "PLTW students perform at or above the level of their non-participating peers" (Tai, 2012, p. 4). PLTW student research indicated students who participated in PLTW Engineering programs were also successful in the areas of mathematics and science (Tran & Nathan, 2010).

PLTW Teacher Research

Nathan, Atwood, Prevost, Phelps, and Tran (2011) concluded, "PLTW teachers increased their reporting of effective STEM integration over time, above and beyond pre-existing group differences and re-testing effects" (p. 15). Rogers (2007) indicated teachers who received professional development within the PLTW program indicated the perception of professional development quality was either valuable or very valuable. Daugherty (2009) inspected differences between professional development programs amongst several different engineering-specific programs. Tai (2012) indicated Daugherty's (2009) work was "among the most comprehensive programs focused on instructor training, background and follow-up support during the school year" (p. 4). Tolan (2008) concluded educators who participated in PLTW's professional development programming had a positive and applied experience. PLTW teacher research indicated when teachers participated in professional development sponsored through PLTW, the perception of the professional development received was of high quality (Daugherty, 2009).

PLTW Principal and Parent Research

Research studies regarding PLTW Engineering from a principal and parent perspective were also limited in scope. Rogers (2007) surveyed 37 building-level principals, which represented approximately two-thirds of Indiana building principals who implemented PLTW Engineering into the school districts at the time of Rogers' research (p. 52). These principals' perspectives, according to Rogers (2007), included, 1) students challenged and motivated by teachers and curriculum in the classroom, 2) the view of PLTW Engineering programming as a positive contribution to the school's educational curriculum and 3) the level of teacher motivation in PLTW programs was significant. Shields (2007) focused on the perception of building-level administrators regarding the implementation of PLTW Engineering in their school. Shields' (2007) research indicated cost was the biggest barrier to implementation at the building level and to the school district as a whole. Werner (2009) found parents' views of PLTW Engineering were generally positive. Overall, the perspective of the PLTW classroom from principals and parents indicated a positive student experience.

PLTW Professional Partnership Research

A limited amount of research existed regarding the effect PLTW and PLTW Engineering had on other professional, school-related partnerships. Bottoms and Anthony (2005) studied the partnership between High Schools that Work (HSTW) and PLTW. PLTW had goals which "complimented the major goals of HSTW by blending the essential content of traditional college-preparatory academic studies with challenging career/technical studies, thus increasing the percentages of students completing a quality core curriculum" (Bottoms & Anthony, 2005, p. 1). Bottoms and Uhn (2007) indicated schools that incorporated HSTW into the implementation of the PLTW curriculum had students who "achieved significantly higher scores in mathematics and science on the NAPE-referenced HSTW assessment than similar HSTW career/technical students" (p. 3).

The review of data suggested a limited view of annual evaluations completed by affiliates of PLTW. Individual PLTW evaluations were limited in scope and size (Northwest Evaluation Association, 2010). These studies primarily reviewed student achievement and the academic growth of students. True Outcomes (2005, 2006, 2007, 2008) completed four audits of PLTW Engineering for PLTW, Inc. (as cited in Northwest Evaluation Association, 2010). These reports included the number of students participating in PLTW courses and assessments, student performance on PLTW assessments, the existence of gaps in performance by gender or ethnicity, the proportion of students in PLTW classes meeting the PLTW expectation of concurrent enrollment in an appropriate mathematics or science class, representation of women and minorities in PLTW courses, and post-secondary plans and majors for students participating in PLTW courses (Northwest Evaluation Association, 2010).

McMullin and Reeve (2014) indicated "a need to do research in states that do not have large PLTW programs to see if PLTW programs in those states are successful and why" (p. 5). States like Indiana, Utah, Washington, Oklahoma, and Ohio have a limited number of PLTW programs and PLTW-certified schools (Bertram, 2013; McMullin & Reeve, 2014), therefore the lack of research identified the need to complete additional research to support states with fewer opportunities to implement PLTW curriculum

PLTW Programming Evaluation Instruments

Evaluated for overall effectiveness, a few state and regional organizations, as well as a limited number of technical reports, dissertations, and focused research papers, analyzed student gender, student race, and student motivation related to student achievement. Starobin, Schenk, Laanan, Retwisch, Kollasch, Chen, and Baul (2013) compiled data of students from the state of Iowa in 2009 and 2010 based on gender, race, and achievement in mathematics and science with an additional study in 2012, which examined the impact of student self-efficacy levels. Data collected through the Iowa Department of Education also determined PLTW's influence on student outcomes in standardized assessment testing. True Outcomes (2005, 2006, 2007, 2008) conducted four studies commissioned through PLTW (Northwest Evaluation Association, 2010). Data collected included student participation, student performance on PLTW examinations, gender and ethnicity performance, and post-secondary plans for those study participants. True Outcomes (2005, 2006, 2007, 2008) used reported data to ask questions regarding the performance of students enrolled in PLTW classes (students concurrently enrolled in a mathematics or science class and a PLTW Engineering class), as well as student post-secondary enrollment and gender representation. Rethwisch (2014) indicated a significant lack of research to date about PLTW Engineering and the connection to student achievement, in PLTW areas, as well as in mathematics and science courses at the student's educational institution. A limited number of studies existed which focused on the outcomes of PLTW, but Rethwisch (2014), stated, "A serious limitation of these studies is the lack of control for pre-existing ability" (p. 3).

Summary

Much of the literature available for review included technical reports or research completed by organizations affiliated with engineering and STEM education. Most of the literature review referenced the purpose of engineering as part of the STEM curriculum (Bertram, 2013, 2014; Brophy et al., 2008; Carr, et al., 2012; Hanover Research-District Administrative Practices, 2011). The literature review also highlighted engineering's connection to career and technical education (ACTE, 2009), the role of PLTW Engineering in the ongoing development of engineering curriculum at the secondary level (Bertram, 2013; Merrill, 2014), and the focus on curriculum goals and national goals as stated by the national organization of PLTW Engineering (Tai, 2012).

Further, the literature review highlighted several engineering programs at the secondary level designed to encourage and motivate students to pursue interests within the STEM curriculum, including PLTW and non-PLTW-based curriculums (Bertram, 2014; Cunningham, Lachapelle, & Lindgren-Streicher, 2005; Infinity Project, 2007; Klein & Geist, 2006). Chapter Three provides the methodology to the study, including research questions, study population, sample sizes, interview questions, and data from the researcher's teacher surveys, administrator interviews, and general student achievement information. Subsequent chapters present and discuss the research data, the analysis of data using the mixed-methods approach, and additional research to support the summary of findings from the study, and provide suggestions for further study and research.

Chapter Three: Methodology

Introduction

A mixed methods approach utilized by the researcher assessed the established curriculum goals of PLTW Engineering as implemented within the state of Missouri through the evaluation of Missouri PLTW EOC assessment data, the researcher's teacher survey responses of Missouri PLTW Engineering teachers, and the researcher's interviews of PLTW national and state program representatives. The researcher transcribed oral interviews of Missouri secondary PLTW Engineering teachers and of state and national PLTW program directors. Data analysis included coding of secondary PLTW teacher survey responses related to the researcher's null hypotheses and research questions. The researcher also analyzed Missouri PLTW EOC assessment data to respond to the study's research questions and null hypotheses.

Research Questions

There were nine research questions (RQ) and three null hypotheses as part of this study:

RQ1: How do Missouri PLTW Engineering teachers perceive curriculum implementation on identifying, formulating, and solving engineering problems?

RQ2: How do Missouri PLTW Engineering teachers perceive curriculum implementation on engineering experiments?

RQ3: How do Missouri PLTW Engineering teachers perceive curriculum implementation on techniques, skills, and tools for engineering practice?

RQ4: How do Missouri PLTW Engineering teachers perceive curriculum implementation on the impact of engineering solutions in a global, economic, environmental, and societal context?

RQ5: How do Missouri PLTW Engineering teachers perceive curriculum implementation on opportunities to demonstrate and understand professional responsibility?

RQ6: How do Missouri PLTW Engineering teachers perceive curriculum implementation on the understanding and demonstration of ethical responsibility?

RQ7: How do Missouri PLTW Engineering teachers perceive curriculum implementation to function on multidisciplinary teams in the classroom setting?

RQ8: How do Missouri PLTW Engineering teachers perceive curriculum implementation to communicate effectively in the classroom setting?

RQ9: How do Missouri PLTW Engineering teachers perceive curriculum implementation to recognize the need for and develop an ability to engage in lifelong learning?

Research Null Hypotheses

Null Hypothesis 1: There is no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering problems, in all PLTW coursework and students' scores on national PLTW End of Course assessments.

Null Hypothesis 2: There is no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering needs and students' scores on national PLTW End of Course assessments

Null Hypothesis 3: There is no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation of mathematics, science, and engineering knowledge and students' scores on national PLTW End of Course assessments.

Methodology

The researcher gathered and analyzed three distinct forms of data: Missouri secondary teacher survey information (Appendix B), Missouri PLTW Engineering achievement EOC data, and phone interview questions with regional, state, and national representatives of PLTW Engineering (Appendix B). The researcher designed a teacher survey instrument for this study with modifications to specific research questions; after consulting with the Institutional Research Board at Lindenwood University, the researcher earned approval for the adoption and implementation of the teacher survey. The researcher received electronic contact information for all Missouri PLTW secondary teachers through the office of the Director of PLTW for the state of Missouri. The researcher then sent the survey instrument to all Missouri high school teachers (N = 329) who taught some level of PLTW Engineering coursework, through the researcher's university email address. The researcher then gathered teacher interview responses and utilized an electronic format to store teacher responses. The researcher categorized teacher interview responses to find common themes and interest points. Further, the researcher used a lottery for small monetary compensation to promote the potential increase of participants who responded to and completed the electronic survey.

At the time of this study, 329 secondary teachers in the state of Missouri taught an engineering course at the high school level through use of nationally established PLTW

Engineering curriculum and standards (PLTW Missouri, 2016c). The researcher submitted the IRB application to the Lindenwood University Institutional Review Board (IRB) and received approval in April 2016. Teachers interested in providing information about PLTW Engineering experiences in Missouri and whom indicated an interest through the survey were also extended an invitation to contact the researcher to complete a phone interview.

The researcher requested PLTW EOC assessment data from the state of Missouri through the established electronic data request process to MODESE. The emails included the rationale for the request and specific types of data requested by the researcher, including Missouri student achievement EOC scores for the following classes: Introduction to Engineering Design (IED), Principles of Engineering (POE), Aerospace Engineering (AE), Civil Engineering and Architecture (CEA), Computer Integrated Manufacturing (CIM), Digital Electronics (DE), and Engineering Design and Development (EDD). After numerous inquiries, responses, and ongoing communication to and from MODESE, the researcher received the data requested for two school years, 2013-14 and 2014-15, from the Director of Technology and Engineering at MODESE. Data included national and state totals regarding number of students, number of schools, number of teachers, percentage of students in Missouri who earned proficiency or higher (as defined by a 6 or higher on a 9-point scale) on the state EOC examination by subject, state program enrollment by gender, and state program enrollment by grade.

Interview questions created for state and national leaders solicited a non-teacher perspective of PLTW Engineering and its curricular goals. The Institutional Research Board (IRB) of Lindenwood University also approved these interview questions. Several state or national representatives participated in phone interviews with the researcher to provide feedback on the state of engineering education and PLTW Engineering, both within the state of Missouri and nationally.

Study Population and Sample Selection

The population of participants for this study included PLTW Engineering high school teachers from the state of Missouri, as well as a limited number of state and national individuals of leadership from Missouri University of Science and Technology (Missouri S&T), located in Rolla, MO, and PLTW, Inc., located in Indianapolis, IN. The researcher utilized target population sampling selection for this study, because all Missouri high school PLTW Engineering teachers were provided the survey instrument and had multiple opportunities to respond to the researcher's electronic correspondence.

Experience as a PLTW Engineering teacher within the state of Missouri was critical to the sample selection of this study, as a program evaluation of PLTW Engineering in Missouri required teacher and leadership qualitative feedback, as well as quantifiable student assessment results. These pieces of data, in combination, provided a varied perspective on the national curriculum goals of PLTW Engineering. Due to the participant population limits of the study, the researcher determined the best course of mixed-methods study design would be triangulation. Fraenkel, Wallen, and Hyun (2012) stated, "The underlying rationale for the use of the triangulation design is the strengths of the two methods will complement each other and offset each method's respective weaknesses" (p. 561). The qualitative elements of the study, interviews and responses to open ended teacher and leadership survey questions, and the quantitative elements of the study, Missouri statewide and district level data, provided equal opportunities for influence as part of the researcher's study.

Study Participants

The researcher sent 329 teacher surveys to potential participants in August 2016 and received 61 Missouri PLTW Engineering teacher responses to the initial survey request to participate. Of these 61 surveys, 54 were fully completed, and seven were partially completed. Approximately 18% (n = 61) of the total electronic surveys (N = 329) sent to teachers received responses, allowing the mixed-methods study to exceed the definition of a qualitative study indicated by Fraenkel et al. (2012), who stated, "In qualitative studies, the number of participants in a sample is usually somewhere between 1 and 20" (p. 103). Of the 61 teachers who responded, four teachers (n = 4) indicated an interest to provide more information regarding PLTW Engineering in the state of Missouri and agreed to participate in a follow-up phone interview. Interviews were also conducted with selected national and state leaders associated with PLTW Engineering (n = 5). These individuals were chosen based upon previous professional involvement within PLTW and included both then-current and retired directors of PLTW Missouri, then-current and retired directors of technology and engineering education with MODESE, and the national public relations coordinator for PLTW, Inc.

The total number of participants for the teacher survey was 61. The researcher used all participant response data for each research question, and the survey included no demographic information of the respondents to ensure anonymity, due to the limited number of participants of this study and due to the potential for identification of the participants. The researcher asked participants for information about years of experience teaching PLTW Engineering and their classes taught within the PLTW Engineering program. Further, participants were asked questions related to the PLTW Engineering program to gain perspectives on specific curriculum elements, including problem identification, problem solutions, program design with realistic constraints, experimentation design, conducting of experiments, analysis and interpretation of data, knowledge application, use of tools and techniques, impact of solutions, professional and ethical responsibility, multidisciplinary team functions, ability to communicate effectively, knowledge of contemporary engineering issues, and lifelong learning within engineering. The teacher survey questions used PLTW's nationally established goals for engineering as direction for the study. Senior research associates at PLTW, Inc. (Appendix A) provided the national goals to the researcher for use in this study.

Table 3

Study Participant Characteristics of Secondary Missouri PLTW Engineering Teachers

Classes Taught	Responses	Pct.
Introduction to Engineering Design	46	76.67
Principles of Engineering	36	60
Aerospace Engineering	5	8.33
Civil Engineering and Architecture	15	25
Computer Integrated Manufacturing	5	8.33
Digital Electronics	14	23.33
Engineering Design and Development	22	36.67
Total (N)	143	

Note. Participants were allowed to respond to all courses which they then-currently taught, so total responses (n = 143) were greater than the total number of participants (n = 61)

Missouri PLTW teachers who responded to the researcher's survey provided information regarding the type of class or classes taught as part of the PLTW Engineering curriculum. Introductory classes, such as Introduction to Engineering (IED) and

Principles of Engineering (POE), had the greatest number of responses, primarily because these classes were first and second-year classes of a four-year curriculum (Table 3).

Education of Missouri PLTW Secondary Teachers

Participants (n = 61) of the study varied in educational backgrounds. All PLTW Engineering teachers had a bachelor's degree as required by MODESE for state educator certification purposes. However, many teachers of PLTW Engineering in Missouri secondary high schools had undergraduate degrees in something other than engineering. Teachers typically had backgrounds in mathematics or science. However, only approximately half of the respondents to the survey chose to answer this question (Table 4) for information on undergraduate majors of secondary Missouri PLTW Engineering teachers.

Table 4

Undergraduate Major of Secondary Missouri PLTW Engineering Teachers

Undergraduate Major of respondents	Responses	Pct. of responses
Mathematics	10	33.33
Biology	3	10
Chemistry	2	6.67
Physics	2	6.67
Computer Science	2	6.67
Engineering	11	36.67
Total (N)	30	

Note. Not all survey respondents chose to respond to this question (n = 30)

Experience of Missouri PLTW Secondary Teachers

The level of teaching experience was specific to being a teacher in a PLTW Engineering classroom in the state of Missouri. Survey responses did not reflect any prior years of experience as a classroom teacher in non-engineering fields (Table 5) for information regarding specific PLTW classroom experience of Missouri teachers.

Table 5

Years of Experience as a Secondary Missouri PLTW Engineering Teacher

Years of experience by respondent	Responses	Pct. of responses
0-2 years	12	20.34
3-5 years	21	35.59
6 or more years	26	44.07

Note. Not all survey respondents chose to respond to this question (n = 59)

Study Procedure

The study procedure involved the acquisition of email addresses of then-current secondary PLTW Engineering teachers in the state of Missouri, as of the fall 2016 semester. Each teacher received an individual email from the researcher at the beginning of the school year, sent through the researcher's university email address, with an invitation to participate in the study. The researcher used a collegiate institutional email address to limit any undue influence on the respondents of the survey, because the researcher at the time of the study was a high school principal in the state of Missouri.

The researcher received electronic survey responses from 61 of the potential participants, all of which were then-current PLTW Engineering teachers within the state of Missouri. During this survey distribution process, approximately 25 individuals responded after the first electronic communication from the researcher. The researcher sent a second electronic communication request approximately three weeks after the initial request. After the second request, 36 additional respondents replied, totaling 61 teacher respondents for this study. The researcher sent all potential respondents an electronic link to a website, where the teacher had access to an electronic survey via

Survey Monkey. The researcher gathered results electronically and stored information in a password-protected account. Upon closure of the teacher survey, the faculty chair of this study randomly selected four participants to receive a $20 gift card to Subway as participatory compensation for the study. Additionally, the researcher reviewed and coded study participant responses for relevance to the study research questions and the null hypotheses (Maxwell, 2013).

The researcher used state and school district assessment data regarding PLTW Engineering for this study. The researcher obtained state and national PLTW assessment data from MODESE through multiple data requests. Data collected supported the mixed-methods study, specifically the quantitative aspect of the study. The Director of Technology and Engineering Education provided state and national data from MODESE to support this study. MODESE granted the data request in November 2016 with non-identifiable data, specific to student identification. Data provided to the researcher identified individual high schools within the state of Missouri and the corresponding data associated with the institution. As part of this study, the research did not include identifiable information by student or school.

The study also included interviews conducted by the researcher with PLTW Missouri Engineering teachers, Missouri PLTW state leaders, and the national PLTW Senior Director of Media and Public Relations who volunteered to provide further perspective on engineering within the state of Missouri, as well as nationally. These participants volunteered through the initial teacher survey process. The researcher recruited state and national leaders for this study based upon individual professional involvement within the PLTW organization. Each interview began with the researcher providing information about the study to the participants. The researcher communicated the voluntary nature of the survey to the participants. All participants were age 18 or older. Additionally, all participants were certified teachers in the state of Missouri. The researcher electronically recorded all interviews. The researcher transcribed each interview with participants (teachers and leaders) into a Microsoft Word document. The researcher enabled password protection to protect each electronic document and excluded identifiable information from the transcribed documents. Table 6 represents the participants of interviews, including pseudonyms and role within the PLTW program.

Table 6

Participants and roles of PLTW Engineering Interviews

Name	Role Within Study
Dean	High school PLTW Engineering teacher.
Jane	National PLTW administrator.
Eugene	Missouri PLTW administrator.
Edmund	Former Missouri PLTW administrator/current PLTW teacher.
Lee	Missouri PLTW administrator.
Allen	Missouri PLTW administrator.
Jordan	High school PLTW Engineering teacher.
Michael	High school PLTW Engineering teacher.

Note. One interview participant did not provide information deemed usable by the researcher.

Survey and Interview Questions

The researcher created teacher survey questions as part of the mixed-methods study. These questions identified participant’s basic professional background information, such as classes taught, prior educational experience, and perception of curriculum as related to PLTW Inc.'s nationally established goals for PLTW Engineering (Appendix A). PLTW, Inc., had nationally stated engineering goals, as obtained via electronic correspondence (Cahill, personal communication, July 2, 2015) which included five specific outcomes with aligned national PLTW referenced goals, as referenced in Table 7.

Table 7

Specific Outcomes for National PLTW Curriculum Goals

Goal No.	Stated Goal
1	Demonstrate an ability to identify, formulate and solve engineering problems.
2	Demonstrate to design systems to meet desired needs, conduct experiments, use techniques and apply knowledge.
6	Understand the impact of engineering solutions.
7, 8	Demonstrate professional and ethical responsibility as well as function on multidisciplinary teams.
9, 11	Demonstrate an ability to communicate, gain knowledge and engage in life-long learning.

Note: Referenced from Appendix A.

Additionally, the researcher developed interview questions (Appendix B) for both state and national level PLTW representatives. Both sets of interview questions were similar, except for the use of the word 'state' exchanged with the word 'national.' Design of the interview questions was open-ended in nature and allowed participants the opportunity to discuss PLTW Engineering goals. Interview questions also discussed characteristics of students who took a PLTW Engineering class, quantifiable concepts, such as college graduation rates in engineering programs, the creation of national engineering standards, the leadership role of the PLTW Engineering teacher, and PLTW's recruitment techniques of underrepresented populations in engineering, such as African-Americans and women. The interviews conducted with Missouri PLTW teachers, Missouri state PLTW leaders, and national PLTW leaders were audio recorded using Voice Record Pro, an app available in the Apple App Store. The researcher used this app because of its ability to record interviews on a cellular device, convert the files into MP3 or MP4 files, and save to the cloud, as well as export and modify existing files. The researcher listened to each audio recording, transcribed the participants' responses to a Microsoft Word document, and converted the Word files into Microsoft Excel cells to categorize participant responses. The researcher categorized all teacher interviews, state leader interviews, and national leader interviews. The researcher classified categories of the participants' responses to determine relevance to the study's nine research questions.

Data Collection and Analysis Procedures

Study results utilized both quantitative, overall PLTW Engineering EOC state assessment scores, and parametric techniques, such as PPMC tests, to indicate if a relationship between variables existed. The researcher's intention was to use the mixed-methods approach because "by using multiple methods, researchers are better able to gather and analyze considerably more and different kinds of data than they would be able to using just one approach" (Fraenkel et al., 2012, p. 11). The researcher also utilized qualitative indicators through interviews with Missouri PLTW Engineering secondary teachers, Missouri PLTW state leaders, and national PLTW leaders.

The researcher collected data between August 2016 and January 2017. Teacher survey participants completed the survey instrument online via *Survey Monkey*, an online survey creation tool. The researcher coded each response of each respondent's survey and categorized the information as part of the study. The researcher utilized quantitative data to conduct multiple Pearson Product Moment Correlation (PPMC) tests. Further, the researcher audio recorded and transcribed interviews of each of the focus groups (i.e. Missouri PLTW teachers, state leaders, and national leaders). The researcher analyzed state teacher information with national teacher information and state academic achievement with national academic achievement to study statistical trends.

The intent of the researcher's analysis of the study was to ensure internal validity of the use of the data. Factors such as subject characteristics, mortality, location, and instrumentation were potential problems to this, as well as to any study (Fraenkel et al., 2012). The rationale of the researcher to utilize triangulation design was "that the strengths of the two methods will complement each other and offset each method's respective weaknesses" (Fraenkel et al., 2012, p. 561).

Summary

The researcher's mixed-methods approach to evaluate the curriculum goals of PLTW Engineering allowed for the consideration of multiple layers of information, both qualitatively and quantitatively. The researcher relied on teacher survey information, regional, state, and national interview responses and two years of Missouri and national PLTW Engineering data to consider the state of student and teacher performance regarding specific PLTW Engineering courses and overall, to the PLTW Engineering experience. The teacher survey measured the level of satisfaction regarding the development of curriculum, specific to the teachers' self-perception of the success of PLTW Engineering within the classroom and/or school. Teacher, state, and national interviews conducted by the researcher measured participants' self-perceptions regarding PLTW Engineering being goal and experience oriented, standards-based, inclusive to all individuals (especially those underrepresented in the engineering field), and the classroom experience driven by professional development opportunities. The researcher also utilized EOC examination data provided to the researcher by MODESE to evaluate the level of academic performance by Missouri high school engineering students during the 2013-2014 and 2014-2015 school years. The data provided enrollment information (students, schools and teachers), distribution of males and females, EOC achievement information (both overall and by district), achievement information by course taken, and number of students (by grade) enrolled in PLTW Engineering courses.

Chapter Four presents statistical evidence and analysis of data the researcher collected to evaluate the Missouri PLTW Engineering program and specific curricular goals. The primary goal of the researcher was to determine if Missouri high schools met the stated national curriculum goals of PLTW, Inc., through an evaluation of Missouri PLTW assessment data, PLTW teacher survey responses, and program representative interviews.

Chapter Four: Results

Overview

This study originated due to the researcher's professional experience as a high school principal in the state of Missouri. In 2007, the researcher's high school transitioned from an industrial arts curriculum to the PLTW Engineering curriculum. The decision to transition was due to district leadership's perspective about the inadequacy of the district's industrial arts curriculum, the lack of qualified candidates with appropriate certification in industrial arts, and the inability to prepare high school students with specific technical skills which could lead to better paying employment opportunities after high school graduation. The decision to implement PLTW Engineering received the full support of the researcher's school district Board of Education, but the adoption of the program was not initially popular due to the community's prior experiences with the curriculum and with the teacher of the curriculum. The researcher believed the PLTW Engineering program could benefit the students of the school in more advanced technical capabilities and create increased opportunities for students to use technical skills and computer software in a practical and applicable manner to prepare students for experiences beyond high school.

The purpose of the researcher's study was to conduct a program evaluation of PLTW Engineering curriculum goals in the state of Missouri through a mixed methods approach. Qualitative analysis included teacher interviews, state PLTW administrator interviews, and a national PLTW director interview. Quantitative data collection included secondary data, specifically Missouri school district EOC achievement data regarding PLTW Engineering, national PLTW Engineering achievement data, and data collected from researcher-developed Missouri PLTW high school teacher survey.

Qualitative Data

At the end of the Missouri PLTW high school teacher survey, the researcher provided study participants an interview opportunity for an expanded response to the survey. The researcher received four teacher responses (out of 61 study participants) to participate in the expanded interview format. In addition, the researcher interviewed five individuals in various present or previous administrative roles within the PLTW program. These five individuals maintained involvement with PLTW Engineering either in Missouri or nationally. The researcher transcribed, analyzed, and categorized interview responses into study headings for organization and identification of consistent themes.

Quantitative Data

The researcher created an instrument which aligned with nationally stated goals of PLTW Engineering (Cahill, personal communication, July 2, 2015) (Appendix A). The instrument's design provided the researcher insight to the experiences of PLTW Missouri teachers and focused on problem solving skills, such as identification, formulation and solution of engineering problems and experiments, the interpretation and application of data, and the development of a skill set. The instrument also measured concepts, such as professional and ethical responsibility, teamwork, communication skills, and the emphasis on continued, lifelong learning.

The researcher obtained national and state (Missouri) data for PLTW student assessments through a data request to MODESE. Data obtained from MODESE was from the 2013-2014 and 2014-2015 school years. Information from the data request included enrollment statistics (by student, school, and teacher), demographic data by gender of students, and achievement data (EOC) by course.

Involvement of Students in Missouri Technology Student Associations (TSA's)

Although Missouri public schools did not require a Technology Student Association (TSA), the student program provided students in PLTW programs opportunities to become involved in the school. MODESE Division of Career Education provided sponsorship of TSAs in 52 Missouri school districts and provided approximately 3,500 Missouri students within these districts to learn more about technology, leadership, and problem solving skills (MODESE, n.d.a).

Table 8

Existence of Technology Student Association Chapters in Missouri

Active Technology Student Association	# of survey responses	Response percentage
Yes	32	54.24
No	27	45.76
Total	59	100

Note. Not all survey respondents chose to respond to this question (n = 59).

PLTW Teacher and Student Populations (National and Missouri)

The PLTW program showed increased levels of population in terms of the number of teachers who received professional development to become certified to implement the program, as well as the total number of students enrolled in the PLTW Engineering program from 2013 through 2015. This increased level of growth existed both at the national level and in the state of Missouri (Table 9).

Table 9

Number of PLTW Engineering teachers and students (national and state of Missouri) from 2013-2014 and 2014-2015 school years

Category	2013-2014	2014-2015	Percentage Growth
Teachers (nationally)	6,275	7,673	+22.2%
Teachers (Missouri)	309	425	+37.5%
Students (nationally)	211,499	241,037	+13.9%
Students (Missouri)	12,233	13,916	+13.7%

Based upon previous information, there was not a significant growth of TSA organizations in the state of Missouri. Despite this lack of growth, PLTW educational programming grew both nationally and in Missouri from 2013 to 2015 by over 115 teachers, and students enrolled within the program grew by over 1,700 students.

Research question one. ‘How do Missouri PLTW Engineering teachers perceive curriculum implementation on identifying, formulating, and solving engineering problems?’ Leadership interview questions four and nine provided participant feedback regarding students’ abilities to solve engineering problems within the PLTW Engineering classroom. The qualitative data addressed the identification, formulation, and solution to engineering problems in two ways: 1) through application of STEM curriculum concepts to solve engineering problems and 2) through the exposure to engineering curriculum to solve engineering problems. The researcher identified consistent themes suggesting PLTW Engineering teachers perceived PLTW Engineering students’ levels of preparation in problem identification and problem solving in engineering concepts was better than peers who lacked access to any PLTW Engineering classes. During the leadership interviews, adults associated with PLTW Engineering indicated students enrolled in PLTW Engineering classes possessed greater problem solving abilities in STEM-related concepts when compared to other students who did not have PLTW classroom experience.

RQ1 theme one: Application of problem solving concepts to solve engineering problems. The identification of five main areas by the researcher from study participant interviews suggested application of mathematics and science concepts by students as important indicators to student success. These areas of importance to student success included: 1) student level of preparation, 2) strong foundational concept knowledge, 3) ability to develop soft skills — such as communication skills and teamwork skills, 4) classroom engagement of STEM concepts, and 5) the concept of failing forward. These concepts helped make students' PLTW Engineering experiences more successful and ultimately, from the perspective of the PLTW Engineering teachers, led to greater pursuits of STEM-related college majors by PLTW Engineering students after high school.

Level of preparation. Summarizing survey information of adults associated with PLTW Engineering, all interviewed adults either specifically mentioned or eluded to the level of preparation of students to be able to solve engineering problems successfully. Students who participated in PLTW Engineering required concurrent enrollment in a mathematics class and a science class during the school experience as a stipulation of organizational agreement with PLTW, Inc. This concurrent enrollment provided more rigorous and greater levels of preparation than provided for students who did not take PLTW Engineering classes. Additionally, all interviewed for this study indicated, either directly or indirectly, students who participated in PLTW Engineering were more successful because of the experiences with learning the problem solving process in

PLTW classes. Prior to interview analysis, the researcher assigned pseudonyms for participants' names to report the results and to maintain the participants' anonymity as part of the study.

Dean, an interview participant, described students' levels of preparation and stated about students, 'They get exposure to something that they have never seen before.' He also stated, from a classroom student's perspective:

> The math and science is well beyond what you taught us, but the concepts that you taught us, if we paid attention, is basically what the (college) professors are starting with — you know, the professors go well beyond what we touched, but it gives them a level of comfort knowing that they have something going on and they're not completely drowning in the material.

Another interviewee, Jane, described perspectives frequently heard from students:

> They will say that they feel much better prepared than their peers that they sat next to in Engineering classes in college. First year engineering is a weed out year in many schools, but they flew right through it feeling it was exactly what they experienced in their PLTW Engineering program in high school. I think the reason for that is they have a strong foundational knowledge already.

Eugene, a person interviewed for this study, indicated:

> So I think that the success of students . . . what I've found is that students who come with a PLTW background are far ahead of their peers who haven't, even with students who have 4.0s and 36s on their ACT's . . . they understand the process of problem solving.

Marcus, a teacher participant, concluded:

'Students who participate in PLTW Engineering practice skills that give them an advantage in the work force . . . and make them a valuable STEM employer.'

Strong foundational concept knowledge. Study participants identified the need for students to have strong foundational concept knowledge to best understand engineering problems and formulate solutions to these problems. Some study participants referred to the opinion of individuals who were involved in teaching PLTW classes and whether they could tell a student had taken a PLTW course. All interviewed participants suggested mathematics and science conceptual understanding made success in PLTW Engineering classes more likely. Study participants indicated a general interest of students in mathematics and science enrolled in PLTW Engineering and suggested PLTW Engineering students had the necessary background to understand the mathematics and science involved in the class. Students could focus more on the application of the subject material and used an engineering journal to better support the growth of one's conceptual knowledge. Students also used the journal to document the growth of one's thinking process.

Several study participants referenced students' academic backgrounds in mathematics and science and one's ability to connect the subjects to achieve greater success in PLTW Engineering classes. For example, Edmund (who previously served as a teacher and administrator) stated:

> They have the background to get through the courses that most students just cannot handle. You have to have the background. If you are not ready for the math, the trigonometry and the functions you are going to have to do in college, you just cannot survive. These students are prepared. I have seen that myself.

Possessing strong, foundational concept knowledge of engineering made PLTW Engineering more appealable to high school students, according to some study participants. As Eugene stated:

> Students who have gone through the program and have decided to be in a STEM-related field, whether it was science, engineering or math, they have actually made intelligent decisions because the curriculum is designed in such a way that the students from the 1st course to the last course are very immersed into being helped to understand what engineering is all about and what STEM-related fields are all about.

Ability to develop soft skills, including communication and teamwork skills. Some study participants indicated the need for students to learn soft skills and have opportunities to work as a team while practicing these skills. Edmund stated:

> Students need these things (soft skills) after graduation all the way through school and into the world of work. I think those are the things that students get, the ability to think for oneself rather than depend on the teacher to stand at the blackboard and give them all of the answers.

Others within the study supported soft skills development and attainment as it related to solving engineering problems. Lee stated:

> The biggest attribute of PLTW is not necessarily in preparing them to be an engineer. The biggest attribute is how the experiences through PLTW are how those experiences are presented in the classroom. Really, it is soft skills development. Teamwork, multiple solutions, failing forward, continuous improvement. Those things are not necessarily tied to just becoming a great

> engineer. It is tied to simply becoming a more competitive employee in no matter what job that they do.

Several study participants referenced what teamwork looks like in PLTW classes. Edmund stated, ‘In PLTW classes, if you set a team of 3-4 students, every student has a job and they learn very quickly that if I do not do my job, the others are not going to get their job done.’

Lee reiterated Edmund’s stance on soft skills development and referenced what employers want most out of an employee:

> If you can walk out of your experiences with skill development in those four areas (teamwork, multiple solutions, failing forward and continuous improvement), you’re going to make yourself way more competitive than the person who doesn’t . . . employers want soft skills development and what’s intriguing them to PLTW is how the information is delivered through a project, problem-based approach.

Classroom engagement of STEM concepts. A concept described in the review of the literature regarding engineering curriculum and standards included classroom engagement of content. Evidence existed for engagement of STEM-related concepts in PLTW Engineering classes, according to all interviewed (Bybee, 2009; Carr, Bennett, & Strobel, 2012; NAE, 2010; Rutherford, 2009). Most study participants had insight into academic core concepts of mathematics and science in PLTW Engineering and the benefit of classroom engagement on students’ learning. For example, Dean stated, ‘Students are actually doing something with the math and science versus, we have always had kids that are good at math and science, but they could not do engineering — now they have a basis for doing that.”’ Dean also stated the role of teachers in PLTW

Engineering was different from other classrooms. Discussing cross discipline approaches, he said,

> We're starting to cross the discipline so math isn't a silo, science isn't a silo, tech isn't a silo . . . our class gives reason as to why they are learning what they are learning and how it can be applied somewhere.

Jane described the 'engineering mindset' and stated about students, 'They've learned how to grow that engineering mindset so they are ready for that higher level engineering content.' Another study participant, Allen, mentioned high engagement levels in PLTW Engineering classes made it 'exciting to learn, because it excited them (students) in meaningful and worthy activities.'

Failing forward. A few study participants addressed the concept of 'failing forward.' This concept focused on students not being afraid to make a mistake and fail at solving a problem (such as an engineering problem). As described by Allen, students used engineering logbooks to develop ideas. Sometimes, these ideas would not work but the failures created the opportunity for students in PLTW Engineering classes to learn from individual mistakes and to improve because of 'failing forward.' Allen further stated:

> The design of PLTW . . . failing forward is one of their main concepts. We never tell kids that at school . . . you know; you always want to be perfect. In the engineering program, kids have to keep engineering logs where they have to write, they journal if you will . . . they draw their diagrams, they synchronize, they plan, they experiment . . . if it does not work, they try it again and learn about failure as learning.

Lee verified Allen's stance on 'failing forward', understanding the PLTW Engineering program's global goals and stated,

> There are a lot of kids who are really great at school, but when they fail, they don't handle it well. Failing forward . . . what does that look like? Those are some of the mechanisms that students gain, that they will take with them to whatever their passions and jobs take them to, which will make them an exceptional employee.

These views corresponded to the teacher survey for the item, 'What is your perception of the status of PLTW curriculum for students to identify engineering problems, in all PLTW coursework?' This item scored a mean Likert rating of 3.50 (on a scale of one, 'very dissatisfied,' to four, 'very satisfied') (Table 10). Additionally, information in Table 10 included teachers' perspectives of students' abilities to formulate and solve engineering problems — important parts of the problem solving process.

Table 10

Perceptions of Identifying Engineering Problems – Engineering Curriculum Survey

Engineering Curriculum Survey Item – Identify, Formulate, and Solve Problems	Mean Score
Status of PLTW curriculum for students to identify engineering problems	3.5
Status of PLTW curriculum for students to formulate engineering problems	3.4
Status of PLTW curriculum for students to solve engineering problems	3.5

In general, PLTW teachers believed the PLTW Engineering curriculum provided students opportunities to identify engineering problems, and the mean score, 3.5, indicated a level of satisfaction between 'satisfied' and 'very satisfied' (Table 10). Teachers also believed in the success of the PLTW curriculum to formulate problems in the PLTW classroom through the mean score of 3.4 on a Likert scale. Finally, teachers believed PLTW students succeeded in the ability to solve engineering problems as presented by the PLTW curriculum, as indicated by a mean score of 3.5 on a 4.0 scale. Among all teacher survey participants, zero participants indicated perception of identifying, formulating, or solving engineering problems as part of the PLTW Engineering curriculum as being ‘very dissatisfied.’

RQ1 theme two: Exposure to engineering curriculum to solve engineering problems. Interview participants’ perceptions to the exposure of curriculum to PLTW Engineering students suggested one major theme: positive student interest in the subject area. As part of this theme, concepts such as academic resiliency, owning their learning and college and career readiness emerged from the interview participants’ responses. Each of these concepts related to how exposure to engineering curriculum supported students’ interests in identifying, formulating, and solving engineering problems.

Academic resiliency. According to study participants, PLTW students generally possessed strong academic skills, especially in the areas of mathematics and science. However, even students with strong academic skills did not always possess exposure to the PLTW Engineering curriculum. Academic resiliency identified as directly or indirectly related by most study participants as a necessary skill to identify, formulate, and solve engineering problems. Jane stated the following about students, generalized views of PLTW curriculum and application to the first year of college experience, ‘They’re (students) ready for that higher level engineering content and in some cases, students say this is exactly what I learned in PLTW in high school — and I’m kind of bored.’ Jane also stated, ‘I think this also shows that they are more likely to get through that 'weed out' year that most universities put their freshman engineering students through.'

Edmund referenced college retention rates as being significantly higher for PLTW students who began the freshman year as a STEM major and stated, 'The dropout rate for PLTW students in college is far below non-PLTW students. They just don't drop out.'

Owning student learning. A common theme among study participants was the need for students to be responsible for concepts learned in class and how exposure to mathematics and science helped PLTW students understand the problem solving process. Regarding the process of 'owning their learning', Jane stated:

> They gain the experience of owning and leading their own learning and having access to real world problems that they have to solve . . . and putting those skills that we empower them to develop: critical thinking, problem solving, the communication . . . and putting those into practice.

Allen talked about students' experiences in the learning process and stated, 'Students have rich experiences in the PLTW curriculum. It is activity and project based, where the kids have to pursue learning.' Dean related the learning activities of students in PLTW to professional development, where he was responsible for his own learning. He stated, 'I'm very happy that this program has come along, because it has made a difference in kids' preparation for longer term projects.'

College and career readiness. PLTW required students to have concurrent enrollment in a mathematics class and a science class. A benefit of the agreement was students took upper levels of mathematics and science, which created a deeper exposure to the foundation of STEM knowledge. All participants interviewed mentioned PLTW

Engineering students were more likely to pursue STEM-related college majors. Jordan, a study participant, mentioned a study conducted by the Milwaukee School of Engineering (MSOE), which compared Advanced Placement (AP) and PLTW students. Jordan stated, 'PLTW students seem to be sticking with their major more than AP students.' Jane referenced a study completed by Indiana University-Purdue University Indianapolis (IUPUI) and stated 'PLTW participation was significantly linked to attrition into the 2nd year of college in engineering, especially for those who have taken three or more PLTW courses.' Jane also mentioned the significance of career education and the importance of PLTW in the role of education: 'They [students] experience a lot of careers and they experience a lot of career opportunities and that really helps broaden their understanding of what is available to them once they leave high school.' Lee referenced the types of experiences students obtained from taking a PLTW class and shared, 'Those are some of the mechanisms that students gain, that they will take with them to whatever their passions and jobs take them to, which will make them an exceptional employee.' Allen mentioned the level of career education PLTW embedded into the curriculum process and stated:

> Kids have a much richer background of real life. They are doing what business and industry clamor for and it is not just sit and get learning. As far as the process goes, they learn a lot about what specific careers are and if they want to go into them or not. Kids at career centers . . . they know that if they decide to go to college from a career center, they know why they are going. Most kids go to college because people tell them that they are supposed to. Everybody wants to be a doctor or lawyer . . . this is so much more than that!

Eugene spoke globally about experiences with PLTW students and the preparation for college and careers when he stated, 'I've always said, even if a student is not interested in doing engineering, if they were to take these courses, they would be so much better prepared, not only for college but also in life.' He followed up with, 'Many students tell me that the skills that they are learning, they find themselves using them in their daily lives at home. It was kind of cool, because they recognized the value of what they are learning.' Table 10 results summarized a positive level of satisfaction with the perception of how the PLTW Engineering curriculum addressed students' abilities to identify, formulate and solve engineering problems in the classroom.

Research question two. 'How do Missouri PLTW Engineering teachers perceive curriculum implementation on engineering experiments?' Leadership interview question three provided participant feedback regarding students' abilities to design experiments in the classroom setting as part of the PLTW Engineering curriculum. The qualitative data for Research Question two suggested teacher and leadership support for student-created experiments and highlighted student interest in the postsecondary pursuit of STEM-related college majors, with a specific interest in engineering as a career pathway.

RQ2 theme one: Postsecondary pursuit of STEM-related college majors. Teacher interview responses indicated the PLTW Engineering curriculum provided opportunities for students to design and conduct experiments, which many times supported students' career interests. Through leadership interview responses, all teacher and administrative interviews either directly or indirectly indicated the offering of a career pathway, specifically in engineering, which allowed students to pursue STEM-related college majors in areas where students lacked prior experience. The concept of a career pathway offering reinforced the importance of experiment design in PLTW Engineering classes. Consistent responses emerged during the interview process, which included career pathway opportunities and STEM awareness.

Career pathway opportunities. MODESE listed STEM as one of 16 career clusters available to guide students in career decision-making (MODESE Division of Career Education, n.d.). These clusters provided opportunities for students to make decisions about career paths, including careers in STEM-related fields. With STEM [including engineering] as an option, teachers like Dean indicated a perspective on opportunities for students to experience career pathways in STEM and engineering. ‘They [students] would have never done engineering if they had not taken a class with me…that is a great feeling.’ Jordan, another teacher, indicated similar thoughts and stated, ‘By having an entire pathway, students are given opportunities to focus on specific engineering fields.’ Jane further supported the teachers’ views and stated:

> In 2014, researchers at IUPUI School of Education did a study of 56,000 high school graduates from Indiana. Their study found that high school graduates who participated in PLTW were three times as likely to major in STEM careers and three to four times more likely to study engineering than those who did not study PLTW.

Lee supported the views of other interview respondents and stated, ‘PLTW made them [students] aware of STEM-related fields and maybe put a spin on STEM, maybe that this is what STEM is. I think that has increased STEM awareness.’ Allen summarized and stated, ‘The PLTW experience gets kids experiences they might not otherwise get. So I think they do pursue STEM-related majors more because of this (PLTW) experience.’

Teachers' perceptions of the status of PLTW curriculum for students to design and conduct experiments in the PLTW classroom exhibited some level of teacher satisfaction, with a Likert rating of 3.09 for the item 'Students to design experiments in all PLTW coursework' (Table 11).

Table 11

Perceptions of Design and Conduction of Engineering Problems – Engineering Curriculum Survey

Engineering Curriculum Survey Item – Design and Conduct Experiments	Mean Score
Status of PLTW curriculum for students to design experiments	3.1
Status of PLTW curriculum for students to conduct experiments	3.1

The mean scores for designing experiments and the ability to conduct engineering experiments (Table 11) were lower than the participants' views on identifying, formulating, and solving engineering problems (Table 10). The researcher's perspective revealed more difficulty for students to design and conduct engineering experiments because students did not have enough background knowledge in the engineering field to apply the skills learned in the PLTW classroom.

Research question three: 'How do Missouri PLTW Engineering teachers perceive curriculum implementation on techniques, skills, and tools for engineering practice?' Teacher interview question 13 provided information on PLTW's vision for the engineering program and adult responses highlighted the experiences of students using skills and tools from the PLTW curriculum to practice engineering techniques. The qualitative data for Research Question three suggested mixed results regarding the term 'engineering practice' and meaning when applied to student experience.

RQ3 theme one: Student experience. Regarding PLTW's vision for student experiences and practice, all nine participants interviewed mentioned 'engineering practice', which involved problem-solving skills. One interview participant, Dean, stated,

> They are trying to turn engineering into math and science. They've taken out a lot of engineering types of activities, where the kids are doing things, building things and experiencing things. . . They (PLTW) have turned it from — let's have fun with engineering and teach you some things about engineering stuff along the way to a hodgepodge of math, science and engineering.

However, Jane provided an alternative perspective and stated:

> Our programs continue to evolve as trends evolve and we continue to provide students with the knowledge and transferrable skills through the program so that they have all of the tools and resources that they need in order to continue to take advantage of career opportunities and really thrive in this rapidly technological world.

Jane also stated, 'We want students to develop and hone those problem solving skills, think critically, be creative, have students work with each other to be better communicators.'

Despite the mixed perspectives regarding curriculum implementation on techniques, skills, and tools for engineering practice, teachers' perceptions of the status of PLTW curriculum for students to use the techniques, skills, and tools for engineering practice in the PLTW classroom exhibited a positive level of teacher satisfaction. This question received a 3.35 Likert rating for the item ‘Students to use the techniques, skills, and tools for engineering practice’ (Table 12).

Table 12

Perceptions of Techniques, Skills, and Tools for Practice – Engineering Curriculum Survey

Engineering Curriculum Survey Item – Techniques, Skills, and Tools Score	Mean
Status of PLTW curriculum for students to use techniques, skills, and tools	3.35
Status of PLTW curriculum for students to apply STEM knowledge	3.53

The mean scores for the use and application of techniques, skills, and tools within engineering practices indicated Missouri PLTW teachers taught students how to incorporate engineering techniques, skills, and tools into the curriculum. Ninety-four percent of the interview participants indicated students used the techniques, skills, and modern engineering tools for engineering practice as part of the PLTW curriculum.

Research question four: ‘How do Missouri PLTW Engineering teachers perceive curriculum implementation on the impact of engineering solutions in a global, economic, environmental, and societal context?’ Leadership interview questions one and two addressed the problem solving process and gathering solutions within the context of the state of Missouri. The qualitative data for Research Question four suggested two different thought processes of interview participants: 1) PLTW Engineering was more about mathematics and science with little focus on engineering solutions and 2) PLTW Engineering was primarily about the technical problem solving process and providing students the opportunities to find solutions to problems. One area identified by most interview participants to address teachers’ perceptions of engineering solutions in multiple contexts was how the state and national PLTW programs had become more popular within school districts (as measured by increases of student enrollment). Generally, teachers perceived when enrollment increased in districts, more students possessed opportunities to gain understanding regarding engineering solutions within larger global contexts. Another area identified by interview participants included the opportunity for students to practice solving engineering problems throughout the learning processes practiced in the PLTW Engineering classroom.

RQ4 theme one: State and national program development and 'access for all.' The researcher asked interview participants about the goals of PLTW Engineering and if the state of Missouri succeeded in achieving these goals. All interview participants provided unique perspectives on the goals of PLTW Engineering and noted the state of Missouri had been successful in achieving the goals, as perceived by the interview respondent. Jordan's view of the goals of PLTW Engineering was 'to grow the field of engineering for all students interested in math, science and technology.' Edmund's perspective focused on personal economic factors, 'It's to better prepare students for college, the world of work and our global economy.' Lee's comment supported Edmund's perspective when 'the goal of Missouri PLTW is to create a new generation of project, problem-based individuals through the concept of access for all.' From a societal context, Allen's perspective was 'in a nutshell, it's to produce engineers.' Eugene complemented Allen's view and added, 'There are a couple of major goals: one is to stimulate and excite kids about STEM-related fields and how STEM really plays an important part in their lives no matter what field they choose to go.' Results from Research Question four indicated a modest level of perception regarding the status of understanding the impact of engineering solutions in a global, economic, environmental, and societal context. This question received a 3.2 Likert rating for the item 'Students to pursue broad education to understand the impact of engineering solutions within multiple contexts' (Table 13).

Table 13

Perceptions of the impact of Engineering Solutions – Engineering Curriculum Survey

Engineering Curriculum Survey Item – Impact of Engineering Solutions	Mean Score
Status of PLTW curriculum for students to understand impact of engineering solutions	3.2

While 91% of interview respondents identified with either 'very satisfied' or 'satisfied' regarding the status of education needed to understand the outcome of engineering solutions, 10% of the survey respondents replied with either being 'dissatisfied' or 'very dissatisfied.' One respondent indicated significant dissatisfaction with how the PLTW curriculum prepared students to understand the outcome of engineering solutions in a global, economic, environmental, and societal context. The researcher believed this lack of satisfaction was due to teachers' experiences with students' lack of experience in global, economic, environmental, and societal understanding and matters within the school setting.

Research question five: 'How do Missouri PLTW Engineering teachers perceive curriculum implementation on opportunities to demonstrate and understand professional responsibilities?' Teacher interview questions nine and 10 addressed the types of professional experiences students received while being part of PLTW Engineering. Additionally, the questions looked ahead to students' potential long-term goals of becoming interested in engineering opportunities and pursuing post-secondary STEM-related opportunities. The qualitative data for Research Question five suggested interview participants encouraged student concepts such as teamwork, empowerment, organizational skills, time management and critical thinking skills. Participants perceived technical skills acquired through PLTW Engineering addressed opportunities to demonstrate professional responsibilities of engineers within the workforce.

RQ5 theme one: Professional skills practiced in the PLTW classroom. The researcher asked interview participants' perspectives regarding the implementation of the curriculum provided students with regard to the opportunity to experience engineering professional responsibilities within the PLTW classroom setting. Participants described the types of students' experiences within the PLTW classroom and how opportunities afforded to students highlighted the professional set of skills expected as engineers. Jane described one of many experiences students received in the classroom setting and stated, 'They [the curriculum] give a lot of experiences working with their community and working with companies in their community and understanding how their learning connects to the broader world around them.' Jane also stated, 'In our curriculum, we give a lot of power of choice, in the ability for students and teachers to customize things and to meet the needs of their community and their students.' Edmund described student PLTW Engineering experiences and the relationship with engineering professional experiences and stated, 'The ability to use higher order thinking without even considering that's what they're doing…and working as part of a team . . . that's important.' Edmund further discussed how the PLTW curriculum provided opportunities for all to experience the life of an engineer and stated, 'PLTW has made a commitment to trying to diversify the curriculum enough to allow for everyone — better than a lot of curriculum that I've seen.' Lee highlighted the process of empowerment and stated, 'One of the priorities of

PLTW Engineering is to empower these groups to thinking that STEM could be something that they could actually have as a job.' Lee also stated, 'I've seen over my career with PLTW, just natural leadership coming out because the curriculum requires it to be taught.'

Results from Research Question five indicated a general satisfaction level of the curriculum to demonstrate an understanding of professional responsibility. The question received a Likert scale result of 3.2 for the item, 'Students demonstrate an understanding of professional responsibility' regarding the PLTW Engineering curriculum (Table 14).

Table 14

Perceptions to Demonstrate Understanding of Professional Responsibilities – Engineering Curriculum Survey

Engineering Curriculum Survey Item – Demonstrate professional responsibility	Mean Score
Status of PLTW curriculum for students to demonstrate professional responsibility	3.2
Status of PLTW curriculum to gain knowledge of contemporary engineering issues	3.2

While most of the teacher survey respondents indicated a level of being 'very satisfied' or 'satisfied', six survey respondents indicated a level of dissatisfaction with how the PLTW Engineering curriculum demonstrated professional responsibility within the curriculum. The researcher believed the level of dissatisfaction amongst teacher survey participants was due to the potential disconnect between the curriculum and how the professional responsibilities of engineers were viewed by teacher survey participants as significantly different than what the curriculum standards indicated to be taught.

Research question six: The sixth research question asked, 'How do Missouri PLTW Engineering teachers perceive curriculum implementation on the understanding and demonstration of ethical responsibility?' Teacher interview questions eight and 12 addressed teacher leadership experiences and professional development opportunities for teachers, of which the researcher interpreted the concepts of personal leadership development and professional growth development to be part of a PLTW Engineering teacher's professional responsibilities. The qualitative data for Research Question six suggested teachers' leadership skills and opportunities for professional development enveloped the roles as teacher and, indirectly, led to ethical skills practiced by teachers.

RQ6 theme one: Personal leadership development. The researcher asked interview participants' perspectives regarding gained leadership experiences from teaching PLTW Engineering. Participants described teacher leadership experiences obtained as a PLTW teacher and how the experiences provided benefits to leadership through the development of confidence, understanding of the applicability of the subject material, and how the responsibility of teaching provided many opportunities to the interview participants to practice concepts such as helping, doing, and being involved with outreach opportunities. Dean described the leadership experience opportunities gained through teaching PLTW Engineering, when the experiences 'gave me the confidence when I did things, understanding and knowing that what I'm doing is actually applicable because I don't have an engineering degree.' Mark, another interview participant, described the network of teachers in the PLTW Engineering program as a group which 'offers many opportunities to collaborate and grow as a teacher.' Jane described the teacher leadership experiences in the PLTW program and stated, 'It gives them [teachers] a leadership opportunity when PLTW teachers come together and lead one another and coach one another and help one another . . . often times, PLTW teachers will end up being teacher leaders in their own schools.' Edmund possessed a different perspective on leadership and indicated ‘leadership opportunities for the teacher are not necessarily in the classroom.’ Edmund mentioned student STEM activities at places such as Six Flags and Silver Dollar City as better opportunities for exhibited teacher leadership. Lee’s perspective about teacher leadership discussed specific teacher gains as ‘there are other ways to educate students . . . it’s not just presenting content and then having a mechanism to assess it.’ Eugene mentioned the value of learning and practice in the craft (education) and stated, ‘teachers have to teach their students to learn how to work in teams . . . they begin to develop those skills in leadership.’

Results from Research Question six indicated a general satisfaction level of the curriculum to demonstrate an understanding of ethical responsibility. This question received a Likert scale result of 3.0 for the item, ‘Students to demonstrate an understanding of ethical responsibility’ regarding the PLTW Engineering curriculum’ (Table 15).

Table 15

Perceptions to Demonstrate Understanding of Professional Responsibilities – Engineering Curriculum Survey

Engineering Curriculum Survey Item – Demonstrate ethical responsibility	Mean Score
Status of PLTW curriculum for students to demonstrate ethical responsibility	3.0

While many of the teacher survey respondents indicated a level of being ‘very satisfied’ or ‘satisfied’, ten respondents indicated being ‘dissatisfied’ and one respondent indicated a level of being ‘very dissatisfied.’ The researcher believed the level of dissatisfaction amongst teacher survey participants (representing 20% of the total number of teacher responses) was due to the researcher’s perception of PLTW, Inc.’s lack of ethical responsibility concepts built into the PLTW curriculum for students to experience and apply within the students' personal lives.

RQ6 theme two: Professional educator growth development. Interview participants of this study indicated a need for a professional educator growth development plan. The concepts learned from a quality professional educator growth plan and how the network of PLTW teachers supported both the teachers and the students of PLTW Engineering classrooms through the interview participants' perceptions of the quality of individuals within the PLTW Engineering classroom. Edmund provided perspective on the professional development opportunities offered by PLTW and how the concept of ethics was part of the professional development process. Edmund suggested reliance on the PLTW network and described the feedback as,

> You know the curriculum and the master teachers behind it are always there if you have a question . . . I've emailed these guys a thousand times over the last two to three years with questions like how do I solve this issue.

Edmund's comment suggested the willingness of other PLTW Engineering teachers and PLTW master teachers to consistently help others, which reflected Edmund's suggestion of the quality of the individuals involved in the PLTW Engineering program and the ethical practices of helping, providing direction, and putting others before self. Dean supported Edmund's perspective of the PLTW Engineering program and the supports of the program; 'They [PLTW teachers] do have supports, where people can grow and learn as they go.' Jordan's stated opinion of the PLTW professional development was 'PLTW offers the best teacher training with ongoing professional learning development through the learning management system (LMS, an online platform for PLTW students and

PLTW teachers to post grades and create a virtual classroom environment with others in the PLTW network).’ Jane described the environment of a PLTW Engineering classroom as a ‘different kind of instruction happening’ and further stated the teachers must have a ‘growth mindset and continue to grow even after professional development.’ Jane appeared to suggest the ongoing growth after professional development is just as important as the varied programs PLTW teachers participated in for professional growth and guidance. Although Jane’s comments did not suggest a practice of ethical behavior by PLTW Engineering teachers, the comments indirectly suggested the expectation of growth beyond the classroom as a necessity and the ‘different kind of instruction’ can include ethical practices of helping students and teachers, especially in the PLTW Engineering programs.

Research question seven: ‘How do Missouri PLTW Engineering teachers perceive curriculum implementation to function on multidisciplinary teams in the classroom setting?’ Leadership questions five and seven identified teacher perspectives regarding students’ and teachers’ experiences in the PLTW classroom setting with focus on the long-term student experiences (into students’ college engineering experiences) and the role of the teacher in the PLTW classroom. The qualitative data for Research Question seven suggested students who obtained PLTW Engineering experiences while in high school had less difficulty than college engineering peers who did not have PLTW Engineering experiences in high school. Additionally, teacher participant feedback indicated the role of the teacher in the PLTW classroom was important, beyond the dissemination of information. Teachers indicated students did best in a PLTW classroom where teachers and students were actively involved in multidisciplinary teams and were excited about the active participation in the PLTW Engineering classroom.

RQ7 theme one: Preparation for success — PLTW high school experiences with multidisciplinary teams. Interview participants noted the state of Missouri's only post-secondary institution with a focus on engineering, Missouri S&T located in Rolla, MO, was the Missouri location where more students went to study engineering than other places, either within the state or outside of the state. For example, Dean mentioned the following regarding the status of high school student preparation and college engineering graduation rates: 'I can't tell you whether or not if their graduation rates are better, but I do know the number of kids who come back and say they started at Rolla doing engineering and did not continue engineering has decreased.'

Jane mentioned a study conducted by Indiana University Purdue University Indianapolis (IUPUI), which suggested PLTW high school experiences were linked to greater attrition rates in the students' second year of engineering. Jane suggested, 'PLTW students have already learned how to apply their learning . . . they have learned how to grow that engineering mindset.' Edmund indicated PLTW students (from information he received from Missouri S&T) 'just don't drop out' and that the dropout rate of PLTW students at Missouri S&T 'was less than 5% . . . they just stay.' Lee indicated the data related to college engineering graduation rates related to PLTW Engineering participation was 'limited' but referenced Robert Tai and the White Paper research about national PLTW studies completed.

Allen mentioned the one piece of data acknowledged to him from others frequently in meetings was '35% of students who enroll at Missouri Science &

Technology are PLTW high school graduates.' Allen also discussed the application of content learned in PLTW classrooms among multidisciplinary teams and stated,

> They [PLTW] started at high school with engineering and then added computer science and biomedical and then said, that's not soon enough . . . so then middle school got Gateway started and then that wasn't enough . . . so then came elementary Launch.

Allen defended his thoughts on the development of the PLTW curriculum programming and stated, 'Historically, schools teach natural sciences [biology, chemistry, physics, earth science and physical sciences] but rarely, if ever, talk about what man does with it in nature and that is what engineering is . . . everything made has been engineered.' He further elaborated, 'engineering, simply put, is man's effort to make life more convenient and more comfortable . . . but we don't emphasize that . . . we have a stereotype about engineers being a "brainiac with a pocket protector."'

Eugene acknowledged Edmund and Lee's data and stated,

> At Missouri Science & Technology, they have about a 95% retention rate for PLTW students . . . and the national average is more in the 60s and low 70s . . . if they change majors, they are changing to a different engineering.

Edmund also referenced a study conducted by Missouri S&T, which he commissioned. Initial first year results showed college students with PLTW Engineering high school experiences were academically ahead of their peers, but by the end of their degree program, students' academic success in engineering leveled out. Eugene stated,

> What we think is the first 2 years are more like what they are doing in PLTW . . . and their junior and senior years, is more theoretical—those students who have always been theoretical kinds of students tend to catch up.

RQ7 theme two: Role of the teacher—active engagement and multidisciplinary teams. All interview respondents stated the role of the teacher in PLTW Engineering is important. Dean said the role was 'massively' important. Jordan said the role can 'make or break a program', while Jane said 'Teachers are really just guiding the student outcomes by fostering creativity and curiosity, rather than use lecture in that student dynamic that we typically see.' Edmund stated, 'If the teacher isn't on board with the program, then it's no better than any other class you have in a school.' Lee stated the role of the teacher was, 'The absolute number one.' Eugene also stated, 'it is absolutely the most important . . . they [teachers] are the key to the whole program.'

The interview participants followed up on the responses and discussed the role of active student and teacher engagement in the classroom setting as well as stated the importance of multidisciplinary teams. Dean noted, 'Kids aren't going to be as interested if the teacher isn't as interested and that's not going to flow as nicely for the students and they're not going to get much out of it.' Dean added, 'When they [kids] are excited, they're going to perform well.' Jordan provided a simpler assessment of the success of PLTW programs and stated, 'The curriculum is great . . . all you need is a good teacher and the students will flock to the program.' Jane described PLTW Engineering as creating a 'shift in the classroom and also said, 'When you go into a PLTW classroom, you'll see a lot of teachers facilitating students to build on their knowledge and skills and take ownership of their learning . . . students are actively engaged.' Jane also spoke about the role of teacher engagement in the PLTW classroom and highlighted the difference from the regular classroom environment, described as, 'You will see teachers doing a majority of the work . . . they are lecturing and students kind of wait for direction. They only respond directly to the teacher.'

Edmund described the experience an engaged teacher within the PLTW Engineering classroom can have and stated, 'It is crucial that the school finds a teacher that is interested in seeing both the program and his or her students succeed. If you don't have that teacher, then you just have a classroom full of stuff.' Edmund also described the potential consequences of the lack of engagement by a PLTW classroom teacher and stated, 'If the teacher knows nothing about it or doesn't want to, within three years, there are no students taking the courses.' Lee supported Edmund's potential consequences of not having a supportive PLTW classroom teacher and stated, 'You can take a great curriculum and have a teacher that isn't really very excited about the subject or is thinking about retirement or basically, doesn't want to change . . . the kids are going to see that.'

Eugene discussed the benefits to implementing a PLTW classroom and highlighted the active engagement as well and stated,

> It [PLTW Engineering] helps program solving and the whole process of working in teams. Teachers claim they have better students, but what's really happening is that they are better teachers, especially in that field of hands-on types of teaching and learning — the problem-based pedagogy. It is not the sit and get, like what many teachers are used to doing. Really, it is a round robin kind of thing, where students are doing a better job; teachers are more motivated and ready to do a

better job. I've often over the last few years when I was working with districts and I would constantly have administrators tell me they are either working on it or wish they could get their other subject area teachers to learn to teach the way PLTW is taught.

Results from Research Question seven indicated a high satisfaction level by teachers for students to demonstrate an ability to function on multidisciplinary teams. This question received a Likert scale result of 3.31 for the item, 'Students to demonstrate an ability to function on multidisciplinary teams' regarding the PLTW Engineering curriculum (Table 16).

Table 16

Perceptions to Demonstrate an Ability to Function on Multidisciplinary Teams – Engineering Curriculum Survey

Engineering Curriculum Survey Item – Multidisciplinary team function	Mean Score
Status of PLTW curriculum for students to demonstrate ethical responsibility	3.31

A clear majority of the teacher survey respondents (50 out of 55) indicated a level of being 'very satisfied' or 'satisfied' with students' abilities to function on multidisciplinary teams (91%). The researcher believed this result was due to curriculum construction and corresponding activities created for students to apply skills learned in the PLTW Engineering classroom setting within a team setting. The PLTW Engineering curriculum developed for teachers to implement in the classroom included opportunities for student engagement and an expectation of teamwork by participating students, facilitated by the PLTW Engineering teacher.

Research question eight: 'How do Missouri PLTW Engineering teachers perceive curriculum implementation to communicate effectively in the classroom setting?' Teacher interview question eight identified the process for creating engineering standards as part of PLTW and how teachers used the standards to work towards effectively communicating with their students, and specifically, to model the communication behaviors for the students of the PLTW Engineering classroom. The qualitative data for Research Question eight suggested interview participants felt somewhat disconnected with the ability to create and coordinate curriculum goals and activities to enhance students' learning opportunities in the classroom setting. Interview participants acknowledged PLTW, Inc., (the national affiliate) created the curriculum for all the PLTW Engineering classes and utilized the Common Core standards for mathematics and English Language Arts as well as the Next Generation Science Standards (NGSS) in developing the curriculum. Further, PLTW Engineering specifically used the International Technology and Engineering Educator's Association standards for technology literacy. All the participants recognized the influence PLTW, Inc., had regarding engineering standards and activities and discussed the quality of the product PLTW, Inc., implemented in the secondary setting. Teachers recognized a concise and standards-aligned curriculum provided students and teachers a clear and effective model for communicating to each other.

RQ8 theme one: Effective standards communication — teachers to students. All teacher participants acknowledged the use of national STEM standards to create a curriculum designed for implementation in the secondary classrooms. Jane stated, 'PLTW looks closely at the curriculum to make sure it aligns to those standards. The curriculum is also flexible enough for states to take their state standards into consideration and align to those as well.' Jane also recognized a driving force behind the development of the curriculum which no other teacher communicated and stated PLTW ‘has deep conversations with business leaders to figure out the business trends and where business trends are going, evaluating the current market and market research . . . figuring out where the biggest gaps are in industry to fill those gaps.’ Jane further identified how the curriculum assisted with communication when, ‘We take into consideration what is age appropriate and make sure that skills students are learning are foundational and align industry trends so that students are prepared for what is to come five to ten years down the road.’ In Missouri, Lee discussed student activities and said, ‘Activities that were created were project-based and national science standards helped guide the state.’ Eugene communicated,

> PLTW has professional curriculum writers on staff, but they recognized that curriculum . . . it is a living document with living programs and is always subject to change. They do not just pull things out of the air . . . they work with professionals in the field.

Dean was the one teacher who dissented with the rest of the respondents and stated, “They [PLTW] have gotten so big and so corporate that people who are involved now don’t really care for input.” Dean also stated about the lack of effective communication, ‘They [PLTW] change their timeline because nobody communicates anymore . . . it is kind of an ivory tower nowadays.’

RQ8 theme two: Effective standards communication — students to teachers. Jane recognized the importance of student perspective, specifically regarding the ability for students to demonstrate effective communication in the classroom setting and said, ‘PLTW starts with a high level problem statement they want to achieve and want students to be able to do, then work backwards to create the knowledge and skills students need to learn to solve that problem statement.' Jane eluded to PLTW, Inc.'s desire and ability to create a curriculum focused on students and how the curriculum standards drove all other concepts in the classroom, from the teaching style of the teacher to the shared teamwork activities of students to positively influence communication with each other as well as the PLTW instructor. Eugene summarized thoughts on teacher and student communicated, 'I think teaching PLTW has really improved a lot of teachers' communication skills by helping them learn how to communicate with students.'

Results from Research Question eight indicated a high satisfaction level by teachers for students to demonstrate an ability to communicate effectively in the PLTW classroom. This question received a Likert scale result of 3.37 for the item, 'Students to demonstrate an ability to communicate effectively' regarding the PLTW Engineering curriculum' (Table 17).

Table 17

Perceptions to Demonstrate Ability to Communicate Effectively – Engineering Curriculum Survey

Engineering Curriculum Survey Item – Effective communication	Mean Score
Status of PLTW curriculum for students to demonstrate ability to communicate	3.37

Almost all teacher survey respondents (52 out of 54) indicated a level of being 'very satisfied' or 'satisfied' with students' abilities to demonstrate an ability to communicate effectively in the PLTW classroom (96%). The researcher believed this positive response was due to student interest in the subject area, teacher interest in the subject area, common experiences of students while in the PLTW classroom and a generally positive consideration of the PLTW teacher by students within the classroom setting.

Research question nine: 'How do Missouri PLTW Engineering teachers perceive curriculum implementation to recognize the need for and develop an ability to engage in lifelong learning?' Teacher interview question 11 identified the perspective of teachers regarding students' lifelong learning abilities, especially in underrepresented engineering students, such as females and minorities. The qualitative data for Research Question nine suggested teacher interest in the implementation of PLTW Launch, an applied mathematics and science program geared towards elementary age students. Interview participants also provided input regarding reasons for the lack of interest, particularly in young girls and minority students. Teachers perceived female and minority students often opted out of mathematics and science at an early age due to lack of self-esteem in STEM-related content. Teachers also indicated activities created by PLTW needed to be generically neutral to take any type of racial or gender bias out of the purpose of the activity. Some individuals acknowledged the need for female and minority students to have access to engineers and other STEM-related professionals to better model participation in professional fields such as engineering. Teachers indicated students' abilities to engage in lifelong learning within the PLTW Engineering classroom would be most successful if students (especially female and minorities) felt supported by both teachers and peers.

RQ9 theme one: Lifelong learning through PLTW Launch and STEM experiences. Several respondents mentioned the potential ability of a school district to implement PLTW Launch (the elementary PLTW applied mathematics and science program) as helpful to support the lifelong learning of all students in the PLTW classroom. PLTW Launch was a program created by PLTW, Inc., which supported elementary age students in STEM education through a hands-on approach to science and mathematics education.

PLTW Launch: Some participants, including Jordan, felt students who had the opportunity to see the results of class activities could support lifelong learning. Jordan stated, ‘Showing the students the projects and the process helps recruit all students who like math and science.’ Jane suggested PLTW Launch supported lifelong learning of students and stated, ‘Students, particularly young girls and minority students, will often self-select out of math and science because they see other students who seemed to be better at it or are told there are other students who are better at it.’ Edmund also said PLTW Launch was important and concluded, ‘get them [students] started early, because we lose girls in math by the time that they reach 3rd grade and if we lose them, we never get them back.’ Jane further supported her PLTW Launch perspective when, ‘The reason PLTW started the Launch program was to get to those females and minority students to get to them earlier and excite them in the STEM subjects if they don’t already have that spark to ignite that spark.’ Edmund supported a positive tone directed towards students to encourage STEM education and said, ‘Engineering is great for you — yes, you can — you can do this” and “this is for everybody — come on, join us.’ Dean reiterated this positive message and clarified the perspective in support of underrepresented populations, such as females and minority students. Dean suggested at his school, ‘We have a Women Engineer Day, where we bring women engineers in and we bring in middle school girls especially — there’s a kind of sister type of thing going on.’ Dean also provided a potential female engineer's perspective when he stated, 'One of the things that I've heard out of my older female students . . . is that they didn't think they could be an engineer and be a mom and do the things that you normally see.'

Lifelong learning: Jane also discussed lifelong learning and engagement of students when the goal for students is 'to keep them engaged as they progress throughout their education and show all students can do this . . . it's fun to combat those stereotypes and messages that they may be hearing outside or even inside of school for that matter.' Edmund focused more on career education alignment for students when he stated, 'Maybe you'll like it [Launch], maybe you'll see this as a career.' Dean supported Edmund's view of career education through the platform of minority student enrollment, encouraging students to be part of the PLTW program. Dean also commented on minority students,

> Minorities have the same thing that girls do (enrollment and participation), they aren't represented much in class and they are much more class oriented in terms of they want to see someone like them if they don't have common people like them.

He further stated, "They [minorities] seem to shy away from things even more than girls in a classroom full of boys."

Hypotheses

In the analysis of the hypotheses statements as part of this study, the researcher utilized the results of the teacher survey administered through *Survey Monkey* along with results of PLTW achievements tests administered in every school district in the state of Missouri by specific class (equaling seven, in total). Within the null hypotheses, the researcher outlined the statistical instrument used to produce the measures of the study. Each null hypothesis addressed parts of the overall teacher survey, as survey questions focused on various details, such as solving engineering problems, solving engineering needs, and student STEM knowledge.

Null Hypothesis 1: There is no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering problems, in all PLTW coursework and students' scores on national PLTW End of Course assessments.

2013-2014 School Year

Table 18

PMCC: 2013-2014 PLTW Teacher Curriculum Perception and PLTW EOC Scores by Subject

	Mean	R value	P value	N
Engineering Problems Survey Score	3.33	---------	---------	61
Introduction to Engineering (IED) EOC	5.56	-0.1112	0.4671	45
Principles of Engineering (POE) EOC	5.26	0.0196	0.9083	37
Aerospace Engineering (AE) EOC	5.45	----------	---------	10
Biotechnology Engineering (BT) EOC	7.35	----------	---------	1
Civil Engineering& Architecture (CEA) EOC	5.55	-0.3481	0.2036	15
Computer Integrated Manufacturing (CIM) EOC	5	----------	---------	5
Digital Electronics (DE) EOC	4.72	-0.2647	0.2462	21

Note: IED, POE, CEA and DE were the only PLTW EOC assessments with the conduction of a PMCC, due to the limited enrollment and offering in certain PLTW class offerings.

The researcher utilized a PPMC coefficient to determine the strength of the relationship between specific teacher survey questions and results from PLTW EOC examinations. Null Hypothesis 1 utilized teacher survey questions 5, 6, 7, and 11 (listed as Engineering Problems survey score in Table 18), which included perceptions of identification of engineering problems, formulating engineering problems, solving engineering problems, and analyzing and interpreting data in PLTW coursework. The teacher responses for these questions were averaged to give each teacher an Engineering Problems Survey score. Research values calculated separately for the 2013-2014 and 2014-2015 school years.

Introduction to Engineering Design *(IED)*: The researcher conducted a test for correlation to investigate whether there was a relationship between the Engineering Problem survey scores of the teachers and the EOC scores of the students in Introduction to Engineering courses. The analysis revealed there was no relationship between the two variables, where $r(43) = -0.1112$, $p = 0.4671$, with $\alpha = .05$. Therefore, there was no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering problems, within Introduction to Engineering Design (IED) coursework and students' scores on national PLTW IED EOC assessments for the 2013-2014 school year.

Principles of Engineering *(POE)*: A test for correlation was run to investigate whether there was a relationship between the Engineering Problem survey scores of the teachers was related to the EOC scores of the students in Principles of Engineering courses. The analysis revealed that there was no relationship between the two, $r(35) = .0196$, $p = 0.9083$, with $\alpha = .05$. Therefore, there was no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering problems, within the Principles of Engineering coursework and students' scores on national PLTW POE EOC assessments for the 2013-2014 school year.

Civil Engineering and Architecture *(CEA):* A test for correlation was run to investigate whether there was a relationship between the Engineering Problem survey scores of the teachers was related to the EOC scores of the students in Civil Engineering and Architecture courses. The analysis revealed that there was no relationship between the two, $r(15) = -0.3481$, $p = 0.2036$, with $\alpha = .05$. Therefore, there was no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering problems, within the Civil Engineering and Architecture coursework and students' scores on national PLTW CEA EOC assessments for the 2013-2014 school year.

Digital Electronics *(DE)*: A test for correlation was run to investigate whether there was a relationship between the Engineering Problem survey scores of the teachers was related to the EOC scores of the students in Digital Electronics courses. The analysis revealed that there was no relationship between the two, $r(21) = -0.2647$, $p = 0.2462$, with $\alpha = .05$. Therefore, there was no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering problems, within the Digital Electronics coursework and students' scores on national PLTW DE EOC assessments for the 2013-2014 school year.

2014-2015 School Year

Table 19

PMCC: 2014-2015 PLTW Teacher Curriculum Perception and PLTW EOC Scores by Subject

	Mean	R value	P	N
Engineering Problems Survey Score	3.33	---------	-----	61
Introduction to Engineering (IED) EOC	5.04	0.0414	0.7619	56
Principles of Engineering (POE) EOC	4.72	-0.1095	0.4588	48
Aerospace Engineering (AE) EOC	5.36	----------	-----	11
Biotechnology Engineering (BT) EOC	7.84	----------	-----	2
Civil Engineering and Architecture (CEA) EOC	4.82	----------	-----	14
Computer Integrated Manufacturing (CIM) EOC	5.00	----------	-----	4
Digital Electronics (DE) EOC	4.65	-0.2140	0.3938	18

Note: IED, POE and DE were the only PLTW EOC assessments with the conduction of a PMCC, due to the limited enrollment and offering in certain PLTW class offerings.

***Introduction to Engineering Design** (IED)*: The researcher conducted a test for correlation to investigate whether there was a relationship between the Engineering Problem survey scores of the teachers and the EOC scores of the students in Introduction to Engineering courses. The analysis revealed there was no relationship between the two variables, where $r(54) = 0.0414$, $p = 0.7619$, with $\alpha = .05$. Therefore, there was no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering problems, within Introduction to Engineering Design (IED) coursework and students' scores on national PLTW IED EOC assessments for the 2014-2015 school year.

Principles of Engineering Design *(POE)*: The researcher conducted a test for correlation to investigate whether there was a relationship between the Engineering Problem survey scores of the teachers and the EOC scores of the students in Principles of Engineering. The analysis revealed there was no relationship between the two variables, where $r(46) = -0.1095$, $p = 0.4588$, with $\alpha = .05$. Therefore, there was no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering problems, within Principles of Engineering (POE) coursework and students' scores on national PLTW POE EOC assessments for the 2014-2015 school year.

Digital Electronics *(DE)*: The researcher conducted a test for correlation to investigate whether there was a relationship between the Engineering Problems survey scores of the teachers and the EOC scores of the students in Digital Electronics. The analysis revealed there was no relationship between the two variables, where $r(16) = -0.2140$, $p = 0.3938$, with $\alpha = .05$. Therefore, there was no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering problems, within Digital Electronics (DE) coursework and students' scores on national PLTW DE EOC assessments for the 2014-2015 school year.

Null Hypothesis 2: There is no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering needs and students' scores on national PLTW End of Course assessments.

The researcher utilized a PPMC coefficient to determine the strength of the relationship between specific teacher survey questions and results from PLTW EOC examinations. Null Hypothesis 2 utilized teacher survey questions 8, 9, 10, 13, 14, 15, 16, 17, 18, 19, 20, and 21 (listed as Engineering Needs survey score in Table 20), which included perceptions of desired needs within realistic constraints, the design and conducting of experiments, techniques for engineering practice, impact of engineering solutions, professional and ethical responsibility, function on multidisciplinary teams, effective communication, contemporary engineering issues, and lifelong engineering learning. The responses for these questions were averaged to give each teacher an Engineering Needs Survey score. Research values calculated separately for the 2013-14 and 2014-15 school years.

2013-2014 School Year

Table 20

PMCC: 2013-2014 PLTW Teacher Curriculum Perception and PLTW EOC Scores by Subject

	Mean	R value	P	N
Engineering Needs Survey Score	3.13	---------	-----	61
Introduction to Engineering (IED) EOC	5.04	-0.2059	0.1748	45
Principles of Engineering (POE) EOC	4.72	-0.1053	0.5351	37
Aerospace Engineering (AE) EOC	5.36	----------	-----	10
Biotechnology Engineering (BT) EOC	7.84	----------	-----	1
Civil Engineering and Architecture (CEA) EOC	4.82	-0.3627	0.1840	15
Computer Integrated Manufacturing (CIM) EOC	5.00	----------	-----	4
Digital Electronics (DE) EOC	4.65	-0.2699	0.2498	20

Note: IED, POE, CEA and DE were the only PLTW EOC assessments with the conduction of a PMCC, due to the limited enrollment and offering in certain PLTW class offerings.

Introduction to Engineering Design *(IED)*: The researcher conducted a test for correlation to investigate whether there was a relationship between the Engineering Needs survey scores of the teachers and the EOC scores of the students in Introduction to Engineering courses. The analysis revealed there was no relationship between the two variables, where $r(43) = -0.2059$, $p = 0.1748$, with $\alpha = .05$. Therefore, there was no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering needs, within Introduction to Engineering Design (IED) coursework and students' scores on national PLTW IED EOC assessments for the 2013-2014 school year.

Principles of Engineering *(POE)*: The researcher conducted a test for correlation to investigate whether there was a relationship between the Engineering Needs survey scores of the teachers were related to the EOC scores of the students in Principles of Engineering (POE) courses. The analysis revealed there was no relationship between the two variables, where $r(43) = -0.2059$, $p = 0.1748$, with $\alpha = .05$. Therefore, there was no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering needs, within Principles of Engineering (POE) coursework and students' scores on national PLTW POE EOC assessments for the 2013-2014 school year.

Civil Engineering and Architecture *(CEA):* The researcher conducted a test for correlation to investigate whether there was a relationship between the Engineering Needs survey scores of the teachers and the EOC scores of the students in Civil Engineering and Architecture (CEA) courses. The analysis revealed there was no relationship between the two variables, where $r(13) = -0.3627$, $p = 0.1840$, with $\alpha = .05$.

Therefore, there was no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering needs, within Civil Engineering and Architecture (CEA) coursework and students' scores on national PLTW CEA EOC assessments for the 2013-2014 school year.

***Digital Electronics** (DE)*: The researcher conducted a test for correlation to investigate whether there was a relationship between the Engineering Needs survey scores of the teachers and the EOC scores of the students in Digital Electronics (DE) courses. The analysis revealed there was no relationship between the two variables, where $r(18) = -0.2699$, $p = 0.2498$, with $\alpha = .05$.

2014-2015 School Year

Table 21

PMCC: 2014-2015 PLTW Teacher Curriculum Perception and PLTW EOC Scores by Subject

	Mean	R value	P	N
Engineering Needs Survey score	3.13	----------	----	51
Introduction to Engineering (IED) EOC	5.04	-0.0391	0.7853	51
Principles of Engineering (POE) EOC	4.72	-0.2148	0.1666	43
Aerospace Engineering (AE) EOC	5.36	----------	----	9
Biotechnology Engineering (BT) EOC	7.84	----------	----	2
Civil Engineering and Architecture (CEA) EOC	4.82	----------	----	12
Computer Integrated Manufacturing (CIM) EOC	5.00	----------	----	2
Digital Electronics (DE) EOC	4.65	-0.3136	0.2550	15

Note: IED, POE and DE were the only PLTW EOC assessments with the conduction of a PMCC, due to the limited enrollment and offering in certain PLTW class offerings.

Therefore, there was no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering needs, within Digital Electronics (DE) coursework and students' scores on national PLTW DE EOC assessments for the 2013-2014 school year.

Introduction to Engineering Design: The researcher conducted a test for correlation to investigate whether there was a relationship between the Engineering Needs survey scores of the teachers and the EOC scores of the students in Introduction to Engineering Design (IED) courses. The analysis revealed there was no relationship between the two variables, where $r(49) = -0.0391$, $p = 0.7853$, with $\alpha = .05$. Therefore, there was no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering needs, within Introduction to Engineering Design (IED) coursework and students' scores on national PLTW IED EOC assessments for the 2014-2015 school year.

Principles of Engineering Design: The researcher conducted a test for correlation to investigate whether there was a relationship between the Engineering Needs survey scores of the teachers and the EOC scores of the students in Principles of Engineering Design (POE) courses. The analysis revealed there was no relationship between the two variables, where $r(41) = -0.2148$, $p = 0.1666$, with $\alpha = .05$. Therefore, there was no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering needs, within Principles of Engineering (POE) coursework and students' scores on national PLTW POE EOC assessments for the 2014-2015 school year.

Digital Electronics: The researcher conducted a test for correlation to investigate whether there was a relationship between the Engineering Needs survey scores of the teachers and EOC scores of the students in Digital Electronics (DE) courses. The analysis revealed there was no relationship between the two variables, where $r(13) = -0.3136$, $p = 0.2550$, with $\alpha = .05$. Therefore, there was no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering needs, within Digital Electronics (DE) coursework and students' scores on national PLTW DE EOC assessments for the 2014-2015 school year.

Null Hypothesis 3: There is no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation of mathematics, science, and engineering knowledge and students' scores on national PLTW End of Course assessments.

The researcher utilized a PPMC coefficient to determine the strength of the relationship between specific teacher survey questions and results from PLTW EOC examinations. Null Hypothesis 3 utilized teacher survey question 12 (listed in Table 22) and included perceptions of building STEM knowledge in all PLTW coursework. The responses for these questions were averaged to give each teacher a STEM knowledge survey score. Research values calculated separately for the 2013-14 and 2014-15 school years.

2013-2014 School Year

Table 22

PMCC: 2014-2015 PLTW Teacher Curriculum Perception and PLTW EOC Scores by Subject

	Mean	R value	P	N
STEM Knowledge Survey score	3.46	----------	----	61
Introduction to Engineering (IED) EOC	5.56	-0.0775	0.6128	45
Principles of Engineering (POE) EOC	5.26	0.0481	0.7774	37
Aerospace Engineering (AE) EOC	5.45	----------	----	10
Biotechnology Engineering (BT) EOC	7.35	----------	----	1
Civil Engineering and Architecture (CEA) EOC	5.55	-0.2061	0.4612	15
Computer Integrated Manufacturing (CIM) EOC	5.00	----------	----	4
Digital Electronics (DE) EOC	4.72	-0.1347	0.5713	20

Note: IED, POE, CEA and DE were the only PLTW EOC assessments with the conduction of a PMCC, due to the limited enrollment and offering in certain PLTW class offerings.

Introduction to Engineering Design *(IED)*: The researcher conducted a test for correlation to investigate whether there was a relationship between the STEM knowledge survey scores of the teachers were related to the EOC scores of the students in Introduction to Engineering Design (IED) courses. The analysis revealed there was no relationship between the two variables, where $r(43) = -0.0775$, $p = 0.6128$, with $\alpha = .05$. Therefore, there was no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to build STEM knowledge, within Introduction to Engineering Design (IED) coursework and students' scores on national PLTW IED EOC assessments for the 2013-2014 school year.

Principles of Engineering *(POE)*: The researcher conducted a test for correlation to investigate whether there was a relationship between the STEM knowledge survey scores of the teachers were related to the EOC scores of the students in Principles of Engineering (POE) courses. The analysis revealed there was no relationship between the two variables, where $r(35) = 0.0481$, $p = 0.7774$, with $\alpha = .05$. Therefore, there was no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to build STEM knowledge, within Principles of Engineering (POE) coursework and students' scores on national PLTW POE EOC assessments for the 2013-2014 school year.

Civil Engineering and Architecture *(CEA):* The researcher conducted a test for correlation to investigate whether there was a relationship between the STEM knowledge survey scores of the teachers and the EOC scores of the students in Civil Engineering and Architecture (CEA) courses. The analysis revealed there was no relationship between the two variables, where $r(13) = -0.2061$, $p = 0.4612$, with $\alpha = .05$. Therefore, there was no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to build STEM knowledge, within Civil Engineering and Architecture (CEA) coursework and students' scores on national PLTW CEA EOC assessments for the 2013-2014 school year.

Digital Electronics *(DE)*: The researcher conducted a test for correlation to investigate whether there was a relationship between the STEM knowledge survey scores of the teachers and EOC scores of the students in Digital Electronics (DE) courses. The analysis revealed there was no relationship between the two variables, where $r(18) = -0.1347$, $p = 0.5713$, with $\alpha = .05$. Therefore, there was no relationship between Missouri

PLTW Engineering teachers' perception of curriculum implementation to build STEM knowledge, within Digital Electronics (DE) coursework and students' scores on national PLTW DE EOC assessments for the 2013-2014 school year.

2014-2015 School Year

Table 23

PMCC: 2014-2015 PLTW Teacher Curriculum Perception and PLTW EOC Scores by Subject

	Mean	R value	P	N
STEM Knowledge Survey score	3.46	----------	-----	51
Introduction to Engineering (IED) EOC	5.04	0.1226	0.3914	51
Principles of Engineering (POE) EOC	4.72	-0.1036	0.5085	43
Aerospace Engineering (AE) EOC	5.36	----------	-----	9
Biotechnology Engineering (BT) EOC	7.84	----------	-----	2
Civil Engineering and Architecture (CEA) EOC	4.82	----------	-----	12
Computer Integrated Manufacturing (CIM) EOC	5.00	----------	-----	2
Digital Electronics (DE) EOC	4.65	0.2779	0.3159	15

Note: IED, POE and DE were the only PLTW EOC assessments with the conduction of a PMCC, due to the limited enrollment and offering in certain PLTW class offerings.

Introduction to Engineering Design: The researcher conducted a test for correlation to investigate whether there was a relationship between the STEM knowledge survey scores of the teachers and EOC scores of the students in Introduction to Engineering Design (IED) courses. The analysis revealed there was no relationship between the two variables, where $r(49) = 0.1226$, $p = 0.3914$, with $\alpha = .05$. Therefore, there was no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to build STEM knowledge, within Introduction to

Engineering Design (IED) coursework and students' scores on national PLTW IED EOC assessments for the 2014-2015 school year.

Principles of Engineering Design: The researcher conducted a test for correlation to investigate whether there was a relationship between the STEM knowledge survey scores of the teachers and EOC scores of the students in Principles of Engineering (POE) courses. The analysis revealed there was no relationship between the two variables, where $r(41) = -0.1036$, $p = 0.5085$, with $\alpha = .05$. Therefore, there was no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to build STEM knowledge, within Principles of Engineering (POE) coursework and students' scores on national PLTW POE EOC assessments for the 2014-2015 school year.

Digital Electronics: The researcher conducted a test for correlation to investigate whether there was a relationship between the STEM knowledge survey scores and EOC scores of the students in Digital Electronics (DE) courses. The analysis revealed there was no relationship between the two variables, where $r(13) = 0.2779$, $p = 0.3159$, with $\alpha = .05$. Therefore, there was no relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to build STEM knowledge, within Digital Electronics (DE) coursework and students' scores on national PLTW DE EOC assessments for the 2014-2015 school year.

Summary

Chapter Four reports on the mixed methods approach of qualitative and quantitative measurements collected while researching engineering curriculum goals of Project Lead the Way Engineering. PLTW teacher survey responses, voluntary interview responses, and Missouri achievement scores for PLTW Engineering supported research questions and null hypotheses to investigate teachers' perceptions in the curriculum implementation process. The results of qualitative research indicated an overall satisfaction with the state of curriculum in PLTW Engineering. In interviews, respondents consistently discussed students' levels of preparation and how PLTW Engineering provided greater levels of rigor, preparation, engagement, and exposure to STEM concepts in comparison to regular mathematics and science curriculum provided in secondary schools. Survey participation results indicated the highest Likert scores for students having success in identifying and solving engineering problems.

The results of quantitative research indicated none of the three null hypotheses addressed in this study for either the 2013-2014 or 2014-2015 school years possessed any level of statistical significance when comparing the potential relationship between teacher survey results and state level PLTW EOC assessments. In Chapter Five research findings are discussed and future research recommendations are given.

Chapter Five: Discussion and Reflection

Introduction

The purpose of Chapter Five is to discuss findings regarding qualitative and quantitative data collected as part of this study regarding the condition of engineering curriculum in Missouri secondary high schools. The researcher's topic of study emerged from his professional experience as a school administrator in a Missouri high school. Despite the fact of no then-current established national secondary education engineering standards (NAE, 2010), PLTW was an organization which provided schools the opportunity to purchase engineering curriculum aligned to various standards (International Society for Technology, 2016; NGSS, 2013; National Science Board, 2006). This curriculum specifically advertised itself for its alignment with the Common Core State Standards in English and mathematics, as well as the NGSS (Bertram, 2014), to market itself as a federal and state-aligned resource. The curriculum served as a foundation of engineering studies for high school students nationwide and evident in the state of Missouri as determined by growth of student population enrolled in one or more PLTW classes as well as the increased number of schools participating within the PLTW network.

This research study focused on the 11 PLTW national engineering curriculum goals and the level of success regarding the measured implementation of these goals (Table 2). The researcher's focus was specific to the state of Missouri and utilized the following methods of evaluation: 1) an evaluation of Missouri PLTW EOC assessment data for various engineering classes offered in Missouri, 2) the development, implementation, and analysis of a Missouri PLTW teacher survey based upon national

PLTW Engineering curriculum goals, and 3) program representative interviews with those affiliated with PLTW (local, state, and national-level positions). The study provided an opportunity for 329 Missouri PLTW Engineering instructors to respond. The study obtained 61 survey participants, equating to an 18.54% participation rate. Additionally, the researcher conducted interviews with nine PLTW representatives (Missouri teachers, state PLTW administrators, and a national PLTW administrator). Some consistent data trends occurred from the data analysis including the participants' perspectives on identifying, formulating, and solving engineering problems, designing and conducting experiments, analysis and interpretation of data, application of STEM concepts, professional and ethical responsibilities, and the need to communicate as part of a team within the PLTW curriculum. The research questions and hypotheses utilized for this study included:

Research Questions and Hypotheses

RQ1: How do Missouri PLTW Engineering teachers perceive curriculum implementation on identifying, formulating, and solving engineering problems?

RQ2: How do Missouri PLTW Engineering teachers perceive curriculum implementation on engineering experiments?

RQ3: How do Missouri PLTW Engineering teachers perceive curriculum implementation on techniques, skills, and tools for engineering practice?

RQ4: How do Missouri PLTW Engineering teachers perceive curriculum implementation on the impact of engineering solutions in a global, economic, environmental, and societal context?

RQ5: How do Missouri PLTW Engineering teachers perceive curriculum implementation on opportunities to demonstrate and understand professional responsibility?

RQ6: How do Missouri PLTW Engineering teachers perceive curriculum implementation on the understanding and demonstration of ethical responsibility?

RQ7: How do Missouri PLTW Engineering teachers perceive curriculum implementation to function on multidisciplinary teams in the classroom setting?

RQ8: How do Missouri PLTW Engineering teachers perceive curriculum implementation to communicate effectively in the classroom setting?

RQ9: How do Missouri PLTW Engineering teachers perceive curriculum implementation to recognize the need for and develop an ability to engage in lifelong learning?

Hypothesis 1: There is a relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering problems, in all PLTW coursework and students' scores on national PLTW End of Course assessments.

Hypothesis 2: There is a relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation to solve engineering needs and students' scores on national PLTW End of Course assessments

Hypothesis 3: There is a relationship between Missouri PLTW Engineering teachers' perception of curriculum implementation of mathematics, science, and engineering knowledge and students' scores on national PLTW End of Course assessments.

Teacher Instructional Background and School Program Implementation

As part of the teacher survey, the researcher asked study participants about their content background as well as classroom instructional assignments. Of the 61 teacher participants, approximately half (n = 30) of the teachers had some level of mathematics, science, or engineering backgrounds, while the other half did not (or did not report a response through the teacher survey question). Although the ability to teach PLTW Engineering courses did not require a specialized certificate in Missouri, all PLTW teachers attended and successfully completed a training for each class in which they taught. As Tai (2012) suggested, 70% of professionals in areas such as science become interested in an area of specialization before beginning high school. Therefore, teachers involved within the PLTW program who possessed previous experience in science or mathematics were more likely interested in the subject area before becoming a teacher. Maltese and Tai (2010) reported teaching experiences with positive conclusions helped provide teachers with more confidence and better overall classroom and teaching experiences.

Research statistics also suggested school districts’ commitments to offering basic foundational engineering courses for students. The state of Missouri PLTW programming continued to show growth, both in the number of schools and districts, which initiated the program, as well as in the number of students who chose to take a PLTW Engineering class as coursework in high school (Table 9). However, basic growth in introductory courses, such as Introduction to Engineering Design and Principles of Engineering, also showed limited growth (or occasional enrollment decline) in more advanced engineering courses (Appendix D). Courses designed around higher levels of curriculum standards were limited in scope, due to the lack of interest by Missouri secondary students to enroll for these upper level courses. Table D6 also suggested as PLTW Engineering students progressed from an introductory class such as Introduction to Engineering Design (IED), to a second year class such as Principles of Engineering (POE), Missouri school district success became more limited with a growing percentage of school districts scoring below national standards. As PLTW Engineering students progressed into third and fourth-year classes, school district achievement data indicated the variance of Missouri schools in achievement results. The number of undeterminable scores of districts in upper level courses were due to the lack of a minimum number (10) of students enrolled for a class in any particular Missouri school district (PLTW, 2016). Classes with an enrollment less than 10 did not have specific data reported as part of the data release from MODESE, but were determined into the statistical analysis.

The researcher measured teacher perception of PLTW curriculum design and implementation, utilized Missouri EOC PLTW assessment data, and interviewed teachers, administrators and other leaders regarding their experiences. Data triangulation suggested high levels of satisfaction by teachers for students to experience skills professional engineering students and skilled engineers needed within the field. Teachers who responded to this study, through surveys and interviews, indicated students' abilities to engage in the same problem solving process engineers would likely participate. Teachers, administrators, and various PLTW leaders consistently cited personal experiences and statistical evidence to support the perspectives on PLTW Engineering implementation in Missouri secondary schools. Teacher survey respondents' perspectives, measured by a Likert scale, measured between 3.0 and 3.5 for all survey items. Requirements to teach PLTW classes included mandatory professional development training, and the work of Tolan (2008) and Daugherty (2009), along with interviews of select participants, consistently stated the level of preparation and training for teachers to teach PLTW classes was significant and of high quality. The review of literature and the analysis of interviews, surveys, and state achievement data suggested the importance of teacher training and school program implementation as fundamentals to success of PLTW Engineering curriculum and the positive perception among professional educators in the engineering education field.

Benefits to Students and Developing the Engineering Mindset

While there were benefits of implementing a PLTW Engineering program for teachers and schools (i.e. quality professional development and integrated STEM curriculum offerings within a school), students also benefitted in a variety of ways from enrollment in PLTW Engineering courses (Heywood, & White, 2011; Kelley, 2008; Schenk, Rethwisch, Chapman, Laanan, Starobin, & Zhang, 2011; Tai, 2012; Tran & Nathan, 2010). Research Question one focused on student exposure to engineering curriculum and on applying STEM knowledge to solve problems. Interviews conducted with teachers and other leaders strongly suggested students' levels of STEM preparation improved while in PLTW Engineering courses, mainly due to interest in subject content and improved problem solving abilities. Teachers also suggested practical skills, such as 'soft skills,' learned through the PLTW Engineering curriculum developed students who were ahead in any profession due to the opportunity to work in teams while in the PLTW Engineering classroom.

Additionally, opportunities for students existed in offerings of such organizations as Technology Student Associations (TSA). Approximately half of survey respondents' schools offered a TSA. These organizations promoted and provided further STEM opportunities for students to learn about problem solving, gain leadership experience, and to promote STEM learning opportunities. According to Research Question three, student experiences were part of PLTW's vision for the program and positive student experiences, as well as opportunities mentioned within interviews. Likert scale ratings for students to apply STEM knowledge and use engineering techniques were some of the highest-scaled scores of the study (Table 12). Ninety-four percent of the interview participants also mentioned students' abilities to use engineering tools as a positive practice within the PLTW curriculum.

Student engagement was also a qualitative benefit to students, as described by interview participants of this study. Several study participants discussed activities students would complete and how the interdisciplinary approach to the PLTW curriculum allowed students to be more excited in the classroom setting because students were doing activities with academic rigor and personal relevance as part of the curriculum. The experiences students had in PLTW Engineering classes provided a relevant answer to why students were learning specific content material; thereby, expanding the 'engineering mindset' of students, as described by a study participant. Whether students intended to pursue college or career routes to employment, the goal of PLTW was to expose and teach all students about the field of engineering and how engineering's place within the STEM curriculum adopted an integrated, collaborative approach to the curriculum.

Growing the Field of Engineering through Student Success

Several interview participants acknowledged the original purpose for the development of engineering curriculum offered through PLTW. In PLTW's 21-year history, the purpose of the organization's creation was to "inspire students and address the shortage of engineering students at the college level" (Bertram, 2014, p. 52). Kimmel et al. (2007) discussed the need for structures to get students interested in engineering on a consistent basis to lead to more engineering students at colleges and universities across the United States. Although PLTW did not specifically state as a purpose the growth of student engineering populations, the organization promoted a broad set of skills applicable in any type of field. These skills included problem solving, thinking critically, and collaborating with others to complete job tasks. A by-product of PLTW's intent was the growth of all curriculum programs, including Engineering, Biomedical Science, and Computer Science. In Table 9, growth of PLTW Engineering teachers and students involved in PLTW Engineering suggested a strong increase from 2013 to 2015, both nationwide and in Missouri. Strong, continued growth suggested to the researcher a demand by school districts to offer a curriculum developed with science, technology, and mathematics standards in mind (Bybee, 2009; Meyrick, 2011), which promoted and exposed students to problem solving intertwined with science and mathematics (Kelley, 2008), and which promoted higher achievement levels, both in PLTW classes and other norm-referenced tests, such as the NAEP (Bottoms & Uhn, 2007). Further, enrollment growth in the field of engineering, as supported by Appendix B, which addressed a national and state view on school development, assessed student growth and how during the 2014-2015 school year, approximately one-quarter million students nationwide took

EOC assessments, indicating an interest and willingness to show what the curriculum goals of PLTW Engineering taught them in their classroom experiences.

Collaborative Opportunities and Student Soft-Skill Development

Oral interviews conducted during the research described the PLTW classroom experience as a transformative learning experience where students could develop global skills. PLTW encouraged many opportunities for student collaboration to better develop student soft skills. Several interview participants described attributes of the PLTW Engineering program, specifically from individual perspectives about what PLTW valued most. To advocate the continued need for development of engineers in our nation, the PLTW curriculum focused on the development of teamwork and continued improvement of ideas and methodology. Professional literature identified soft skills as skills continuously developed within students in PLTW classes (Bertram, 2013; PLTW, 2014). Interview participants also referenced soft skills as characteristics employers would like to see out of an employee new to the organization. Specific reference by an interview participant spoke to development of skills in teamwork, multiple solutions to problems, failing forward, and continuous improvement. These workplace readiness skills were in demand by employers and individuals involved with PLTW, who spoke highly regarding the problem-based approach and the collaborative efforts required by students to solve real-world problems.

Other Areas of Significance

The then-current state of the professional literature regarding PLTW Engineering found areas of significance, such as attrition within the work place (ACT, 2014; ACTE, 2009). Although the study focused on an analysis of curriculum goals of PLTW

Engineering in the state of Missouri, the study also recognized the then-recently identified gap in engineering students and professional engineering opportunities in the United States. To address the employment trend and the level of preparation needed to pursue engineering as a career pathway, the researcher asked the interview group participants Research Question one, 'How do Missouri PLTW Engineering teachers perceive curriculum implementation on identifying, formulating, and solving engineering problems?' The skills identified by PLTW, Inc., reflected the organization's national curriculum goals. The Likert scale results for Research Question one indicated three of the four highest areas measured in the teacher survey (identification, formulation, and solving of engineering problems) next to the concept of application of STEM knowledge.

A research study published in 2010 by the Northwest Evaluation Association was the closest study identified by the researcher to have similar study components and methodology. The objectives of the previous Northwest Evaluation Association study included:

> 1) review the available prior evidence from PLTW internal data to evaluate the program's effectiveness in achieving its goals, 2) review prior studies of PLTW to evaluate their findings on the effectiveness of PLTW programs, and 3) conduct an analysis that compares the academic growth of PLTW participants and non-participants, to determine whether PLTW participation is associated with any differences in academic growth rates. (2010, p. 4)

Although the objectives of the Northwest Evaluation Association (2010) study were not the same as the objectives of the researcher's study, some of the data components possessed similar characteristics. The Northwest study struggled to respond to the significant growth of students taking PLTW classes (like the growth of PLTW programming in Missouri). Median results of upper level PLTW classes indicated a lower score than introductory classes (Northwest Evaluation Association, 2010, p. 6). The Northwest study focused on progress of goals in areas such as academic achievement and interest in college-level STEM studies (similar to the researcher's historical context of STEM education and use of statewide school district data to reflect academic achievement). Differences within the study included the sampling of individual student data for group analysis and the instrumentation to measure progress in STEM-related areas and curriculum development. Overall, the conclusions of similar studies, such as the Northwest study, indicated PLTW Engineering made some level of progress in achieving the study's objectives. This researcher's study did not measure academic growth in content areas, but in a review of Likert scale results, all areas measured scored at a 3.0 or higher on a 4.0 scale.

Recommendations for Replication and Future Research

Recommendations for replication or expansion of the researcher's study would encourage the continued development of certain topics. First, the limited sample of Missouri PLTW Engineering teachers responding to the survey request may have influenced the study's outcome, since convenience sampling was used in the selection of the sample for the study. There may have been bias due to the teacher's involvement within the organization studied by the researcher (Fraenkel et al., 2012). With the use of a convenience sample, the sample, "cannot be considered representative of any population" (Fraenkel et al., 2012, p. 562). The researcher recommends any replication involve a multi-state study to gather a more significant sampling of the population of PLTW Engineering teachers.

Further, when the researcher composed the research questions to the study and obtained approval through the Lindenwood University IRB process, consideration should have been given in future studies to split multi-characteristic questions. The established goals of PLTW Engineering grouped actions such as identify, formulate, and solve. As part of future research, the isolation of steps in the problem solving process may provide more accurate information to future research and create more detailed information about potential areas of celebration or concern within the established goals of PLTW Engineering.

Second, the study was limited due to the limited population enrolled in upper level PLTW Engineering courses. Classes such as Aerospace Engineering, Biotechnical Engineering, Civil Engineering and Architecture, and Computer Integrated Manufacturing had limited numbers of students enrolled in the classes and limited numbers of school districts able to offer the advanced engineering classes. Districts who enrolled less than 10 students into any course program counted in study statistics as undefined because of the limited statistical relevance of the data in small sample sizes.

Recommendations for future research would involve separate components of qualitative and quantitative within a mixed-methods study. From a qualitative element, further questioning related to student academic achievement in areas such as mathematics or science would provide better perspective beyond the curriculum goal focus of this study. From a quantitative element, an increased sample size through the expansion of other states or a specified view of introductory PLTW Engineering classes would provide a stronger sample size and more relevance to the goals of any future PLTW study. From a mixed-methods element, the use of PLTW assessment data from other states would expand the opportunity to do random sampling or stratified random sampling. Further recommendations for research include the ability of future researchers to use the curriculum evaluation model created by this researcher and to apply the model to other PLTW programs, such as Biomedical Science or Computer Science. A newly created survey instrument would provide views of other PLTW teachers and leaders to measure the success of curricular objectives. Another recommendation for future research would be to use the PLTW Engineering curriculum philosophy goals (Table 2) and create a separate survey or utilize the curriculum philosophy goals to add to the level of questioning and analysis of survey instruments created to measure the effectiveness of PLTW curriculum.

Recommendations for Practice and Policy

To summarize, the primary goal of the researcher was to determine if Missouri high schools met or exceeded the stated national curriculum goals of PLTW through an evaluation of Missouri PLTW EOC assessment data, PLTW teacher survey responses, and interviews conducted with leading PLTW experts in the field. The determination made by the researcher, utilizing a mixed-methods approach, concluded the state of Missouri met the stated national curriculum goals of PLTW, but did not exceed the goals due to overall student performance on PLTW EOC examinations. Making recommendations for future educational practice involved an acknowledgment of STEM education and the role of PLTW programs within STEM education. Organizations, such as the NSF, PCAST, and ACTE all recognized the role of STEM education in the redevelopment of skills needed to be successful within 21st century classrooms (ACTE, 2009; PCAST, 2012). The purpose of STEM education, according to PCAST (2012), was to expand a workforce with individuals possessing skills to allow students to gain advanced employment and to address achievement gaps identified through international and national STEM-related assessments.

The overarching goal of PLTW was similar to the goals of STEM education. Despite the lack of national standards and federal financial investments to grow innovation, PLTW recognized the opportunity which existed to provide a standards-based curriculum, when no other agreed upon standards were utilized in the field. Because of the communication of standards, objectives, branding, and professional affiliations, the researcher concluded, PLTW programming thrived in terms of expanding programs in school districts, in schools, and in growing interest in students throughout the nation. PLTW remained true to the organization's purpose of creating high-quality curriculum and professional development, and leveraging resources to create partnerships with world-class employers to continue to promote and grow the brand. The limited scope of research regarding PLTW Engineering revolved around student achievement, teacher professional development, and perceptions of parents, principals, and professional partners. The instrumentation created for this study allowed the researcher to measure curriculum as an objective of a method available, utilizing triangulation to support the measurement of the concept of an outcomes-based curriculum.

References

ACT, Inc. (2014). *The condition of STEM 2014.* Retrieved from http://www.act.org/ stem condition.

Association for Career and Technical Education. (2009, June). *CTE's role in science, technology, engineering, and math.* (Issue Brief). Alexandria, VA: H. Meeder.

Augustine, N. (Chair). (2005). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. National Academies Committee on Prospering in the Global Economy of the 21st Century. Washington, D..C: National Academies Press.,Bertram, V. M. (2013). *Hearing on STEM education: Industry and philanthropic initiatives*. Retrieved from http://docs.house.gov/meetings/SY/SY14/20130313/ 100506/HHRG-113-SY14-Wstate-BertramV-20130313.pdf

Bertram, V. M. (2014). *One nation under taught: Solving America's science, technology, engineering, and math crisis*. New York, NY: Beaufort.

Bottoms, G., & Anthony, K. (2005, May). *Project Lead the Way: A pre-engineering curriculum that works (a new design for high school career/technical studies).* (Research Brief). Atlanta, GA: Southern Regional Education Board.

Bottoms, G., & Uhn, J. (2007, September). *Project Lead the Way works: A new type of career and technical program*. (Research Brief). Atlanta, GA: Southern Regional Education Board.

Boynton, M., & Hossain, F. (2010). Improving engineering education outreach in rural counties through engineering risk analysis. *Journal of Professional Issues in*

Engineering Education and Practice, 136(4), 18-30. Retrieved from http://dx.doi.org/10.1061/(ASCE)EI.1943-5541.0000026#sthash.FzbYnxSL.dpuf

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. *Journal of Engineering Education, 97*(3), 369-387. Doi: 10.1002/j.2168-9830.2008.tb00985.

Bybee, R. W. (2009). *K–12 Engineering Education Standards: Opportunities and barriers. Workshop on standards for K–12 engineering education*. Washington, DC: National Academies Press.

Burghardt, D. & Hacker, M. (2004). Perspectives on K-12 engineering. *K-12 Engineering, n.d.,* 1-9. Retrieved from http://www.hofstracsr.org/wp-content/uploads/2017/04/Perspectives_on_K-12_Engineering.pdf.

Bybee, R. W. (2011). K-12 Engineering Education Standards: Opportunities and barriers. *Technology and Engineering Teacher*, *70*(5), 21-29. Retrieved from http://eric.ed.gov/?id=EJ914379.

Carr, R. C., Bennett, L. D., & Strobel, J. (2012). Engineering in the K-12 STEM standards of the 50 U.S. states: An analysis of presence and extent. *Journal of Engineering Education, 101*(3), 1-26. Doi: 10.1002/j.2168-830.2012.tb00061.

Cejka, E. (2005). *Inservice teachers' approaches to open-ended engineering design problems and the engineering design process*. Medford, MA: Tufts University.

Chen, X., & Soldner, M. (2013). *STEM attrition: College students' paths into and out of STEM fields* (NCES 2014-001). National Center for Education Statistics, Institute of Education Sciences. Washington, DC: U.S. Department of Education.

Clough, G. (Chair). (2004). *The Engineer of 2020: Visions of engineering in the new century*, National Academy of Engineering, Washington, DC: National Press.

Cole, B., High, K., & Weinland, K. (2013). High school pre-engineering programs: Do they contribute to college retention? *American Journal of Engineering Education*, *4*(1), 85-98. Retrieved from http://dx.doi.org/10.19030/ajee.v4i1.7860.

Common Core State Standards Initiative (2016, January). Read the standards (Standards establishment). Retrieved from http://www.corestandards.org/read-the-standards/

Cunningham, C., Lachapelle, C., & Lindgren-Streicher, A. (2005, June). *Assessing elementary school students' conceptions of engineering and technology.* Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition, Boston, MA.

Daugherty, J., Zeng, Y., Westrick, M., Custer, R., & Merrill, C. (2007). *Research in engineering and technology education*. Retrieved from National Center for Engineering and Technology Education website: http://digitalcommons.usu.edu/ncete_cstudies/8/.

Daugherty, J. L. (2009). Engineering professional development design for secondary school teachers: A multiple case study. *Journal of Technology Education, 21*(1), 10-24. Doi: https://doi.org/10.21061/jte.v21i1.a.1

Diaz, N. V. M., & Cox, M. (2012, Summer). *An overview of the literature: Research in P-12 engineering education, 3*(2) 1-37. Doi: 10.1002/j.2168-9830.2008.tb00985.

Dortch, C. (2014). *Carl D. Perkins Career and Technical Education Act of 2006: Implementation issues*. Washington, DC: Congressional Research Service.

Douglas, J., Iversen, E., & Kalyandurg, C. (2004). *Engineering in the K-12 classroom: An analysis of current practices and guidelines for the future.* Retrieved from American Society for Engineering Education website: http://teachers.egfi-k12.org/wp-content/uploads/2010/01/Engineering_in_the_K-12_Classroom.pdf.

Duderstadt, J. (2005). Engineering for a changing world: A roadmap to the future of American engineering practice, research and education. In D. Grasso & M. Burkins (Eds.), *Holistic engineering education: Beyond technology* (pp. 17-35), New York, NY: Springer-Verlag. Doi: 10.1007/978-1-4419-1393-7_3.

Dym, C., Agogino, A, Eris, O, Frey, D., & Leifer, L. (2005). Engineering design: Thinking, teaching, and learning. *Journal of Engineering Education, 94*(1). Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.72.1593&rep=rep1&type=pdf.

Fadali, M. S., Robinson, M., & McNichols, K. (2000, June). *Teaching engineering to K–12 students using role playing games*. Presented at 2000 ASEE Annual Conference, American Society for Engineering Education. Washington, DC.

Fraenkel, J., Wallen, N., & Hyun, H. (2012). *How to design and evaluate research in education*. New York, NY: McGraw-Hill.

Galama, T., & Hosek, J. (2008). *U.S. competitiveness in science and technology*. Santa Monica, CA: RAND Corporation.

Grayson, L. (1980). A brief history of engineering education in the United States. *IEEE Transactions on Aerospace and Electronic Systems, 68*(3), 373-392. DOI: 10.1109/TAES.1980.308907

Hagedorn, L. (2006). *How to define retention: A new look at an old problem*. Lanham, MD: Rowman and Littlefield.

Hanover Research-District Administrative Practices. (2011). *K-12 STEM overview*. Retrieved from http://nicole-renee.com/actionresearchineducation/2014/05/30/k-12-stem-education/

Heywood, J., & White, S. (2011). Evaluation of Project Lead The Way in Rockwell-sponsored middle schools (fourth year report). Milwaukee, WI: University of Wisconsin-Milwaukee.

Holt, B. (2011). *An exploratory study of Project Lead the Way secondary engineering educators' self-efficacy* (Doctoral Dissertation, University Libraries of Virginia Polytechnic Institute and State University). Retrieved from https:// theses.lib.vt.edu/theses/available/etd-11122001-0930513/.../Holt_BD_D_ 2011. pdf

Hynes, M. (2008). Middle school teachers' use and development of engineering subject matter and pedagogical content knowledge: Doi: 10.1007/s10798-010-9142-4.

Infinity Project. (2007). *The Infinity Project: Engineering education for today's classroom*. Retrieved from http://www.ti.com/corp/docs/csr/factsheets/infinity. shtml

International Society for Technology. (2013). *Nets for administrators* (2nd ed.). Retrieved from www.iste.org

International Society for Technology. (2016). *ISTE Standards*. Retrieved from https:// www.iste.org/standards/standards/for-students-2016

Jackson, S. (2004). *The quiet crisis: Falling short in producing American scientific and technical talent*. Rensselaer Polytechnic Institute. Retrieved fromhttps://www.rpi. edu/homepage/ quietcrisis/best.html

Jackson, S. (2007). Waking up to the "quiet crisis" in the United States. *The College Board Review, (2007)*Winter/Spring, 21-27.

Jeffers, A. T., Safferman, A. G., & Safferman, S. I. (2004). Understanding K-12 engineering outreach programs. *Journal of Professional Issues in Engineering Education and Practice, 130*(2), 95-108.

Kimmel, H., Carpinelli, J., & Rockland, R. (2007, November). *Bringing engineering into K-12 schools: A problem looking for solutions?* Paper presented at the International Conference on Engineering Education. Coimbra, Portugal.

Katehi, L., Pearson, G., & Feder, M. (2009). The status and nature of K-12 engineering education in the United States. *K-12 Engineering Education*, *39*(3), 5-10. Retrieved from https://www.nae.edu/Publications/Bridge/16145/16161.aspx

Klein, S., & Geist, M. (2006). The effect of a bioengineering unit across high school contexts: An initial investigation in urban, suburban, and rural domains. *New Directions for Teaching and Learning*, 98(108), 93-106. Doi: 10.1002/tl.258

Kelley, T. R. (2008). Cognitive processes of students participating in engineering-focused design instruction. *Journal of Technology Education, 19*(2), 50-64. Retrieved from http://digitalcommons.usu.edu/ncete_publications/38

Langdon, D., McKittrick, G., Beede, D., Khan, B., & Doms, M. (2011). *STEM: Good jobs now and for the future*. United States Department of Commerce, Economics and Statistics Administration. Retrieved from http://www.esa.doc.gov/sites/default/files/stemfinalyjuly14_1.pdf.

Lewis, T. (2005). Coming to terms with engineering design as content. *Journal of Technology Education, 16*(2), 37-54.

Maltese, A. & Tai, R. (2010). Eyeballs in the fridge: Sources of early interest in science. *International Journal of Science Education*, *32*(5), 669-685. Retrieved from http://dx.doi.org/10.1080/09500690902792385

Martin, B. R. (2011). *Factors influencing the self-efficacy of Black high school students enrolled in PLTW pre-engineering courses*. Retrieved from ProQuest http://search.proquest.com/docview/856127478

Maxwell, J. (2013). *Qualitative research design: An interactive approach*. Los Angeles, CA: Sage.

McMullin, K., & Reeve, E. (2014). Identifying perceptions that contribute to the development of successful Project Lead the Way pre–engineering programs in Utah. *Journal of Technology Education, 26*(1), 22-46. Retrieved from https://doi.org/10.21061/jte.v26i1.a.2

Meyers-Sharp, J. E., (2004). Branching out. *PRISM: American Society on Engineering Education*, *14*(2), 38–41. Retrieved from http://www.prismmagazine.org/oct04/tt_branching_out.htm

Meyrick, K. M. (2011). How STEM education impress student learning. *Meridian K-12 School Computer Technologies Journal, 14*(1), 1-6. Retrieved from https://ncsu.edu/meridian/summer2011/meyrick/print.html

Missouri Department of Elementary and Secondary Education. (n.d.a). *Technology and engineering education*, Division of Career Education. Retrieved from https://dese.mo.gov/sites/default/files/te_program_ planning_handbook_1. pdf.

Missouri Department of Elementary and Secondary Education. (n.d.b). Division of Career Education. *Common Standards for Career Education Programs*. Retrieved from https://dese.mo.gov/sites/default/ files/tsa-common-standards-for-career-ed-programs.pdf

Missouri Economic Research and Information Center. (2014a). *Missouri STEM and STEM-related occupations*. Missouri Department of Economic Development. Retrieved from https://www.missourieconomy.org/occupations/ stem.stm

Missouri Economic Research and Information Center. (2014). *Missouri's STEM occupations and education*. Missouri Department of Economic Development. Retrieved from https://www.missourieconomy.org/pdfs/stem_ed_ booklet.pdf.

Nathan, M., Atwood, A., Prevost, A., Phelps, L.A., & Tran, N. (2011). How professional development in Project Lead the Way changes high school STEM teachers' beliefs about engineering education. *Journal of Pre-College Engineering Education Research, 1*(1), 16-29. Retrieved from http://dx.doi.org/ 10.7771/2157-9288.1027

National Academy of Engineering. (2010). *Engineering in K-12 Education: Understanding the status and improving the prospects*. Washington, DC: The National Academies Press. Retrieved from https://doi.org/ 10.17226/12635

National Governor's Association Center for Best Practices. (2008). *A governor's guide to NGA*. Retrieved from https://www.nga.org/files/live/sites/NGA/files/pdf/1010 GOVSGUIDENGA.PDF

National Research Council. (2010). *Standards for K-12 Engineering Education?*. Washington, DC: The National Academies Press. Retrieved from https://doi.org/ 10.17226/12990

National Science Board. (2006). Science and engineering indicators: 2006. [Two volumes. Volume 1, NSB 06-01; volume 2, NSB 06-01A.] Arlington, VA: National Science Foundation.

National Science Board. (2010). Science and engineering indicators, 2010. (NSB 10-01). Arlington, VA: National Science Foundation.

Next Generation Science Standards. (2013). *Next Generation Science Standards: For states, by States*. Washington, DC: The National Academies Press.

Northwest Evaluation Association. (2010). Project Lead the Way — Initial program evaluation. Retrieved from www.socialimpactexchange.org/sites/www.../NWEA-PLTW_Evaluation(2010)_0.pdf

Ontiveros, C., & Alvarez, E. (2012, July). *Inspiring and engaging the next generation in STEM through PLTW and REAL*. Paper presented at ASQ Advancing the STEM Agenda in Education, the Workplace and Society, Session 1-2, July 2012, Stout, WI: University of Wisconsin-Stout.

Paslov, L. S. (2007). *The effect of a piloted middle school pre-engineering program on girls' interest and achievement in mathematics*. (3258491 Ed.D.). Ann Arbor, MI: Southern Connecticut State University.

Pearson, G., & Young, A. (Eds.). (2002). *Technically speaking: Why all Americans need to know more about technology*. Washington, DC: National Academy Press.

Pinelli, T., & Haynie, W.J. (2010). A case for the nationwide inclusion of engineering in the K- 12 curriculum via technology education. *Journal of Technology Education, 21*(2), 52-68.

PLTW California. (2017, January 3). Goals and objectives. Retrieved from http://www. pltwcalifornia.org/view-content/10/Goals.html

PLTW Missouri. (2014). Contract agreement for PLTW Biomedical and PLTW Computer Science initiative. St. Charles, MO: Project Lead the Way Missouri.

PLTW Missouri. (2016a). Missouri achievement indicator report for PLTW end of course assessments in 2013-2014. Rolla, MO: Project Lead the Way Missouri.

PLTW Missouri. (2016b). Missouri achievement indicator report for PLTW end of course assessments in 2014-2015. Rolla, MO: Project Lead the Way Missouri.

PLTW Missouri. (2016c). Missouri school locator. Retrieved from https://www.pltw. org/experience-pltw/school-locator?search_school=&state= MO&lat=&long=

PLTW Missouri. (2016d). Missouri state data for PLTW assessments in 2013-2014. Rolla, MO: Project Lead the Way Missouri.

PLTW Missouri. (2016e). Missouri state data for PLTW assessments in 2014-2015. Rolla, MO: Project Lead the Way Missouri.

President's Council of Advisors on Science and Technology. (2012). Engage to excel: Producing 1,000,000 additional college graduates with degrees in science, technology, engineering, and mathematics. Retrieved from https://webcache. googleusercontent.com/search?q=cache:POh_vZXfhCIJ:https://obamawhitehouse

.archives.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_2-25-12.pdf+&cd=3&hl=en&ct=clnk&gl=us

Rethwisch, D. (2014, October). *A study of the impact of Project Lead the Way on achievement outcomes in Iowa*. Paper presented at ASEE North Midwest Section Conference, October 2014, Iowa City, IA.

Rogers, C. (2007). The perceptions of Indiana High School Principals related to PLTW. *Journal of Industrial Teacher Education*, *44*(1), 49-65.

Rogers, C., & Portsmore, M. (2004). Bringing engineering to elementary school. *Journal of STEM Education, 5*(3), 14–28.

Rutherford, J. (2009). *Standards 2.0: New models for the new century alternatives to traditional content standards*. Washington, DC: National Academies Press.

Schenk, T., Rethwisch, D., Chapman, M., Laanan, F., Starobin, S., & Zhang, L. (2011). *Achievement outcomes of Project Lead the Way: A study of the impact of PLTW Iowa*. Retrieved from https://www.asee.org/public/conferences/8/papers/3308/download

Schrader, C. (2013, February 14). STEM education: Where the girls are not. *St. Louis Post-Dispatch*. Retrieved from www.stltoday.com

Schunn, C. (2009, Fall). How kids learn engineering: The cognitive science perspective. *The Bridge, 39*(3). Retrieved from http://www.lrdc.pitt.edu/ schunn/research/ papers/ Schunn- Bridge-v39n3.pdf.

Selingo, J. (2008, March). Help wanted. *PRISM, 17*(7). Retrieved from https//www.prism-magazine.org/mar08/feature_01.cfm

Shields, C. (2007). Barriers to the implementation of Project Lead the Way as perceived by Indiana high school principals. *Journal of Industrial Teacher Education*, *44*(3), 43-70

Starobin, S., Schenk, T., Laanan, F., Retwisch, D., Kollasch, A., Chen, Y., & Baul, T. (2013). Evaluation research of the Iowa Project Lead the Way: Final project report, June 2013.

Stone, J.R., III, Alfeld, C., Pearson, D., Lewis, M., & Jensen, S. (2006). *Building academic skills in context: Testing the value of enhanced math learning in CTE* (Final study). St. Paul, MN: National Research Center for Career and Technical Education, University of Minnesota. Retrieved from http://136.165.122.102/UserFiles/File/Math-in-CTE/MathLearningFinalStudy.pdf.

Tai, R. (2012). An examination of the research literature on Project Lead the Way. Charlesville, VA: University of Virginia (November).

Thornberg, D. (2008). Why STEM Topics are interrelated: The importance of interdisciplinary studies in K-12 education. Thornberg Center for Space Exploration. Retrieved from tcse-k12.org/pages/stem.pdf

Tolan, L. (2008). *Career concerns, pathing and professional development of high school technology educators* (Doctoral dissertation). Available from ProQuest Dissertations and Theses database. (UMI No. 3342606).

Tran, N., & Nathan, M. (2010). Pre-college engineering studies: An investigation of the relationship between pre-college engineering studies and student achievement in science and mathematics. *Journal of Engineering Education, 92*(2), 143-157.

True Outcomes. (2005, June). Report on the first year of implementation of the true outcomes assessment system for Project Lead the Way. York, PA: Author.

True Outcomes. (2006, October). Report on the second year of implementation of the true outcomes assessment system for Project Lead the Way. York, PA: Author.

True Outcomes. (2007, October). Report on the third year of implementation of the true outcomes assessment system for Project Lead the Way. York, PA: Author

True Outcomes. (2008, October). Report on the fourth year of implementation of the true outcomes assessment system for Project Lead the Way. York, PA: Author

University of Massachusetts Donahue Institute. (2011). *Increasing student interest in science, technology, engineering, and math (STEM): Massachusetts STEM pipeline fund programs using promising practices*. Retrieved from http://www. mass.edu/stem/documents/Student%20Interest%20Summary%20Report.pdf.

Van Overschelde, J. P. (2013). Project Lead the Way students more prepared for higher education [Special edition]. *American Journal of Engineering Education, 4*(1), 1-12.

Vest, C. (Chair), Baldeschweller, J., Berkeley III, A. R., Bergeneau, R., Dunderstadt J., Greenwood, M. R. C., Irani, R., . . . Wince-Smith, D. (2003, October). *Critical choices: Science, energy, and security*. Final Report of the Secretary of Energy Advisory Board Task Force on the Future of Science Programs at the Department of Energy. Retrieved from https://deep blue.lib.umich.edu/bitstream/handle/ 2027.42/88579/2008_SEAB_Vest_Report. pdf?sequence=1&isAllowed=y

Vanderbilt Instruction in Biomedical Engineering for Secondary Science. (2008). Challenge based interdisciplinary science. Retrieved at http://www.vanth.org/vibes

Werner, G. (2009). Perceptions of parents related to Project Lead the Way (Master's Thesis). Available from ProQuest Dissertations and Theses database. (UMI No. 1469944).

Wigal, C., & Betro, V. (2012, April). *Engineering education's role in improving student understanding and learning of mathematics and sciences*. Paper presented at 2012 ASEE Southeast Section Conference, Chattanooga, TN.

Yates, B. (2013). Project Lead the Way accreditation visit. St. Charles, MO: PLTW Missouri.

Appendix A

The following are the electronic survey questions asked of individuals who volunteered to provide information regarding PLTW Engineering in the state of Missouri:

1) What PLTW Engineering classes do you teach (mark all that apply)?
2) What was your undergraduate major (mark all that apply)?
3) How long have you taught Project Lead the Way classes?
4) Does your school have a Missouri Technology Student Association (TSA) in your district?
5) What is your perception of the status of PLTW curriculum for students to identify engineering problems, in all PLTW coursework?
6) What is your perception of the status of PLTW curriculum for students to formulate engineering problems, in all PLTW coursework?
7) What is your perception of the status of PLTW curriculum for students to solve engineering problems, in all PLTW coursework?
8) What is your perception of the status of PLTW curriculum for students to design a system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability, in all PLTW coursework?
9) What is your perception of the status of PLTW curriculum for students to design experiments, in all PLTW coursework?
10) What is your perception of the status of PLTW curriculum for students to conduct experiments, in all PLTW coursework?

11) What is your perception of the status of PLTW curriculum for students to analyze and interpret data, in all PLTW coursework?

12) What is your perception of the status of PLTW curriculum for students to apply knowledge of mathematics, science and engineering, in all PLTW coursework?

13) What is your perception of the status of PLTW curriculum for students to use the techniques, skills, and modern engineering tools for engineering practice, in all PLTW coursework?

14) What is your perception of the status of PLTW curriculum for students to pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context, in all PLTW coursework?

15) What is your perception of the status of PLTW curriculum for students to demonstrate an understanding of professional responsibility, in all PLTW coursework?

16) What is your perception of the status of PLTW curriculum for students to demonstrate an understanding of ethical responsibility, in all PLTW coursework?

17) What is your perception of the status of PLTW curriculum for students to demonstrate an ability to function on multidisciplinary teams, in all PLTW coursework?

18) What is your perception of the status of PLTW curriculum for students to demonstrate an ability to communicate effectively in all PLTW coursework?

19) What is your perception of the status of PLTW curriculum for students to gain knowledge of contemporary engineering issues, in all PLTW coursework?

20) What is your perception of the status of PLTW curriculum for students to recognize the need to engage in lifelong learning, in all PLTW coursework?

21) What is your perception of the status of PLTW curriculum for students to develop an ability to engage in lifelong learning, in all PLTW coursework?

Appendix B

Missouri Secondary Teacher Survey Information Questions

The following are the interview questions asked of individuals who volunteered to provide further information regarding PLTW Engineering in the state of Missouri:

1) From the state of Missouri's perspective, what are the goals of Project Lead the Way Engineering?
2) Has the state of Missouri been successful in achieving these goals?
3) Do you think that PLTW Engineering high school experiences have caused more students to pursue STEM-related college majors? Why or why not?
4) Through your observations, do you see students who enter college with PLTW Engineering experiences being better prepared than their peers who did not have access to any PLTW Engineering classes?
5) Have you seen any measurable impact on college engineering graduation rates due to previous educational experiences through PLTW Engineering?
6) How are the engineering standards created for PLTW?
7) How important do you think the role of the teacher is in PLTW Engineering?
8) What types of leadership experiences do you believe teachers gain from teaching PLTW Engineering?
9) What kind of experience do you think a student obtains from taking PLTW Engineering?
10) How does PLTW offer equitable and inclusive opportunities to all students, especially underrepresented engineering populations like females and minorities?

11) What specific strategies does PLTW use in attracting females and minority students to consider and ultimately enroll in PLTW Engineering classes?

12) How effective are the professional development opportunities offered by PLTW?

13) What is PLTW, Inc.'s current vision for the PLTW Engineering program?

Appendix C

Missouri PLTW Engineering Enrollment and Assessment Information

Table C1

Enrollment and Assessment Information

2013-2014		
National and State Comparison of Schools and Students		
	Nationally	Missouri
Total Number of Schools that Administered Exams	2,188	104
Total Number of PLTW Students Tested	211,499	12,233
2014-2015		
National and State Comparison of Schools and Students		
	Nationally	Missouri
Total Number of Schools that Administered Exams	2,628	128
Total Number of PLTW Exams Administered	272,304	15,939
Number of Individual Students that Took PLTW Exams	258,215	15,384

Appendix D

Descriptive Statistics

Table D1

National and State Summary (by course) (2013-2014 & 2014-2015)

PLTW Course (13-14)	# students nationally	# students Missouri
Aerospace Engineering	4,143	167
Biotechnical Engineering	2,459	94
Civil Engineering & Architecture	10,520	393
Computer Integrated Manufacturing	6,831	119
Digital Electronics	17,500	607
Introduction to Engineering Design	92,757	4,775
Principles of Engineering	42,092	2,209

PLTW Course (14-15)	# students nationally	# students Missouri
Aerospace Engineering	4,902	201
Biotechnical Engineering	1,843	93
Civil Engineering & Architecture	11,371	396
Computer Integrated Manufacturing	7,559	124
Digital Electronics	18,119	717
Introduction to Engineering Design	113,336	5,897
Principles of Engineering	47,941	2,368

Table D2

National and State Summary (schools) (2013-2014 & 2014-2015)

PLTW Course (13-14)	# schools nationally	# schools Missouri
Aerospace Engineering	220	10
Biotechnical Engineering	133	4
Civil Engineering & Architecture	632	30
Computer Integrated Manufacturing	349	8
Digital Electronics	874	50
Introduction to Engineering Design	1953	98
Principles of Engineering	1589	83

PLTW Course (14-15)	# schools nationally	# schools Missouri
Aerospace Engineering	260	14
Biotechnical Engineering	98	4
Civil Engineering & Architecture	682	33
Computer Integrated Manufacturing	361	8
Digital Electronics	912	55
Introduction to Engineering Design	2,239	115
Principles of Engineering	1,772	94

Table D3

National and State Summary (teachers) (2013-2014)

PLTW Course (13-14)	# teachers nationally	# teachers Missouri
Aerospace Engineering	222	10
Biotechnical Engineering	136	4
Civil Engineering & Architecture	640	30
Computer Integrated Manufacturing	359	8
Digital Electronics	898	50
Introduction to Engineering Design	2350	120
Principles of Engineering	1670	87

PLTW Course (14-15)	# teachers nationally	# teachers Missouri
Aerospace Engineering	261	14
Biotechnical Engineering	98	4
Civil Engineering & Architecture	686	33
Computer Integrated Manufacturing	370	8
Digital Electronics	945	56
Introduction to Engineering Design	2,715	144
Principles of Engineering	1,878	98

Missouri Demographic Information (student) (2013-2014 & 2014-2015)

Table D4

Total # of Missouri PLTW students reported (includes PLTW Engineering, PLTW Biomedical Science and PLTW Computer Science)

Enrollment Demographics	2013-2014 Totals	2014-2015 Totals
Total # of Missouri PLTW students	15355	15384
Total # of males	8394	9944
Total # of females	5202	5440
Total not reported (due to data size of ≤5)	1,759	N/A

Table D5

Missouri Demographic Information (student by grade) (2013-2014 & 2014-2015)

PLTW Demographic Information (by grade)	2013-2014	2014-2015
Total # of Missouri PLTW students	15,355	15,384
Total # of Missouri 8th grade students	6	6
Total # of Missouri 9th grade students	5,256	5,259
Total # of Missouri 10th grade students	4,513	4,520
Total # of Missouri 11th grade students	3,329	3,340
Total # of Missouri 12th grade students	2,236	2,244

Table D6

Breakdown of Student Enrollment, School Achievement and State Achievement (compared to national)

2013-2014 school year	# students enrolled	# schools participating	# MO schools compared to Nat. Avg.	State Avg. compared to Nat. Avg.
Aerospace Engineering	167	14	8 above nat. avg. 2 at nat. avg. 1 below nat. avg. 3 undetermined	MO Avg.: 6 Nat. Avg.: 5
Biotechnical Engineering	94	4	3 above nat. avg. 1 below nat. avg.	MO Avg.: 7 Nat. Avg.: 5
Civil Engineering & Design	393	33	2 above nat. avg. 11 at nat. avg. 4 below nat. avg. 16 undetermined	MO Avg.: 5 Nat. Avg.: 5
Computer Integrated Manufacturing	119	8	1 above nat. avg. 2 at nat. avg. 1 below nat. avg. 4 undetermined	MO Avg.: 6 Nat. Avg.: 5
Digital Electronics	607	55	8 above nat. avg. 6 at nat. avg. 16 below nat. avg. 25 undetermined	MO Avg.: 5 Nat. Avg.: 5
Introduction to Engineering Design	4775	115	44 above nat. avg. 26 at nat. avg. 43 below nat. avg. 2 undetermined	MO Avg.: 5 Nat. Avg.: 5
Principles of Engineering	2209	94	18 above nat. avg. 24 at nat. avg. 41 below nat. avg. 1 undermined	MO Avg.: 5 Nat. Avg.: 5

Table D6 continued

2014-2015 school year	# students enrolled	# schools participating	# MO schools compared to Nat. Avg.	State Avg. compared to Nat. Avg.
Aerospace Engineering	201	14	3 above nat. avg. 5 at nat. avg. 3 below nat. avg. 3 undetermined	MO Avg.: 6 Nat. Avg.: 5
Biotechnical Engineering	93	4	2 above nat. avg. 1 at nat. avg. 1 below nat. avg.	MO Avg.: 7 Nat. Avg.: 5
Civil Engineering & Design	396	33	2 above nat. avg. 11 at nat. avg. 4 below nat. avg. 16 undetermined	MO Avg.: 5 Nat. Avg.: 5
Computer Integrated Manufacturing	124	8	1 above nat. avg. 0 at nat. avg. 3 below nat. avg. 4 undetermined	MO Avg.: 6 Nat. Avg.: 5
Digital Electronics	717	54	8 above nat. avg. 6 at nat. avg. 15 below nat. avg. 25 undetermined	MO Avg.: 5 Nat. Avg.: 5
Introduction to Engineering Design	5,897	112	41 above nat. avg. 27 at nat. avg. 42 below nat. avg. 2 undetermined	MO Avg.: 5 Nat. Avg.: 5
Principles of Engineering	2,368	94	18 above nat. avg. 24 at nat. avg. 41 below nat. avg. 11 undermined	MO Avg.: 5 Nat. Avg.: 5

Vitae

Brian Smith graduated from Quincy (IL) University's School of Education in 2001 and taught middle level students in Communication Arts and Mathematics for four years. He transitioned into a role as an Assistant Principal at Orchard Farm High School in 2005, and in 2007 became the principal of Orchard Farm High School. Brian also earned a Specialist's Degree in Educational Leadership and Policy Analysis in 2005 from the University of Missouri-Columbia. Brian maintains certification as a middle and high school administrator in the state of Missouri. Brian also maintains certification as an elementary teacher, middle school math and English teacher, as well as a high school English teacher. In 2017, after 10 years as a high school principal, Brian left his principal position to become the Executive Director of Planning and Development for the Mehlville School District, allowing him to pursue his passion of strategic planning and school improvement. Upon completion of his doctorate, Brian plans to continue working in the field of education, working as a central office administrator and finishing his remaining classes at Lindenwood University to obtain his Superintendent Certification in the state of Missouri.