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A Quantitative Study Examining Project Lead the Way Gateway Program Outcomes in a Suburban School District

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by

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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.

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Signature: ______________________ Date: 5-3-19

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Abstract

Within the confines of this study, the Researcher investigated Project Lead the Way (PLTW) Gateway program outcomes at a Midwest suburban school district. The study examined specific academic achievement outcomes and attitudes regarding STEAM courses and STEAM careers among students who completed at least one semester in a middle school PLTW Gateway program. The Researcher attempted to determine if there was a difference in student attitudes related to STEAM between students who enrolled in a PLTW Gateway course and students who never enrolled in PLTW Gateway, as determined in an online survey. The Researcher also attempted to determine if there was a difference related to test scores on the Missouri Assessment Program (MAP) in the subject areas of math and science between PLTW Gateway and non-PLTW Gateway students.

Survey results showed that taking one PLTW Gateway course in middle school resulted in more positive attitudes of students, toward future STEAM courses and careers, when compared to peers who did not take any PLTW Gateway courses. Specifically, the study results showed that taking one PLTW Gateway course created more interest in a STEAM career, and resulted in students feeling more prepared for a STEAM career. Also, students who took at least one PLTW course were likely to take another PLTW course in high school. The Researcher's analysis of the historical MAP data from four middle schools over three years (2015, 2016, & 2017) showed no difference between PLTW Gateway and non-PLTW Gateway math and science MAP scores.

The intention of this study was to provide a specific examination of the middle school PLTW Gateway program by comparing attitudes and state test scores of students

who took at least one PLTW Gateway course to those students who did not. Although this study met a need for more specific research examining PLTW Gateway outcomes, a more thorough examination, perhaps a qualitative study of PLTW Gateway students, could expand on the work of this study, shedding even more light on student attitudes regarding STEAM courses and/or careers. The Researcher recommends further research be conducted either by PLTW, Inc., through state PLTW affiliates, or by other individuals, to delve more deeply into attitudes of middle school PLTW Gateway students.

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Chapter One: Introduction

Introduction

Solving problems has been a part of the human experience since humans began to use tools. Transferring the knowledge and skill required to solve problems is one of the things that makes us human. According to Harvard (2011) the biggest challenges taken up by teachers since before the first schools opened included teaching students how to solve problems. As the rate of technological change increased rapidly in the 20th and 21st centuries, teachers preparing future generations for successful adulthood became more complicated. School systems' attempts to prepare students for the future included a broad range of strategies, including constructivist approaches, technical education, and classical liberal arts education. At the end of the 20th century and beginning of the 21st century, the rapidly changing demands of industry in the information age and government pressure created demands from both government and industry to better prepare America's students for a world that was transforming at an increasing pace (Harvard, 2011).

A number of government reports and initiatives beginning with, *A Nation at Risk: The imperative for Educational Reform*, in 1983, and more recently including the, *Common Core State Standards Initiative*, in 2010, and *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics,* in 2012, implored American public schools to better prepare students for the 21st century. A Nation at Risk, Common Core, and Engage to Excel led to a vast array of initiatives in Problem-based Learning (PBL) and Project Based Learning (PBL) and Science, Technology, Engineering, Art, and Math (STEAM) education as a way to meet new societal demands for transferring knowledge and skills to the next generations.

Problem-based Learning and Project Based Learning are interchangeable, per definitions. When spelled out, Problem-based Learning does not have a capital B, while in Project Based Learning, there is no hyphen and all words are capitalized, per definitions and copyright requirement (Tamin & Grant, 2013; Slavich & Zimbardo, 2012). The question of which pedagogies best met the demands for transferring 21st century skills led to many educational studies and initiatives highlighted in this study. Project Lead the Way was one such program initiated on a national level. Specific outcomes of the program at the middle school level and student attitudes about STEAM careers were of particular interest to the Researcher and the focus of this study.

Rationale of the Study

Twenty-first century careers required schools to prepare students with different skills than in the past. According to Larmer (2016), Editor in Chief of the Buck Institute for Education, the profile of a 21st-century graduate was “a responsible, resourceful, persistent critical thinker who knows how to learn, works well with others, is a problem solver, communicates well, and manages time and work effectively” (p. 67). Employers surveyed by the Hart Research Associates (2013) believed that success in the workplace demanded skills, such as creativity, innovative thinking, and application of knowledge and skills to real problems. Both Project and Problem-based learning supported “the development of important real-world skills such as solving complex problems, thinking critically, analyzing and evaluating information, working cooperatively, and communicating effectively” (English & Kitsantas, 2013, p. 129).

PBL offered students a chance to interact with learning in Science, Technology, Engineering, and Math (STEM) while also “fostering student reflection and metacognition" (Ertmer, Schlosser, Clase, & Adedokun, 2014, p. 5). The then-current literature suggested that such skills were sometimes difficult for middle school students to master. Belland, Glazewski, and Richardson (2011) found middle school students often struggled to make the type of evidence-based arguments crucial to scientific inquiry.

Middle school students also struggled with a student role that required "constructing knowledge and making meaning [because] this role conflicts with deeply ingrained habits they have developed through more familiar classroom experiences in which they have been passive recipients of knowledge" (English & Kitsantas, 2013, p. 129). According to the authors cited, exposing students to more PBL and STEAM in middle school had a direct impact on 21st-century career skills. Despite these claims, there was little research on PBL and STEAM at the middle school level.

Other researchers noted that feedback from teachers and peers in PBL and STEAM environments helped students develop fundamental problem-solving abilities, aided students in modifying their thinking, related to problem-solving, and helped them improve the quality of the products they produced (Chaves et al., 2006; Xian & Madhavan, 2013). However, researchers conducted these studies almost exclusively at the college level in engineering and medical programs, where performance on real-world tasks was required (Xian & Madhavan, 2013).

In the Researcher's 24 years of experience in several middle schools, students commonly learned in classroom settings where little performance on real-world tasks was required, and students were passive recipients of knowledge. The Researcher's school district embarked on a PBL/STEAM initiative through the Project Lead the Way (PLTW) program, with the goal of developing 21st-century skills and increasing interest in STEAM careers. Although previous researchers examined PBL and STEAM evidence for specific relationships between PLTW and 21st-century skill development, as well as interest in STEAM careers, a connection was not widely evident in the then-current literature. The Researcher realized that few research studies existed for PLTW Gateway programs.

At the K-12 level, the then-current literature focused on scaffolds, instructional organization models, and teacher training for PBL but not PLTW (Belland, Glazewski, & Richardson, 2011; English & Kitsantas, 2013; Holm, 2011; Liu et al., 2014; Swan, et al., 2013; Tamin & Grant, 2013). The Researcher examined Missouri Assessment Program (MAP) data and surveyed students' attitudes related to STEAM classes and careers, which may potentially allow school districts to create PBL classes that more precisely develop the 21st-century skills essential for success in school and life, while increasing the number of students choosing STEAM careers. If this study reveals a clear difference in math and science state scores for students participating in PBL/STEAM through PLTW, then these findings may add to the then-current literature related to PBL, STEAM, and PLTW.

Purpose of Study

The purpose of this quantitative study was to examine specific academic achievement outcomes and attitudes regarding STEAM courses and STEAM careers among students who completed at least one semester in a middle school PLTW Gateway program. The study participants included 7th through 12th-grade students who took one or more PLTW Gateway courses in middle school and students who did not take a PLTW

Gateway course. The Researcher attempted to determine if there was a difference related to test scores on the MAP in the subject areas of math and science for students enrolled in a PLTW Gateway course and students who never enrolled in PLTW Gateway. The Researcher also attempted to determine if there was a difference in student attitudes related to STEAM between students who enrolled in a PLTW Gateway course and students who never enrolled in PLTW Gateway, as determined in an online survey. The differences outlined in the study, as well as the questions answered, may potentially allow district leaders to make informed decisions related to course offerings, based on the outcomes of the study. The Researcher analyzed the MAP data from four middle schools, over three years (2015, 2016, & 2017), where the PLTW Gateway program served students. The Researcher sought differences among the following variables:

- middle school student participation in PLTW Gateway vs. non-participation and student MAP data in the subject area of math.
- middle school student participation in PLTW Gateway vs. non-participation and student MAP data in the subject area of science.
- middle school participation in PLTW Gateway vs. non-participation and student End of Course (EOC) exam data for Eighth-Grade students in the advanced math subject area of Algebra I.

The Researcher also analyzed data from a student survey to determine the possible relationship between middle school PLTW Gateway and student interest in STEAM careers and also described the findings from the survey concerning percentages and mean ratings. Finally, the Researcher disaggregated survey data collected, based on gender to determine if a difference existed for female students related to interest in STEAM educational programs and STEAM careers.

Hypotheses

Hypothesis 1. There is a difference in knowledge of STEAM education programs between students who participate in PLTW Gateway and students who do not participate in PLTW Gateway.

Hypothesis 2. There is a difference in perceptions of STEAM education programs between students who participate in PLTW Gateway and students who do not participate in PLTW Gateway.

Hypothesis 3. There is a difference in interest in STEAM careers after high school between students who participate in PLTW Gateway and students who do not participate in PLTW Gateway.

Hypothesis 4. There is a difference in interest in STEAM careers after high school between female students who participate in PLTW Gateway and female students who do not participate in PLTW Gateway.

Hypothesis 5. There is a difference in MAP science scores of students who participate in PLTW Gateway and MAP science scores of students who do not participate in PLTW Gateway.

Hypothesis 6. There is a difference in MAP math scores of students who participate in PLTW Gateway and MAP math scores of students who do not participate in PLTW Gateway.

Hypothesis 7. There is a difference in EOC Algebra I scores of students who participate in PLTW Gateway and EOC algebra scores of students who do not participate in PLTW Gateway.

Study Limitations

This study contained some limitations. First, the literature included a large variety of methods for the delivery for 21st-century and STEAM learning. This study focused on only one of those delivery methods - PLTW. Second, the study was limited to one school district in a Midwestern suburban community. Third, the study focused on PLTW Gateway courses offered to students in a middle school master schedule that permitted students only one elective choice. Students who were interested in other electives, such as band, choir, or foreign language did not have the opportunity to take PLTW Gateway courses, and therefore, were not exposed to this program. Finally, the survey used in this study was generated by the Researcher for the population in this specific study in a suburban Midwest school district. Therefore, the survey could not be generalized to other populations.

Definition of Terms

Career and Technical Education: According to the Missouri Department of Elementary and Secondary Education (MODESE, 2018a), **“**Missouri Career Education combines academics and occupational skill training to prepare students of all ages. Training programs are offered in Agriculture, Business, Health Sciences, Family and Consumer Sciences, Skilled Technical Sciences, Technology and Engineering, and Marketing and Cooperative Education” (para. 3).

End-of-Course: according to MODESE (2018b), “The Missouri Assessment Program assesses students' progress toward the Missouri Learning Standards, which are Missouri's content standards. End-of-Course assessments are taken when a student has received instruction on the Missouri Learning Standards for an assessment, regardless of grade level” (para 1).

Missouri Assessment Program: according to MODESE (2018c),

> The Missouri Assessment Program assesses students’ progress toward mastery of the Show-Me Standards which are the educational standards in Missouri. The Grade-Level Assessment is a yearly standards-based test that measures specific skills defined for each grade by the state of Missouri. (para. 1)

All students in grades 3 through 8 took the math and English language arts assessments, while only students in grades 5 and 8 took the science assessment (para. 1).

Problem-based Learning:

> Instructors facilitate learning by having students tackle complex, multifaceted problems in small groups while providing scaffolding, modeling experiences, and opportunities for self-directed learning, which enhances students’ content knowledge, and increases their academic self-efficacy, problem-solving skills, collaboration skills, and self-directed learning skills. (Slavich & Zimbardo, 2012, p. 572)

For this study, The Researcher used Project Based Learning and Problem-based learning interchangeably.

Project Based Learning: “An instructional model that is based in the constructivist approach to learning, which entails the construction of knowledge with multiple perspectives, within a social activity, and allows for self-awareness of learning and knowing while being context dependent" (Tamin & Grant 2013, p. 73). For this study, the Researcher used Project Based Learning and Problem-based Learning interchangeably.

Project Lead the Way: According to MODESE website, PLTW

> offers a dynamic high school program that provides students with real-world learning and hands-on experience. Students interested in engineering, biomechanics, aeronautics, biomedical sciences and other applied math and science arenas will discover PLTW is an exciting portal into these industries. (2017, para. 1)

Project Lead the Way Gateway: According to MODESE website, the middle school version of PLTW (called PLTW Gateway) "illuminates the range of paths and possibilities students can look forward to in high school and beyond." The program consists of several nine-week, stand-alone units implemented in 6th through 8th-grade as determined by each school (2017, para. 5).

Science, Technology, Engineering, Art, and Math: "Intentionally integrating the concepts and practices articulated with 21st-century skills in curriculum, instruction, assessment, and enrichment, while purposefully integrating science, technology, engineering, arts (including but not limited to the visual and performing arts), and mathematics" (Gettings, 2016, p. 10).

Science, Technology, Engineering, and Math: "Teaching and learning in the fields of science, technology, engineering, and mathematics. It typically includes educational activities across all grade levels – from pre-school to post-doctorate – in both formal (e.g., classrooms) and informal (e.g., afterschool programs) settings" (Gonzalez & Kuenzi, 2012, p. 1).

Summary

The push educators felt from government and industry to prepare students for a future world focused on 21st-century skills (like critical thinking, creativity, collaboration, and communication) heightened over the 20 years previous to this writing. The focus on 21st-century skills led school decision-makers to adopt programs in STEAM and PBL. The question of the success of programs designed to prepare students for STEAM careers continued to exist throughout the then-current research. Some programs used stand-alone formats, like PLTW, which offered students courses specifically designed for teaching different elements of STEAM and 21st-century skills. These courses included relevant topics, like engineering or biomedical sciences. Other programs used a more integrated approach where lessons included STEAM and 21st-century skills in many different courses, by emphasizing 21st-century skills corresponding with creativity, collaboration, communication, and critical thinking, and by presenting students with real-world problems to solve. All of these programs produced results with varying degrees of success, as outlined in relevant literature. Some of these programs were studied more thoroughly than others. Because PLTW was widely implemented but sparsely studied, the Researcher's study examined the program outcomes of a specific PLTW program in a suburban district in the state of Missouri. More specifically, Chapter Two examines the history of PBL, STEAM in middle schools, developing 21st-century skills, delivery methods for STEAM and PBL, student attitudes related to STEAM, and the history of PLTW. Chapter Three describes the Researcher's study design, including the methods used to gather historical and survey data. Chapter Four described the study's findings, and Chapter Five discussed the study findings as they related to the existing literature in the field.

Chapter Two: Review of Literature

Introduction

As the second decade of the 21st century rapidly approached, educational leaders around the United States recognized the need to provide programs and research designed to prepare students for daily life and career opportunities. This better preparation depended increasingly on Science, Technology, Engineering, and Math (STEM) literacy and proficiency. A number of different pedagogies emerged from researchers' attempts to prepare students for the 21st century workforce. These pedagogies included high school, middle school and elementary Problem-based Learning (PBL) programs, STEM programs, or Science, Technology, Engineering, Art, and Math (STEAM) programs, and PLTW programs, as well as career outreach and readiness programs (Hess, Sorge, & Feldhaus, 2016).

The Researcher examined the literature for all of these programs in this chapter and organized the literature review based on several themes: the case for PBL, a brief history of PBL, the case for STEAM in middle school, developing 21st-century skills, methods of delivery of STEAM and PBL specifically, attitudes regarding STEAM, and finally the limited research on the specific program of PLTW. The Researcher paid particular attention to the themes of PLTW and attitudes regarding STEAM and STEAM careers, as this was the focus of the data collected in this study.

The Case for PBL

Over the 50 years previous to this writing, pedagogical approaches changed to meet the rapidly changing demands of the 21st-century economy. Slavich and Zimbardo (2012) pointed out that a great deal of research caused the teacher-student relationship to change from one where educators believed students learned as passive receivers of knowledge to one where teachers actively engaged students in their learning. Student objectives shifted over the last half-century as well, with expectations that students did more than just master content. The modern student was also encouraged to develop skills in the areas of self-regulation, self-efficacy, and life-long learning (Slavich & Zimbardo, 2012). As universities and educational practitioners did more research, several new fundamental pedagogical approaches developed. One of them included Problem-based learning (Slavich & Zimbardo, 2012). Savery (2006) defined Problem-based Learning as "an instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem" (p. 12). Many researchers outlined how Problem-based Learning empowered students, not just to acquire knowledge, but also to apply it to real-world problems (Cicchino, 2015; Ertmer et al., 2006; Savery, 2006; Slavich & Zimbardo, 2012).

Research in the area of Project Based Learning defined a similar pedagogical path to improved student learning outcomes, as well. Tamin and Grant (2013) described Project-based Learning as "an instructional model that is based in the constructivist approach to learning, which entails the construction of knowledge with multiple perspectives, within a social activity, and allows for self-awareness of learning and knowing while being context dependent" (p.73). The Buck Institute for Education (2015) described Project Based Learning as "a teaching method in which students learn how to apply knowledge to the real-world, and use it to solve problems, answer complex questions and create high quality products" (p. 1). Project and Problem-based Learning both harkened back to Dewey's constructivist approach. "Constructivism aligns well with PBL as it places emphasis on the learner's ownership of ideas and a personal interpretation of knowledge" (Pecore, 2012, p. 9). In a PBL pedagogy using a constructivist approach, researchers believed that students were important actors and creators of their own learning. Figuring out a problem was the motivating factor for constructing learning in the view of both constructivist and PBL pedagogies (Savery & Duffy, 1995).

The literature often mentioned that these two pedagogical approaches shared overlapping philosophies and even the same acronym, PBL, as to be effectively synonymous pedagogies for this literature review. According to Savery (2006), researchers determined that the critical features of Problem-based Learning included activities that were learner-centered, based on an ill-structured problem, integrated over subjects, collaborative among students, based on real-world problems, and included analysis and reflection. Project-based learning's key features included all mentioned above along with sustained inquiry and creation of a free, public product (Buck Institute for Education, 2016). The research also outlined pedagogical applications in multiple educational settings over the years, from elementary school settings to medical schools, where the modern concept of PBL began (Buck Institute for Education, 2016; Savery, 2006).

A Brief History of Problem and Project-based Learning

An overview of the literature in PBL revealed that as a well-defined pedagogy, PBL began in medical schools in the 1950s where it remained specific to medical education for many years (Savery, 2006). Later, however, educators in other disciplines were influenced by the work of medical school PBL researchers. Xian and Madhavan (2013) revealed, in a bibliographic meta-analysis, the work of PBL pioneer Barrows regarding how the PBL pedagogy was adopted in the fields of engineering and science at the university level, and eventually came to influence K-12 education (as cited in Xian & Madhavan, 2013). The analysis included keywords revealed earlier in the literature review as essential elements of PBL pedagogy (Xian & Madhavan, 2013). The keywords used by researchers in medicine, engineering, science, and two other categories labeled general, or other, included, but were not limited to problem-solving, critical thinking, self-directed learning, active learning, and collaborative learning (Xian & Madhavan, 2013).

PBL was also used by the Indiana University School of Nursing to revamp the Master of Nursing program. The nursing division of medical education also included 10 ill-structured problems, which included PBL key concepts of problem-solving, self-study, applying new knowledge, hypothesis testing, synthesizing, and evaluating the experience (Chaves et al., 2006). Savery (2006) revealed in the very first issue of, *The Interdisciplinary Journal of Problem-based Learning*, that many highly reputable universities adopted PBL, including The University of Delaware, Samford University, and the University of Illinois Mathematics and Science Academy. Moreover, with the publication of the first article in 2006, Purdue University used, *The Interdisciplinary Journal of Problem-based Learning*, to promote the even more extensive application of PBL principals (Ertmer & Simons, 2006). Finally, Savery (2006) pointed out “the adoption of PBL has expanded into elementary schools, middle schools, high schools, universities, and professional schools” (p. 11).

The history of Project-based Learning was highlighted as older but less clearly defined as that of Problem-based Learning. According to Holm (2011), project-based learning as a methodology in K-12 education traced its roots back to Kilpatrick, in 1918. Kilpatrick promoted a project method for teaching that was student-centered and included purposing, planning, executing, and judging ideas which would later be promoted by the Buck Institute for Education as PBL. However, the majority of application of Kilpatrick's ideas and other earlier project-style learning ideas were in the realm of technical education. Almost all public schools in America eventually adopted some variation of industrial education, but few followed any of the principals outlined by Kilpatrick (as cited by Holm, 2011). The idea of combining hands-on work with theoretical knowledge in the field of engineering found its American origins as early as 1835 and the Rensselaer Polytechnic Institute. At this institution, students applied ideas in mechanical philosophy to the machinery of steamboats, mills and factories, which became American's first school of civil engineering. Another school where students applied the ideas of engineering was the Worcester Technical Institute. The Worcester Technical Institute was the first engineering school with a machine shop where students could learn theory in class and then apply it in a real working shop (Kelly, 2012).

More recently, one of the leading proponents of Problem-based Learning and Project Based Learning was Purdue University College of Engineering. Not only did Purdue apply the principals of PBL in their college of engineering, but they also led the study of PBL pedagogy through the publication of, *The Interdisciplinary Journal of Problem-based Learning.* The journal published two issues a year since 2006 and focused on the latest research in the pedagogy of Problem-based Learning and Project Based

Learning (Purdue University Press Open Access Journals, 2019). Finally, according to Slavich and Zimbardo (2012), Problem-based Learning, with its emphasis on complex problems solved by students in groups and individually, was utilized to engage all variety of students in a myriad of educational settings (Slavich & Zimbardo, 2012). The PBL approach, along with several others discussed by Slavich and Zimbardo (2012), was identified as essentially a constructivist approach in which “students generate knowledge and meaning best [because] they have experiences that lead them to realize how new information conflicts with their prevailing understanding of a concept or idea” (p. 574). The thinking of proponents of PBL in the then-current literature suggested that this constructivist approach was, and would be in the future, the best pedagogy to prepare students for a rapidly changing world. This view was best exemplified by Larmer (2016), the Editor in Chief of the Buck Institute for Education, when he described a consensus view of the ideal K-12 graduate as “a responsible, resourceful, persistent critical thinker who knows how to learn, works well with others, is a problem solver, communicates well, and manages time and work effectively” (p. 66).

Despite the praise and promise highlighted in the PBL literature, a healthy amount of reservation and skepticism regarding the effectiveness of this pedagogy was also raised. Savery (2006) pointed out several specific areas where caution related to PBL was warranted, saying, “The widespread adoption of the PBL instructional approach by different disciplines, for different age levels, and in different content domains have produced some misapplications and misconceptions of PBL” (p. 11). Reasons for these misconceptions included: confusing PBL curriculum with teaching problem-solving, adoption of PBL without sufficient staff commitment, lack of research and development, lack of investment in preparation and follow through, and inappropriate assessment and evaluation strategies (Savery, 2006). Another criticism of the PBL approach, according to Hung (2016), was the lack of a concise, systematic framework for designing essential problems in PBL pedagogy. The research before 2016 was full of vague guidelines describing a PBL problem as ill-structured, complex, real-life, and authentic. Maudsley (1999) referred to PBL as “a recycled idea with an identity crisis. Like its parent approach, experiential learning, PBL has been used to describe heterogeneous educational activities” (p. 2). Additionally, Hung (2016) acknowledged that there were no clear guidelines for teachers to develop or design a starting problem for students. As essential as designing and presenting a good problem to students was to successful implementation of PBL instruction, the research lacked clear rules for how to build good problems (Hung, 2016).

Education in Middle Schools

The pedagogy of PBL revealed itself in the literature as significantly linked to STEM education initiatives as well. Much of the literature on PBL overlapped with STEM initiatives in schools, and almost all of the research from both of these educational initiatives claimed an international societal imperative to improve education in the areas of real-world problem-solving and skill development in STEM. According to Byars-Winston (2014), “There is an urgent need to improve the educational and career development of individuals to work in STEM fields” (p. 340). Jensen and Sjaastad (2013) highlighted concern regarding students’ math and science achievement as reflected in their nations’ standardized test scores, as well as low participation in STEM fields. Their study highlighted a Norwegian out-of-school program's influence on motivation or interest in STEM fields (Jensen & Sjaastad, 2013).

In the United States, national interests like the President's Council of Advisor's on Science and Technology (2012) recommended a significant increase in STEM education. In an official document published by the council (2012) titled, "Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics," the council highlighted the need for more college graduates in STEM (President's Council of Advisor's on Science and Technology, 2012). According to this President's Council's Report to the President, "To meet this goal, the United States will need to increase the number of students who receive undergraduate STEM degrees by about 34% annually over current rates" (p. i). The research in the area of STEM and PBL highlighted this need for increased STEM education and also pointed out a wide variety of methodologies available to educational institutions designed to implement STEM.

Much of the literature on STEM instruction integrated STEM and PBL into already existing core curriculum, while other initiatives involved traditional career and technical education programs that existed throughout the 20th century (Kitchel, 2015). Other studies highlighted STEM initiatives outside the traditional school day or that involved adults in STEM fields (Jensen & Sjaastad, 2013; Hall & Miro, 2016). This part of the literature articulated many key trends in STEM education that educators implemented in K-12 education over several years recent to this writing.

One trend was the use of the PBL approach in K-12 classrooms to engage students in STEM thinking. One such study highlighted the need for making science classrooms into STEM classrooms where researchers investigated a science inquiry/PBL-based approach to learning. Hiller and Kitsantas (2014) examined a program in the area of ‘citizen science’ where students were encouraged to work with actual scientists in the field assisting with ongoing research (Hiller & Kitsantas, 2014). The purpose of the study was multileveled; studying a citizen science intervention and a relationship to, “self-efficacy, task interest, outcome expectations, science content knowledge, and career motivation” (Hiller & Kitsantas, 2014, p. 306). According to Hiller and Kitsantas (2014), science educators were accused of boring students into abandoning STEM careers. This study examined improving student interest by solving real scientific problems with real scientists (Hiller & Kitsantas, 2014).

Another study, by Abbott (2016), examined embedding PBL in science classrooms as a way to motivate students to value STEM through solving real-world problems, which was an integral component of PBL, while also serving the need of improving STEM skills and motivation (Abbott, 2016). Abbott (2016) pointed out that through PBL in a science classroom “students become self-directed owners of the problem as their inquiry drives their exploration, enabling them to make meaningful connections between the disciplines and career fields” (p. 34).

Finally, Belland et al. (2011) argued that one of the most critical STEM skills - presenting arguments in support of a solution - was difficult for middle school students to master without specific scaffolds in place for student use. This study presented students with ill-structured problems to solve in a PBL science classroom and then supported student argumentation with a computer-based argumentation scaffold. The authors concluded that this type of scaffolding could support improved student argumentation abilities in a science classroom (Belland et al., 2011). A common theme tying all PBL-based STEM initiatives together was the introduction of authentic scientific problems to solve in a classroom in order to improve STEM academic skills. However, the research was unclear about the impact that PBL had on student motivation in the classroom and students making plans to enter STEM careers.

Another trend found related to STEM education provided students with positive interactions with adults, other than their regular teachers, in order to change attitudes about STEM education. Several programs in the United States (as well as one in Norway) developed educator implemented STEM-based programs in concert with STEM professionals. These STEM programs included student contact with college students studying STEM careers and professional practitioners in STEM fields. Researchers designed and studied this contact with both college students and professionals in the field in order to increase student engagement in STEM content. Jensen and Sjaastad (2013) examined a Norwegian out-of-school program called ENT3R. One of the important discoveries made in this study was the idea that both college students as teachers and professionals as mentors in the program helped students develop positive attitudes towards math and solving complicated math problems. According to Jensen and Sjassstad (2013), participants in ENT3R were “comfortable asking for help on problematic tasks and confident that the help would be beneficial and correct” (p. 1455). The researchers also found that high school-aged participants in this study were able to establish positive relationships with mentors who were professionals in math-related fields. These positive relationships improved student attitudes towards STEM math careers in more than half of the participants (Jensen & Sjassstad, 2013). Hiller and Kitsantas (2014) also found this improvement in STEM attitudes, by noting “that providing this type of experience [working with practicing professional scientists] as a part of a formal classroom program is a viable means for promoting student achievement and STEM career motivation” (p. 309). In both of these studies, participants had multiple exposures to practicing STEM professionals over an extended period with fairly positive results.

In contrast, Clemson University researchers studied elementary-aged participants in a one-day Engineering Expo hosted by the university during National Engineers’ Week (Alongi, 2015). The researchers found in a multi-year study that students from Clemson Elementary, who attended a yearly engineering exposition, had similar perceptions and interests in STEM as students from Central Elementary, who did not attend the exposition. The authors highlighted many factors in student perceptions regarding careers, including parental social guidance and quality of teaching, as well as noting that younger students had more interest toward STEM careers that older students (Kurz, Yoder, & Zu, 2015).

Finally, one study highlighted positive adult influence for STEM career choice from sources other than college students and professional scientists. The research suggested that minorities and other under-represented groups in STEM careers experienced a significant positive influence to choose a STEM career. According to this study, completed in traditionally under-represented communities, Career Development Professionals (CDPs) played an essential role in encouraging minority students to enter STEM careers, thus increasing diversity in these careers (Byars-Winston, 2014). Byars-Winston (2014) pointed out that CDPs could make a difference in attitudes toward STEM where “under-represented minorities attraction to and achievement in these fields are influenced by more than just ability" (p. 345), The key to fostering these positive attitudes was for CDPs to understand STEM careers and articulate the great need for these careers to minority students. Overall, the literature supported more contact between adults in STEM careers than less. However, researchers suggested that more research was required (Byars-Winston, 2014).

Not only did the literature highlight changes for students to prepare them for STEM careers, but also changes for teachers in the areas of training and practice. Ertmer, Schlosser, Clase, and Adedokun (2014) studied a professional development initiative designed to improve both teachers' pedagogy and knowledge related to STEM education. Teachers received intensive training in PBL pedagogy and designed STEM units in a two-week summer professional development session (Ertmer et al., 2014). Researchers surveyed participating teachers, rated their knowledge of PBL as significantly higher after the training, and noted that they gained confidence in their abilities to teach science concepts effectively (Ertmer et al., 2014).

Another study by English and Kitsantas (2013) revealed that teachers not only benefitted from additional professional development, but also well-defined teaching models related to STEM and PBL initiatives. English and Kitsantas (2013) presented a theoretical model for PBL instruction that included student self-regulated learning as a model for helping students work through the challenges of a STEM/PBL classroom. The model clearly outlined practical techniques, especially in the form of learning scaffolds that teachers implemented. These included the well-crafted driving question, clearly stating learning goals, launcher activities, and activity structures to name a few (English & Kitsantas, 2013).

Researchers Swan et al. (2013) studied another model for PBL instruction called Preparation for Future Learning (PFL). Swan et al. (2013) stated, “According to the PFL model, students prepare to learn a particular concept by exploring the domain space and working on sets of problems before they receive formal instruction on how to solve them” (p. 92). In this particular study, students investigated authentic STEM problems, which applied the PFL model to an interdisciplinary data literacy unit. The study conclusions supported the PFL framework as the basis for developing STEM-related instructional materials, specifically related to data literacy in real-world contexts (Swan et al., 2013). Overall, the literature contained several examples of pedagogical models useful in PBL and STEM environments and lent credence to the efficacy of well-designed PBL and STEM initiatives.

Developing 21st-Century Skills through PBL and STEAM

Solving real-world problems was the basis for developing 21st-century skills in much of the literature. Solving problems related to pedagogy in various forms appeared over and over in the literature, where studies outlined specific PBL strategies to improve the 21st-century skill of solving ill-structured problems directly. (Belland et al., 2011, English & Kitsantas, 2013, Savery, 2006). Tawfik and Trueman (2015) described the role that Case-Based Reasoning played in assisting learners in solving ill-structured problems. The study supported both providing students with difficult problems to solve, but also case libraries containing the work of professional practitioners in place of other more restrictive scaffolds. Students were encouraged to not only think critically to solve problems, but to use the collective knowledge of professionals to inform their thinking (Tawfik & Trueman, 2015).

The integration of subjects appeared as an essential element of PBL related to solving problems, as well. Childers et al. (2016) outlined how six high school teachers integrated their subject areas to provide students with the opportunity to solve multiple real-world problems that were part of the local chicken hatchery industry. These ill-structured problems encompassed genetic research, designing, building and maintaining a chicken hatchery, and sharing their results through community partnerships. The researchers described the benefits of solving problems in an integrated PBL environment as “STEM PBL experiences that integrate relevant science and engineering concepts enable students to practice skills in critical thinking, problem-solving, and collaboration” (p. 53). Miles, Slagter van Tryon, and Mensah (2015) described a professional development program called TechMath that brought teachers together with business partners to design a PBL pedagogy consisting of instructional modules designed to elicit solutions to real-world business problems. In a study involving first-year college engineering students, Rodgers et al. (2015) found that students benefited from high quality, specific feedback when solving ill-structured problems. All of these studies noted that problem-solving was a key benefit of PBL in developing 21st-century skills (Childers et al., 2016; Miles, Slagter van Tryon, & Mensah, 2015; Rodgers et al., 2015).

Another 21st-century skill that frequently appeared in the literature as part of PBL pedagogy was collaboration (Hall & Miro, 2016; Imafuku, Kataoka, Mayahara, Suzuki, & Saiki, 2014; Lee, Huh, & Reigeluth, 2015). Researchers described various programs and approaches under the PBL umbrella that emphasized collaboration. Hall and Miro (2016) analyzed four different approaches to STEM education: STEM Traditional Courses, Engineering Optional Programs, STEM Platform School, and Virtual STEM

Academy and found that, when key components of PBL were missing from these approaches, STEM learning and interest in STEM careers was lacking. Both decreased learning and interest in STEM careers among students. Decreased learning and interest in STEM careers were especially true when STEM programs focused on direct instruction as pedagogy, instead of more collaborative PBL approaches. Hall and Miro's (2016) study recommended "higher level questioning strategies, the integration of various subject areas, student discussion, and student self-assessment" (p. 318). The researchers in this study noted that the strategies mentioned had the most impact in PBL environments that were student-centered and included collaborative interaction among students (Hall & Miro, 2016).

Lee, Huh, and Reigeluth (2015) studied Collaborative Project Based Learning (CPBL) specifically and identified three types of conflict that occurred in CPBL: task related, process related, and relationship related. Their findings shed light on fears that may impede teachers from adopting PBL and recommended placing at least one student with strong social skills in each group to serve as a collaboration model, thus creating CPBL that helped students learn how to collaborate, as well as use collaboration to enhance PBL learning experiences (Lee et al., 2015).

In a study conducted by Japanese researchers working in a medical school, researchers identified the benefits of cross-disciplinary PBL tutorials (Imafuku, Kataoka, Mayahara, Suzuki, & Saiki, 2014). This cross-disciplinary collaborative approach improved medical students' understanding of the work of other STEM fields, like dentistry, nursing, and pharmaceuticals for students of medicine. The study also revealed how collaborative PBL improved knowledge construction in the students' chosen fields, as well as collaboration skills in general (Imafuku et al., 2014). Finally, Cicchino (2015) revealed how game-based learning (GBL) engaged students in solving problems as part of a game and required collaboration through student discourse to win the game made up of historical scenarios in an 8th-grade social studies class. In GBL programs, teachers encouraged students to collaborate in order to solve ill-structured problems as part of the game (Cicchino, 2015).

The practice of collaborating to solve problems, just as was the case in other PBL studied throughout the literature, resulted in the development of collaboration skills along with content knowledge. Researchers who implemented PBL provided for the development of the 21st-century skill of collaboration through this pedagogy. PBL instruction also included the application of engineering and design thinking in classrooms, throughout much of the research (Cicchino, 2015; Hall & Miro, 2016; Imafuku et al., 2014; Lee et al., 2015). This pedagogy emphasized exposing students to the thinking processes that engineers and designers went through to solve real-world problems, as well as teaching students how to apply that thinking as a 21st-century skill.

Exposing students to design thinking or the engineering design process occurred in the literature at various grade levels. In one action research project, Abbott (2016), a 6th-grade science teacher, used a PBL unit to introduce her students to the engineering design process (EDP) in order for students to solve a chemical pollution problem in third-world countries. Students designed a chemical filter prototype using a six-step EDP process. The researcher identified the EDP process for her 6th-grade students as follows: “1. State the Problem. 2. Generate Ideas. 3. Select a solution. 4. Build the Item. 5. Evaluate. 6. Present Results” (Abbott, 2016, p. 38). The author also described the six steps as cyclical with the continuation of the process after presentation explicitly expressed to students, as well and noted that the Next Generation Science Standards supported numerous revisions through the design process (Abbott, 2016).

Another study conducted through professional development for teachers encouraged designing lessons using EDP. Billiar, Hubelbank, Oliva, and Camesano (2014) provided an almost identical template for the engineering design process. These researchers included feedback loops from the select-a-solution step to the research step and the test/evaluate step to the select-best-solution step. The researchers in this study also included several different steps, including research and rank, develop possible solutions, and reassess and revise. Both Abbott (2016) and Billiar et al. (2014), in their studies, emphasized the importance of solving problems through a clear step-by-step process, evaluating ideas through trial and error, and testing results through prototyping and publishing to a critical audience (Abbott, 2016; Billiar, Hubelbank, Oliva, & Camesano, 2014).

In contrast to the prescriptive nature of a step-by-step EDP, Cusens and Byrd (2013) emphasized the importance of copying and drawing on analogies with iconic examples as a way to improve design for students of architecture. They emphasized the need for students solving complex design problems to draw on the mentorship of experts early in their education with encouragement to experiment with new design ideas. Whether copying experts' designs or using an EDP template, the literature emphasized the importance of engaging students at all levels in the design process as a way to develop the skills deemed necessary for success in the highly competitive 21st-century job market (Abbott, 2016; Billiar et al., 2014; Cusens & Byrd, 2013).

Along with problem-solving, another skill that was a part of numerous research studies, which looked to prepare students for careers in the 21st century, included the ability to think critically - a skill that traditional schools had often neglected (Campbell & Kresyman, 2015). However, PBL and STEM schools in the literature included the development of critical thinking skills in students as an essential component of PBL and STEM instruction (Hall & Miro, 2016; Larmer, 2016; Tawfik & Trueman, 2015). Cicchino (2015) described how GBL in a PBL context encouraged students to integrate learning from their social studies class with experience that they had with their teammates in GBL. Students integrating their learning from their social studies class and their teammates in GBL provided an extremely high level of critical thinking. Teachers required students participating in GBL to extend thinking and synthesize information to win the game. Tawfik and Trueman (2015) revealed how case libraries in PBL assisted students in developing critical thinking through 'analogical reasoning process.' Students in this study built critical thinking by solving problems with the support of a library of analogous problems solved by experts (p. 17). PBL pedagogy put students in situations where solving problems required critical thinking. Larmer (2016) stated, "With guidance from the teacher students find resources to help answer their questions and evaluate the quality and adequacy of the information they're gathering" (p. 67). Finally, Hall and Miro (2016) noted in their study of multiple delivery methods of STEM that a PBL approach to STEM education encouraged self-regulated learning through trial and error. Self-regulated learning allowed students to reflect on their learning, increasing their critical thinking and reasoning skills. Schools that desired to develop 21st century skills implemented pedagogies that included critical thinking, whether it be through GBL, case libraries in PBL, or self-regulated learning.

Methods of Delivering STEAM/PBL to Students

The importance of preparing students for the 21st-century economy demanded that educators develop PBL and STEM-based pedagogies to meet new essential outcomes for graduates. Educators throughout the United States and the world generally agreed that developing 21st-century skills in all students through both PBL and STEM initiatives was a worthy goal (Hart Research Associates, 2015; Harvard, 2014). However, the literature did not always agree on the best method of delivery for PBL and STEM (Grubbs, 2013; Kitchel 2015; Maudsley, 1999). Several themes for delivering PBL and STEM emerged, falling into five main categories. Those categories included initiatives that revisited traditional Career and Technical Education (CTE) with more emphasis on real-world problem-solving (Grubbs, 2013); programs that emphasized connecting and collaborating with the broader community, especially businesses with 21st-century skill requirements and scientists working in STEM fields (Hayes, 2013); pedagogies that emphasized interdisciplinary problem-solving (Grubbs, 2013); initiatives that immersed teachers in PBL and STEM thinking and teaching strategies through professional development (Miles et al., 2015); and finally, programs that created stand-alone STEM schools or programs within existing schools (Hayes, 2013; Peters-Burton et al.,2014). All of the school initiatives in these five categories contained similarities and differences with each other, and most importantly all claimed to have a positive impact on developing 21st-century skills in some manner.

Traditional career and technical education programs always included the use of technology in a hands-on manner and an emphasis on preparing students for the work world. However, the programs did not often include some other key 21st-century skills, such as collaboration or the integration of skills from multiple disciplines to solve problems. Several initiatives in the literature revealed an approach to STEM education through traditional CTE programs, where hands-on work in a traditional CTE class also included other 21st-century skills, like collaboration and communication. Grubbs (2013) described a robotics program where middle school students not only learned the mechanics of robotics, but also designed robots to solve a real-world problem in their community. Students had to design a robot to clear the streets of their town in design teams autonomously. The author pointed out how students not only learned robotics but also learned and applied state math, science, and communication arts standards, while also developing important collaboration skills (Grubbs, 2013).

In another study Kitchel (2015) examined perceptions of middle and high school principals regarding CTE courses' contribution to school STEM goals, focusing particularly on student leadership and career readiness. The author found that CTE programs, along with student CTE organizations, played an important role in developing 21st-century leadership skills. However, the principals interviewed in the study noted that the integration of traditional math and science courses with CTE courses could improve STEM skills for students. In a case study of one rural CTE school, Peters-Burton et al. (2014) revealed the success of a non-traditional CTE school where teachers emphasized student-centered instruction along with the integration of rigorous math, science, and engineering curriculum. All students took honors courses, and much of the curriculum existed in partnership with a local community college and a nearby four-year college. Students even had the opportunity to stay at the school for a fifth year and obtained an associate's degree from the community college at no charge. Students in this case study not only developed STEM skills, but also scored higher than students in surrounding traditional high schools on state assessments (Peters-Burton et al., 2014).

Hayes (2013) described how a traditional high school CTE program transformed into a state of the art PLTW advanced composites course. This program took an existing CTE structure in the high school and used the PLTW program to meet a need that the local aerospace industry identified in the area of advanced composites. The author's study pointed out a key aspect of this transformation. Traditional CTE teachers made the switch to an advanced, composites course quickly and easily, because they used their skills working with wood and metal, which transferred to advanced composites instruction. Additionally, students' development of this 21st-century technical skill filled an essential need for a growing advanced composites industry, while also helping students learn to use new materials for solving 21st-century problems. Overall, the literature showed how traditional CTE programs were adapting to use PBL and STEM pedagogies to allow more students to develop the skills necessary to compete in a global economy.

Another theme that emerged in PBL and STEM education was a connection with the broader community, especially business with a high demand for graduates with STEM skills, community colleges and universities, and actual scientists and other professionals working in STEM fields. When making specific types of community connections that included K-12 students assisting scientists in actual research, researchers in STEM fields named their collaborative efforts as ‘citizen science.’ These STEM researchers valued citizen science as a way to encourage interest in science generally and as an encouragement to students to see STEM careers as a viable career option (Wolf, 2016). Hiller and Kitstantas (2014) pointed out in their study of a middle school citizen science program that this type of STEM pedagogy both increased mastery experiences in STEM and improved understanding of traditional science standards. Through collecting real data in natural environments for working scientists, middle school students were able to gain formal knowledge and skill, as well as enjoy positive interactions with scientists, ultimately envisioning themselves working in these STEM careers after graduation. The scientists benefited as well, with highly sought-after volunteer work and knowledge that they were passing on through their expertise, as well as interest in their field to future generations of scientists (Hiller & Kitstantas, 2014).

Another example of citizen science was a study of preservice elementary teachers. Scott (2016) noted the benefits to pre-service teachers in both their science content knowledge and their attitudes toward incorporating STEM projects in their future classrooms. This study revealed that both adult and K-12 learners benefitted from STEM projects that focused on local scientific work in the field (Scott, 2016).

Finally, Abbott (2016) showed in another study of middle students how students could use a science classroom to solve a worldwide problem of chemical pollution in the garment industry using the engineering design process to develop prototypes for filtering water. Students submitted written portfolios to the United Nations for their culminating activities. In all of these citizen science projects, students benefited from applying science to real-world problems in collaboration with different partners in the broader community outside of the school classroom (Abbott, 2016).

Another type of STEM community involvement highlighted in the literature included collaboration with business and industry to engage students in solving problems faced daily in these industries. Childers et al. (2016) designed a fully integrated high school PBL unit where students worked with their local community's chicken hatcheries to meet a series of design challenges particular to that industry. Students received feedback from chicken hatchery experts on their genetic engineering proposals, as well as designs for a complete working hatchery. Hayes (2013) demonstrated how the aerospace industry in Washington State collaborated with a local high school CTE and PLTW teacher to engage students in the 21st-century trade of advanced composites. "With district consent . . . and heavy support from local technical colleges and industry, former shop teacher Macdonald put together one of the first high school composite courses in Washington state in 2010" (as cited in Hayes, 2013, p. 52-53). The school district in this article made a major effort to work with aerospace companies to supply this important 21st-century industry with a properly trained workforce. In return, the school district received financial resources, expert advice, and future job opportunities for many students.

Finally, Peters-Burton et al. (2014) explained how Wayne School of Engineering, a rural STEM high school, extended student-learning opportunities outside of the normal school day by requiring students to collaborate with organizations throughout their community. Sophomores completed a community service project, which they researched on a global scale as juniors, and seniors completed a 60-hour internship with a local organization in a STEM field. Throughout the literature, partnerships with business and community proved vital to enhancing STEM and PBL learning experiences and developing students' and teachers' 21st-century skills (Peters-Burton et al., 2014).

Another vital collaboration technique highlighted in the literature included projects that teamed colleges and universities with students in K-12 settings. According to Jensen and Sjaastad (2013) in a study of high school students in Norway, those students developed improved STEM skills through participation in an after-school program called ENT3R. Students in this program received instruction from college student mentors/instructors studying in STEM fields. Students benefitted from the relationships they built with these instructors in areas of expectations for success and interest in STEM careers, and the authors recommended this type of collaboration stating, "The results of this study encourage the initiation of and provide design principles for the development of out-of-school projects that forge school-community-university partnerships" (Jensen & Sjaastad, 2013, p.1457).

In another study, researchers designed a program where a team of graduate students in the field of learning technology developed a multimedia PBL experience for middle school science students. Liu et al. (2014) outlined a unique partnership between graduate students in a learning technologies program and middle school science students. The graduate students developed and implemented a multi-media PBL program for learning science called Alien Rescue. The program involved both the graduate students in PBL, developing and revising Alien Rescue, and students using Alien Rescue as a web-based notebook tool for solving ill-structured space-based problems. Both graduate students and middle school students benefitted from this virtual partnership (Liu et al., 2014)

Miles et al. (2015) described a final example of a university and K-12 STEM partnership. The authors highlighted TechMath as a professional development program created in collaboration among universities, businesses, and teachers to design PBL modules. The study reported that teachers gained information, resources and supportive relationships that improved their PBL modules and often provided the teachers with the first attempt at PBL pedagogy. Teachers benefitted from these interactions with business leaders and university experts, while improving their ability to teach 21st-century skills. Teachers also reported that they would have benefitted from even more collaboration with their business and university mentors. A great deal of the research in this literature review pointed out the benefits of university and K-12 partnerships benefitting students' PBL and STEM experiences in schools all over the country and world (Miles et al., 2015).

Student Attitudes related to STEAM Courses and STEAM Careers

The development of 21st-century skills was not the only important aspect of STEM and PBL instruction in schools revealed in the literature. Efforts to understand and change student attitudes about STEM and STEAM careers also appeared frequently in the literature, especially efforts to understand and change the attitudes of female students (Michael & Alsup, 2016; Yoon Yoon, Lucietto, Capobianco, Dyehouse, & Diefes-Dux, 2014). For many years, most of the research on student attitudes related to STEAM focused on attitudes towards individual subjects, especially math and science. More recently, however, the literature included studies on student attitudes related to engineering and technology (Guzey, Harwell, & Moore, 2014). The literature revealed cases across the spectrum of education where student attitudes related to STEM were studied, including Pre-K through 12th grades, private and public schools, wealthy and poor neighborhoods, and traditional and STEM-focused schools (Abbott, 2016; Michael & Alsup, 2016; Vennix, den Brok, & Taconis, 2018; Yoon Yoon et al., 2014). These studies examined attitudes of students in general and specific groups, such as gender and age groups.

Michael and Alsup (2016) studied attitudes and interests toward STEM careers of male and female students in Protestant Christian middle schools. The researchers explored not only impediments to STEM efficacy related to perceived conflicts between religious teachings and science pedagogy, but also differences in attitudes of males and females toward STEM in middle schools, concluding that middle school female students showed lower attitudes towards engineering and technology while having similar attitudes towards science and math subjects as boys. Yoon Yoon, Lucietto, Capobianco, Dyehouse, and Diefes-Dux (2014) asserted that integrated Science, Technology, and Engineering pedagogy improved student understanding of what engineers did on the job and developed a higher engineering career identity than students in a control group. The researchers used the Engineering Identity Development Scale (EIDS) to measure the differences between the two groups (Yoon Yoon, 2014).

Other researchers used an analysis similar to the EIDS to examine student STEM attitudes. Vennix, den Brok, and Taconis (2018) used a variety of psychological and attitudinal instruments including the Test of Science Related Attitudes to study 729 students in 12 STEM outreach programs in the United States and Norway. The researchers determined that outreach programs where students had autonomous experiences with professionals in STEM careers as part of their high school instruction showed improved attitudes regarding STEM (Vennix et al., 2018). Sadler, Sonnert, Hazari, and Tai (2014) used a retrospective cohort study of 4691 college students from 34 colleges to examine the relationship of advanced placement science and math courses and interest in pursuing a STEM career. The researchers determined that, while taking AP science and math courses had no impact on STEM career interest compared to other AP and non-AP courses, taking more non-AP chemistry and physics courses overall in high school increased interest in STEM careers. According to Michael and Alsup (2015), "Interest in pursuing a career in a STEM field may hinge on whether positive and authentic experiences were provided by educators" (p. 152).

Another study also revealed that STEM academic activities had little impact on interest in STEM careers. Fuesting, Diekman, and Hudiburgh (2017) emphasized in their research that focusing on both student academic motivation and experiences that met students' communal goals provided students with greater motivation and improved perceptions of STEM careers. Several other studies highlighted earlier in Chapter Two of the Researcher's findings also emphasized the importance of improving attitudes regarding STEM careers by emphasizing self-efficacy and communal goals, along with academics. Hiller and Kitsantas (2014) made a strong case for exposing middle school students to real scientific fieldwork as a way to improve both academic performance and career interest in STEM. Another study by Abbott (2016) examined embedding PBL in science classrooms as a way to improve middle school student attitudes regarding STEM careers, by motivating students to value STEM through regular exposure to solving real-world problems. Students in this study felt motivated through the act of solving a problem and having a chance to make a real difference in the world.

Finally, both of the studies referenced in the previous paragraph took place in middle school settings, and several other studies emphasized the importance of exposure to STEM careers at concepts at an earlier age than high school. Wu-Rorrer (2017) pointed out that early engagement in STEM was crucial for increasing student interest in STEM careers and was a much better predictor of obtaining a STEM degree for eighth-graders than high academic achievement. According to Hayden, Ouyang, Scinski, Olszewski, and Bielefeldt (2011), a national program for improving interest in STEM career for minorities called investigations for Quality Understanding and Engagement for Students and Teachers (iQUEST) did improve interest in STEM careers for Hispanic middle school students. Specifically, iQUEST engaged 7th and 8th-grade students in hands-on investigations to improve science understanding and STEM motivation for traditionally underrepresented students in STEM fields. Boyington (2018) pointed out that, in order to make a significant impact on student preparedness, especially for STEM careers, educators needed to reach students early in their school careers, addressing student attitudes early, especially in the middle school years when students started to form more informed attitudes about careers (Boyington, 2018).

Project Lead The Way

PLTW was another major national effort to improve STEAM academic performance, as well as attitudes and interest in STEAM careers (Hess et al., 2016). However, as a national non-profit program rather than a specific pedagogy taught or studied in university education and teacher training programs, very little educational research existed in the literature regarding PLTW for high school students and even less for the middle school and elementary programs, named PLTW Gateway and PLTW Launch, respectively (Hess et al., 2016). The research often revealed PLTW as an impactful pedagogy that helped change students' attitudes towards STEM, rather than one that changed student test scores, offering a positive influence on students' choices related to STEM careers (Tai, 2012).

The research on PLTW also examined this national program as having both a number of strengths as a K-12 STEM pedagogy, as well as a number of weaknesses. The literature contained ample opportunities for continued research on the topic of PLTW as a STEM pedagogy. Several key topics related to PLTW revealed themselves to have large gaps in the then-existing body of research. The lack of research knowledge included investigations related to administrators and counselors, qualitative research on student and teacher attitudes related to PLTW and STEM, and any kind of additional research on PLTW Launch and Gateway programs, specifically (Hess et.al., 2016). The last section of the Researcher's literature review highlights some of the weaknesses of PLTW found in the literature, several key strengths of PLTW, and a few of the gaps in PLTW literature calling for future study.

Much of the research (Hess et al., 2016; Paslov, 2007; Stohlman, Moore, McClelland, & Roehrig, 2011) on PLTW revealed three key weaknesses in the program. The first weakness related to scheduling and implementation, especially in middle schools. The Researcher's experience in a suburban Midwestern middle school, along with a number of studies in the literature revealed that providing access to PLTW coursework could be difficult for schools to build into busy student schedules in both middle schools and high schools (Hess et al., 2016; McMullen & Reeve, 2014; Stohlman et al., 2011). High schools, and particularly middle schools faced challenges related to fitting a prescribed curriculum and units of study designed by PLTW into a school schedule built around specific community needs. The school district in the Researcher's study, along with others in the literature faced several questions regarding how to implement PLTW. Should schools integrate PLTW into general education curriculum or offer it as an elective? What teachers can teach PLTW? Where do we find space for supplies and projects related to hands-on learning? These were a few of the questions revealed in the literature, especially related to middle school settings (Hess et al. 2016; McMullen & Reeve, 2014; Stohlman et.al., 2011).

The second weakness of PLTW revealed itself in quantitative studies of student academic achievement, particularly related to math and science. One study found not only that there was no difference between student achievement in math and science, but also that PLTW students scored worse than their non-PLTW counterparts. According to Tran and Nathan (2010), "Students enrolled in PLTW foundation courses showed significantly smaller math assessment gains than those in a matched group that did not enroll, and no measurable advantages on science assessments, when controlling for prior achievement and teacher experience" (p. 143). The authors, Tran and Nathan (2010) further explained, "While many math standards were touched on across the [PLTW] curriculum, integration between the engineering activities and the mathematical procedures and skills were seldom explicit" (p. 155). Similarly, Wheeler (2008) found that "within the population studied, participation in either IED or POE did not appear to have a significant impact on the tenth-grade mathematics performance" (p. iii).

Finally, in a study of middle school students in Minnesota, researchers found that mathematics standards in PLTW Gateway generally linked to national standards, but not directly to state standards. Therefore, limitations may have occurred in the PLTW platform's ability to improve student performance on discreet math assessments (Stohlman et al., 2011). Overall, little evidence existed in the research supporting PLTW as a program that significantly improved math and science performance (Hess et al., 2016).

One of the few studies that showed academic gains in math and science was a study where, according to researchers, students showed a five-point increase in both science and math scores on the Iowa Test of Educational Development after controlling for selection bias (Rethwisch, Chapman Haynes, Starobin, Laanan, & Schenk, 2012). However, in their conclusions of this study, the authors pointed out that these increases may have been due to a high number of PLTW student participants enrolling in additional advanced math and science courses. The authors did attribute this extended enrollment to increased self-efficacy and motivation developed in PLTW courses (Rethwisch, Chapman Haynes, Starobin, Laanan, & Schenk, 2012).

The third weakness related to the success of PLTW overall, centered on the costs of the program (Hess et al., 2016). Although costs of implementing PLTW varied by the school district and the state, based on assistance provided to schools by various non-school entities, PLTW guidelines required schools to provide the equipment and professional teacher training before, during, and after implementing the program (Hess et al., 2016; PLTW, 2019; Tolan, 2008). The teacher training was so comprehensive as to have two-to-four-week summer sessions where teachers could receive graduate-level credit. Therefore, not only did the training require school districts to pay thousands of dollars for training (including travel and accommodations), but also required teachers to give up time during the summer (Tolan, 2008). School districts in disadvantaged communities proclaimed financial strains to be especially difficult. Even though the potential for federal grants was often greater in these school district communities, knowledge and easy access to those grants made getting the grant money problematic (Hess et al., 2016). Funding the professional development was expensive itself, but so was funding the equipment and other logistical requirements. As Stohlmann, Moore, McClelland, & Roehrig (2011) pointed out, “Schools must attend to numerous logistical considerations when adopting a program like Gateway to Technology” (p. 39). The indirect costs of equipment, physical space, and the time it took counselors and administrators to design and implement new school schedules to accommodate PLTW all made the cost of implementing PLTW too high for many school districts (Hess et al., 2016; Shields, 2007; Stohlmann et al., 2011).

Overall, schools that implemented PLTW deemed the costs of the program as a major consideration in almost all instances. Even though the program offered a great deal of flexibility, allowing schools to implement a full PLTW program from kindergarten to 12th grade or just specific courses at only a few grade levels. Schools in much of the research saw training, equipment, and space for just one course as a significant concern (Hess et al., 2016; Shields, 2007; Tolan, 2008). For example, Shields (2007) in a study of Indiana school administrators’ perceptions of PLTW, found that principals listed the cost of PLTW as the major impediment to implementing a program they found appealing:

> Regardless of the fact that non-PLTW Indiana principals agreed that PLTW was a useful and valid part of the TE curriculum they believed the greatest barrier to implementing PLTW was cost, both of the cost of PLTW equipment and of the PLTW summer training. (p. 66)

Although, the PLTW program specifically explained the equipment costs and the extensive teacher training required to implement any of their K-12 programs, school districts found these costs combined with additional logistical costs of implementing PLTW costly enough to be a major impediment to implementing PLTW at all (Hess et al., 2016; PLTW, 2019; Shields, 2007; Tolan, 2008).

The research also revealed many strengths to the PLTW program. One of those strengths, especially according to teachers, was high-quality professional development embedded in every PLTW program implemented at the state level (Hess et al., 2016). In one study by McMullin and Reeve (2014), "The CTE [Career and Technical Education] directors believed PLTW was implemented for many reasons. It is interesting to note that the most common reason was to 'improve teacher training by providing professional development" (p. 126).

Daugherty (2008) found that PLTW professional development was successful for two main reasons: its focus on hands-on, active learning and instruction from master teachers actively teaching PLTW at the time. This format was possible through PLTW's Summer Training Institutes (STI). At the STI master PLTW teachers instructed the newer PLTW teachers. Teachers worked with the actual curricula and supplies they would later use in their classrooms. In Daugherty's (2008) case study of several pre-engineering programs, the study pointed out positive teacher attitudes regarding PLTW professional development. “In terms of effectiveness, two of the teachers stated that the hands-on aspect of the STI was particularly effective . . . Teachers also commented on the credibility and personality of the master teachers as being particularly effective” (Daugherty, 2008, p. 100). A final strength of PLTW professional development was the requirements for teacher certification that the PLTW program placed on teachers and schools that implemented the program. Several studies pointed to this as a strength of PLTW (Daugherty, 2008; Hess et al., 2016; McMullin & Reeve, 2014).

The PLTW program’s ability to increase student interest in STEM school coursework, particularly math and science, proved to be another strength (Hess et al., 2016). PLTW did an especially effective job of improving minority and female interest in STEM coursework (Sorge, 2014). According to Sorge (2014), “Females at PLTW schools were more likely to persist than boys while gender was not a predictor for students at non-PLTW schools” (p. 111). This study also pointed out that, compared to non-PLTW students, students who took a PLTW course were more likely to major in STEM (Sorge, 2014). Another study revealed that for both middle school boys and girls, the PLTW Gateway program increased positive attitudes about math (Paslov, 2007). Finally, according to Hess, Sorge, & Feldhaus (2016), “For all students, especially students underrepresented in engineering, participating in PLTW fostered student interest in mathematics and engineering” (p. 16).

Finally, the literature showed a common theme that PLTW produced a strong motivation in students to pursue STEM degrees and careers (Hess et al., 2016). According to several studies, PLTW provided students with experiences that allowed them to see themselves majoring in STEM careers. This was especially true for students from female and minority sub-groups (Porter, 2011; Sorge, 2014; Van Overschelde, 2013). The Porter (2011) study concluded, “Students are more influenced to enroll in an engineering major versus a physical science major if they participate in PLTW while in high school.” (p.80). Another study by Van Overschelde (2013) pointed out that students who took PLTW courses in high school were more prepared in mathematics for higher education when compared to non-PLTW peers and also “attended Texas higher education institutions at a higher rate than matched, non-PLTW students” (p. 10). Finally, the national PLTW program served as a model for how school, higher education, and industry leaders could work together to increase the number of students in the STEAM pipeline, filling in the significant gaps in the STEM workforce (Porter, 2011).

The overall body of PLTW literature also contained a number of gaps that provided future researchers opportunity for further study (Hess et al., 2016). The research excluded several key groups of stakeholders including principals, counselors, and parents. The literature also contained gaps related to specific PLTW program research in the areas of the PLTW Biomedical Science and Computer Science curriculum, as well as very little study of the elementary and middle school programs: PLTW Launch and PLTW Gateway (Hess et al., 2016). Also, one study noted a gap in the literature existed related to analysis of standards for engineering and PLTW. This lack of research was specifically pronounced at the state level (Smith, 2017). Finally, research in the area of PLTW was limited to studies of the program in specific states, papers presented at conferences, and studies done by the PLTW organization itself. The literature lacked large national studies or cross-state research (Hess et al., 2016).

Summary

In order to meet the challenges of a quickly changing 21st-century and best prepare students for the demanding workforce required by those changes, schools highlighted in the literature attempted to develop 21st-century skills. The importance of developing develop 21st-century skills was especially true for students from specific minority populations and female students. The Researcher's literature review highlights several different approaches designed to develop these skills.

Problem-based Learning provided schools with pedagogies designed to develop 21st-century skills in an integrated manner through any school curriculum (Cicchino, 2015; Ertmer & Simons, 2006; Savery, 2006; Slavich & Zimbardo, 2012). Project Based Learning allowed students to work on real world projects to develop 21st-century skills (Larmer & Megendoller, 2015). STEM and STEAM initiatives developed STEAM awareness and competencies in students at all grade levels including traditional Career and Technical Education with more emphasis on real-world problem-solving (Grubbs, 2013). The literature also noted programs that emphasized collaborating with scientists working in STEM fields (Hayes, 2013). Finally, other studies revealed programs that created stand-alone STEM schools or programs within existing schools (Hayes, 2013; Peters-Burton et al., 2014). The literature also noted changing student perceptions regarding STEM and STEAM as a way to prepare students for the challenges of the 21st century. Studies highlighted cases across the spectrum of education where student attitudes related to STEM were studied, including Pre-K through 12th grades, private and public schools, wealthy and poor neighborhoods, and traditional and STEM-focused schools (Abbott, 2016; Michael & Alsup, 2016; Vennix et al., 2018; Yoon Yoon, 2014).

Finally, the literature revealed PLTW as a well-developed national program that was highly effective at changing students' attitudes regarding STEAM and STEAM careers but having less positive results for improving student math and science performance (Sorge, 2014; Tran and Nathan, 2010; Wheeler, 2008). Although the results of these studies on PLTW revealed a number of its strengths and weaknesses, a number of gaps in the literature also existed. Opportunities for further research presented themselves in the areas of specific PLTW programing, elementary and middle STEAM instruction, PLTW and engineering curriculum, and national and cross-state studies (Hess et al., 2016; Smith, 2017). The literature ultimately revealed PLTW as one of another curricular and pedagogical approach designed to improve student development of 21st-century skills and to encourage more students to pursue STEM and STEAM careers.

Chapter Three: Research Method and Design

The Researcher conducted a quantitative study examining specific academic achievement outcomes and attitudes regarding STEAM courses and STEAM careers among students who completed at least one semester in a middle school PLTW Gateway program in a suburban school district. The Researcher examined outcomes from two separate data collections. The study utilized data from students at four middle schools from the spring of the 2014-2015 school year through the fall of the 2018-2019 school year. The study also included student participants who completed their time at the four middle schools and then attended one of the two high schools in the study school district.

The study focused on examining specific program outcomes of the middle school PLTW Gateway program by comparing students who participated in the school district's middle school PLTW Gateway program to students who did not participate in the program. The Researcher examined PLTW Gateway program outcomes by analyzing a researcher-generated survey of high school students' STEAM knowledge and attitudes. The Researcher also examined archived historical data collected from students' math and science MAP data and Algebra 1 EOC data for the 2015 through 2017 school years.

Null Hypotheses

Null Hypothesis 1. There is no difference in knowledge of STEAM education programs between students who participate in PLTW Gateway and students who do not participate in PLTW Gateway.

Null Hypothesis 2. There is no difference in perceptions of STEAM education programs between students who participate in PLTW Gateway and students who do not participate in PLTW Gateway.

Null Hypothesis 3. There is no difference in interest in STEAM careers after high school between students who participate in PLTW Gateway and students who do not participate in PLTW Gateway.

Null Hypothesis 4. There is no difference in interest in STEAM careers after high school between female students who participate in PLTW Gateway and female students who do not participate in PLTW Gateway.

Null Hypothesis 5. There is no difference in MAP science scores of students who participate in PLTW Gateway and MAP science scores of students who do not participate in PLTW Gateway.

Null Hypothesis 6. There is no difference in MAP math scores of students who participate in PLTW Gateway and MAP math scores of students who do not participate in PLTW Gateway.

Null Hypothesis 7. There is no difference in EOC Algebra I scores of students who participate in PLTW Gateway and EOC algebra scores of students who do not participate in PLTW Gateway.

Model 1: Survey Data Collection Procedures

The Researcher analyzed middle school students' responses to a researcher generated survey of attitudes regarding STEAM school programs and careers. The Researcher began the process of acquiring survey data by sending an email solicitation to all 3,340 high school students and their parents in the study school district. This email solicitation contained the official Lindenwood-approved parent consent and student assent forms. The Researcher asked parents to return signed consent forms and their child's signed assent form to the Researcher at the district middle school, where the

Researcher worked, or to a closed manila envelope in the office at their child's high school. The form collection process occurred at the end of the 2017-2018 school year and the beginning of the 2018-2019 school year. The Researcher secured the signed forms in a locked cabinet at the Researcher's school.

The Researcher administered and collected the survey data using the Lindenwood University approved *Qualtrics* tool, which protects the anonymity of participants and safeguards the confidentiality of data via the *Qualtrics* program. The 57 students who assented to take the survey completed the survey through an email link sent out by the Researcher using *Qualtrics*. The Researcher emailed the link to the *Qualtrics* survey (see Appendix A) to all students for whom parents and students provided consent and assent forms in the spring and fall of 2018.

The survey assessed student attitudes about STEAM courses and student interests in STEAM careers after high school. The survey remained open to students for a minimum of three weeks, once in the spring of 2018 and again in the fall of 2018. The Researcher's first attempt in the spring of 2018 to solicit at least 50 responses to the survey resulted in only 19 surveys completed. Since the 2017-2018 school year ended as the survey window closed, the Researcher chose to solicit additional participants in the fall of the 2018-2019 school year. The Researcher went to both high schools to solicit additional participants and collected over 40 additional consent and assent forms. The Researcher then sent another email link to the fall participants for the *Qualtrics* survey. After the additional release of the survey, 38 more participants responded, resulting in a total of 57 completed surveys for the study. The Researcher then tabulated results of the survey to determine student attitudes regarding STEAM careers and STEAM middle school and high school courses related to H1 through H4.

Development of the Survey Instrument

All survey questions related to H1 through H4 solicited Likert scale responses as follows: 1 (strongly disagree), 2 (disagree), 3 (neither agree nor disagree), 4 (agree), and 5 (strongly agree). Question one in the survey asked students to identify their gender. Question two identified student grade level. Question three asked students if they had taken a PLTW Gateway course in middle school. The participant answers to this survey question allowed the Researcher to sort the students in the two groups: students who took at least one PLTW Gateway course and those who did not take any such course. Sorting student participants into two groups was necessary to provide the two data sets on which to apply the *t*-tests for difference in means for H1 though H4.

Instrument Alignment for Analysis

The Researcher designed the questions in the survey to gather data to determine the differences of two means, based on H1 through H4. Because questions could not be asked of the two groups in the study in exactly the same way, questions were designed in pairs (see Appendix A). The Researcher designed survey questions 4 through 10 related to H1 through H4 for student participants who took at least one PLTW Gateway course in middle school. The Researcher also designed corresponding survey questions 11 through 17, related to H1 through H4 for student participants who did not take any PLTW Gateway course in middle school. The Researcher disaggregated the survey data into three main groups: students who completed a PLTW Gateway course, students who did not complete such a course, and by student gender. The following codes identified the categories as: PY (Yes - completed PLTW Gateway), PN (No - did not complete PLTW Gateway), M (male), and F (female). The Researcher analyzed null hypotheses H1, H2, H3, and H4 based on the survey data collected from these groups of students, with no other identifiers available to the Researcher, using a *t*-test for difference in independent means. Because the focus of the study was strictly on the middle school PLTW Gateway program, the Researcher did not seek information on PLTW courses taken in high school. The Researcher applied the *t*-test to the following specific question pairs: 4 and 11, 5 and 12, 6 and 13, 7 and 14, 8 and 15, 9 and 16, and 10 and 17, applying the results of the *t*-tests to the appropriate null hypotheses 1 through 4, as shown in Table 1. Multiple questions applied to every null hypothesis except for NH1.

Table 1

Survey Questions and H1, H2, H3, & H4

Question Pairs	Applied to Null Hypothesis	
Question Pair 4 and 11	H1	
Question Pair 5 and 12	H2	
Question Pair 6 and 13	H2	
Question Pair 7 and 14	H3	H4
Question Pair 8 and 15	H2	
Question Pair 9 and 16	H3	H4
Question Pair 10 and 17	H3	H4

Note. Table 1 describes which question pairs were applied to which Null Hypotheses. Multiple questions applied to every null hypothesis, except for NH1.

Population. The Researcher sent survey consent and assent forms to all high students in the study district's two high schools, a population of over 3,300 students. The Researcher collected 57 consent and assent forms and sent out 57 surveys to the respondents from the two high schools. The 57 surveys completed through the *Qualtrics* platform served as a convenience sample where the Researcher applied a *t*-test for difference of two means to NH1 through NH4 (Fraenkel, Wallen, & Hyun, 2015).

2018 Survey Question Descriptive Statistics

Descriptive statistics revealed that students who participated in the research study survey and also participated in PLTW for at least one semester had a mode of 4 and a range of 3 for question pair 4 and 11, related to H1. Descriptive statistics revealed that students who participated in the research study survey and did not participate in PLTW for at least one semester had a mode of 4 and a range of 4 for question pair 4 and 11, related to H1. Additional descriptive statistics are displayed in Table 2.

Table 2

H1: Paired survey questions 4 & 11; Descriptive Statistics

	Q4 PLTW	Q11 Non-PLTW
Mean	3.82	3.12
Standard Error	0.21	0.27
Median	4	3
Mode	4	4
Standard Deviation	1.09	1.36
Sample Variance	1.19	1.86
Kurtosis	-0.94	-1.20
Skewness	-0.54	-0.23
Range	3	4
Minimum	2	1
Maximum	5	5
Sum	107	78
Count	28	25

Descriptive statistics revealed that students who participated in the research study survey and also participated in PLTW for at least one semester had a mode of 4 and a range of 3 for question pair 5 and 12, related to H1. Descriptive statistics revealed that students who participated in the research study survey and did not participate in PLTW for at least one semester had a mode of 3 and a range of 4 for question pair 5 and 12, related to H1. Additional descriptive statistics are displayed in Table 3.

Table 3

H2: Paired survey questions 5 & 12; Descriptive Statistics

	Q5 PLTW	Q12 Non-PLTW
Mean	3.68	3.08
Standard Error	0.16	0.19
Median	4	3
Mode	4	3
Standard Deviation	0.86	0.95
Sample Variance	0.74	0.91
Kurtosis	-0.58	0.22
Skewness	-0.04	0.14
Range	3	4
Minimum	2	1
Maximum	5	5
Sum	103	77
Count	28	25

Table 4

H2: Paired survey questions 6 & 13; Descriptive Statistics

	Q6 PLTW	Q13 Non-PLTW
Mean	3.07	2.92
Standard Error	0.20	0.16
Median	3	3
Mode	3	3
Standard Deviation	1.05	0.81
Sample Variance	1.11	0.66
Kurtosis	-0.53	1.50
Skewness	0.26	0.15
Range	4	4
Minimum	1	1
Maximum	5	5
Sum	86	73
Count	28	25

Descriptive statistics revealed that students who participated in the research study survey and also participated in PLTW for at least one semester had a mode of 3 and a range of 4 for question pair 6 and 13, related to H2. Descriptive statistics revealed that students who participated in the research study survey and did not participate in PLTW for at least one semester had a mode of 3 and a range of 4 for question pair 6 and 13, related to H2. Additional descriptive statistics are displayed in Table 4.

Descriptive statistics revealed that students who participated in the research study survey and also participated in PLTW for at least one semester had a mode of 4 and a range of 3 for question pair 7 and 14, related to H3 and H4. Descriptive statistics revealed that students who participated in the research study survey and did not participate in PLTW for at least one semester had a mode of 4 and a range of 4 for question pair 7 and 14, related to H3 and H4. Additional descriptive statistics are displayed in Table 5.

Table 5

H3 & H4: Paired survey questions 7 & 14; Descriptive Statistics

	Q7 PLTW	Q14 Non-PLTW
Mean	3.82	2.88
Standard Error	0.21	0.27
Median	4	3
Mode	4	4
Standard Deviation	1.09	1.36
Sample Variance	1.19	1.86
Kurtosis	-0.94	-1.29
Skewness	-0.54	0.020
Range	3	4
Minimum	2	1
Maximum	5	5
Sum	107	72
Count	28	25

Descriptive statistics revealed that students who participated in the research study survey and also participated in PLTW for at least one semester had a mode of 3 and a range of 3 for question pair 8 and 15, related to H2. Descriptive statistics revealed that students who participated in the research study survey and did not participate in PLTW for at least one semester had a mode of 3 and a range of 3 for question pair 8 and 15, related to H2. Additional descriptive statistics are displayed in Table 6.

Table 6

H2: Paired survey questions 8 & 15; Descriptive Statistics

	Q8 PLTW	Q15 Non-PLTW
Mean	3.75	2.84
Standard Error	0.20	0.14
Median	4	3
Mode	3	3
Standard Deviation	1.04	0.69
Sample Variance	1.08	0.47
Kurtosis	-1.26	3.17
Skewness	-0.09	-1.45
Range	3	3
Minimum	2	1
Maximum	5	4
Sum	105	71
Count	28	25

Descriptive statistics revealed that students who participated in the research study survey and also participated in PLTW for at least one semester had a mode of 4 and a range of 3 for question pair 9 and 16, related to H3 and H4. Descriptive statistics revealed that students who participated in the research study survey and did not participate in PLTW for at least one semester had a mode of 4 and a range of 3 for question pair 9 and 16, related to H3 and H4. Additional descriptive statistics are displayed in Table 7.

Table 7

H3 and H4: Paired survey questions 9 & 16; Descriptive Statistics

	Q9 PLTW	Q16 Non-PLTW
Mean	4.10	3.56
Standard Error	0.15	0.13
Median	4	4
Mode	4	4
Standard Deviation	0.79	0.65
Sample Variance	0.62	0.42
Kurtosis	0.45	0.08
Skewness	-0.69	-0.24
Range	3	3
Minimum	2	2
Maximum	5	5
Sum	115	89
Count	28	25

Table 8

H3 & H4: Paired survey questions 10 & 17; Descriptive Statistics

	Q10 PLTW	Q17 Non-PLTW
Mean	3.75	3.64
Standard Error	0.25	0.28
Median	4	4
Mode	5	5
Standard Deviation	1.32	1.38
Sample Variance	1.75	1.91
Kurtosis	-0.64	-0.99
Skewness	-0.74	-0.63
Range	4	4
Minimum	1	1
Maximum	5	5
Sum	105	91
Count	28	25

Descriptive statistics revealed that students who participated in the research study survey and also participated in PLTW for at least one semester had a mode of 3 and a range of 3 for question pair 10 and 17, related to H3 and H4. Descriptive statistics revealed that students who participated in the research study survey and did not participate in PLTW for at least one semester had a mode of 3 and a range of 3 for question pair 10 and 17, related to H3 and H4. Additional descriptive statistics are displayed in Table 8.

Model 2: Archived Data Collection Procedures

Null Hypotheses 5, 6, and 7 were not based on a statistical analysis of the Researcher created survey, but on a statistical analysis of archived MAP data The Researcher gathered 8th grade MAP math and science data and 8th grade EOC algebra data, as well as 6th and 7th grade math MAP data from the previous 2014-2015, 2015-2016, and 2016-2017 school years through the School Information Systems (SIS). The Researcher retrieved data that did not identify students by name with the assistance of the school district director of planning and development. The Researcher utilized sorting features in SIS to exclude student names. The Researcher used de-identified data to compare file sets of MAP and EOC information in two categories: students who took a PLTW Gateway course and students who did not.

Population. The Researcher analyzed MAP data from four middle schools, over three years that the PLTW Gateway program served students from a population of 5,411 student MAP scores. The Researcher collected MAP results from the three years included in the study: 2015, 2016, and 2017.

The Researcher selected three random samples of 30 student scores from an overall stratified population of students who took a PLTW Gateway course between 2014 and 2017. The Research then further stratified this set of data for PLTW Gateway students into populations of 116 science MAP, 1,121 math MAP, and 49 EOC Algebra I scores.

The Researcher then selected three additional random samples of 30 student scores from the overall stratified population of students who did not take a PLTW Gateway course between 2014 and 2017. The Researcher then further stratified this data set for non-PLTW Gateway students into populations of 608 science MAP, 3,265 math Map, and 282 EOC Algebra I scores

The Researcher applied a *t*-test for difference of two means for NH5, NH6, and NH7, comparing the two overall populations of PLTW Gateway and non- PLTW Gateway student scores using six stratified random samples of 30 student scores from the following the populations corresponding to NH5, NH6, and NH7: PLTW Gateway math MAP scores, PLTW Gateway science MAP scores, PLTW Gateway Algebra I EOC scores, non-PLTW Gateway math MAP scores, non-PLTW Gateway science MAP scores, and non-PLTW Gateway Algebra I EOC scores. NH5, NH6, and NH7 populations and sample populations are shown in Table 9.

Table 9

H5, H6, & H7 Populations and Sample Populations

	PLTW Gateway	Non-PLTW Gateway
H5 MAP Science		
Population	116	608
Sample Size	30	30
H6 MAP Math		
Population	1,121	3,265
Sample Size	30	30
H7 Algebra I EOC		
Population	49	282
Sample Size	30	30

Note. Included random sample of 30 for each data set (Fraenkel et al., 2015).

The Researcher applied the *t*-test for difference of two means related to NH5, NH6, and NH7 to the random samples in order to determine if there was a difference in student MAP test performance for students in the two groups (PLTW vs. non-PLTW). The Researcher sought differences among the following variables:

- Middle school student participation in PLTW Gateway vs. non-participation and student MAP data in the subject area of math.
- Middle school student participation in PLTW Gateway vs. non-participation and student MAP data in the subject area of science.
- Middle school participation in PLTW Gateway vs. non-participation and student EOC exam data for eighth-grade students in the advanced math subject area of Algebra I.

Null Hypotheses

Null Hypothesis 1. There is no difference in knowledge of STEAM education programs between students who participate in PLTW Gateway and students who do not participate in PLTW Gateway.

Null Hypothesis 2. There is no difference in perceptions of STEAM education programs between students who participate in PLTW Gateway and students who do not participate in PLTW Gateway.

Null Hypothesis 3. There is no difference in student interest in STEAM careers after high school between students who participate in PLTW Gateway and students who do not participate in PLTW Gateway.

Null Hypothesis 4: There is no difference in interest in STEAM careers after high school between female students who participate in PLTW Gateway and female students who do not participate in PLTW Gateway.

Null Hypothesis 5: There is no difference in MAP science scores of students who participate in PLTW Gateway and MAP science scores of students who do not participate in PLTW Gateway.

Null Hypothesis 6: There is no difference in MAP math scores of students who participate in PLTW Gateway and MAP math scores of students who do not participate in PLTW Gateway.

Null Hypothesis 7: There is no difference in EOC Algebra I scores of students who participate in PLTW Gateway and EOC algebra scores of students who do not participate in PLTW Gateway.

2017 Science MAP Descriptive Statistics

Descriptive statistics are displayed in Table 10.

Table 10

H5: 2017 Science MAP; Descriptive Statistics

	PTLW Science Map	*Non PLTW Science MAP*
Mean	2.27	2.53
Standard Error	0.14	0.13
Median	2	2
Mode	3	2
Standard Deviation	0.74	0.73
Sample Variance	0.55	0.53
Kurtosis	-0.97	-0.18
Skewness	-0.48	0.45
Range	2	3
Minimum	1	1
Maximum	3	4
Sum	68	76
Count	30	30

Descriptive statistics revealed that students' 2017 Science MAP scores for those who participated in PLTW for at least one year had a mode of 3 and a range of 2. Students' 2017 Science MAP scores for those who did not participate in PLTW for at least one year had a mode of 2 and a range of 3.

2015 - 2017 Math MAP Descriptive Statistics

Descriptive statistics revealed that students' 2015 - 2017 math MAP scores for those who participated in PLTW for at least one year had a mode of 3 and a range of 3. Students' 2015 -2017 Math MAP scores for those who did not participate in PLTW for at least one year also had a mode of 2 and a range of 3. Additional descriptive statistics are displayed in Table 11.

Table 11

H6: 2015 - 2017 Math MAP Descriptive Statistics

	PLTW Math	Non-PLTW Math
Mean	2.43	2.23
Standard Error	0.18	0.19
Median	2.5	2
Mode	3	2
Standard Deviation	0.97	1.04
Sample Variance	0.94	1.08
Kurtosis	-0.91	-0.6
Skewness	-0.04	0.68
Range	3	3
Minimum	1	1
Maximum	4	4
Sum	73	67
Count	30	30

2015 - 2017 Algebra EOC Descriptive Statistics

Descriptive statistics revealed that students' 2015 - 2016 Algebra EOC scores for those who participated in PLTW for at least one year had a mode of 4 and a range of 1. Students' 2015 -2016 Algebra EOC scores for those who did not participate in PLTW for at least one year also had a mode of 4 and a range of 1. Additional descriptive statistics are displayed in Table 12.

Table 12

H7: 2015 – 2017 Algebra EOC; Descriptive Statistics

	ALG EOC PLTW	*ALG EOC Non PLTW*
Mean	3.7	3.63
Standard Error	0.09	0.09
Median	4	4
Mode	4	4
Standard Deviation	0.47	0.49
Sample Variance	0.22	0.24
Kurtosis	-1.24	-1.78
Skewness	-0.92	-0.58
Range	1	1
Minimum	3	3
Maximum	4	4
Sum	111	109
Count	30	30

Limitations

This study contained some limitations. First, the literature included a large variety of methods of delivery for 21st-century and STEAM learning. This study focused on only one of those delivery methods, PLTW. Second, the study was limited to one school district in a Midwestern suburban community. Third, the study focused on PLTW Gateway courses offered to students in a middle school master schedule that permitted students only one elective choice. Students who were interested in other electives, such as band, choir, or foreign language did not have the opportunity to take PLTW Gateway courses and were not exposed to this program. Fourth, one survey question (#15) was uploaded onto the survey with incorrect wording. This wording may have been confusing to participants trying to answer it. Finally, the survey used in this study was generated by the Researcher for the population in this specific study in a suburban Midwest school district. Therefore, the survey could not be generalized to other populations.

Threat to Validity

Because the Researcher used historical state test data from three consecutive school years and used a stratified random sample of a population size of over 3,000, the data analyzed for null hypotheses 5 through 8 contained both criterion-related validity and predictive validity. The criterion-related validity was assumed as part of the state testing procedures for validity and the predictive validity was based on the review of scores over a three-year period for the same state test (Fraenkel et al., 2015).

Summary

The Researcher's quantitative approach to both student perceptions and MAP state test scores allowed for the consideration of student attitudes related to STEAM careers along with student performance in the areas of math and science as they pertained to the PLTW Gateway program in a suburban middle school. The Researcher was able to compare the two groups of students (those who took a PLTW Gateway course and those who did not) through two sets of statistical analysis: a Likert survey through a convenience sample of 57 students from the two district high schools and a stratified random sample of the school district's archived historical MAP data. These two approaches to data analysis, while both quantitative, allowed the Researcher to examine both student perceptions and student academic performance of those students who participated in PLTW Gateway in a suburban school district as they compared to students who did not take a PLTW Gateway course.

Chapter Four presents statistical evidence and analysis of the PLTW Gateway program outcomes specifically related to null hypotheses 1 through 4 for the Researcher-generated survey of high school students' STEAM knowledge and attitudes. Chapter Four also presents statistical evidence and analysis related to null hypotheses 5 through 7 for the archived historical data collected from students' math and science Map data and Algebra 1 EOC data for the 2014-2015 through the 2016-2017 school years. The goal of the Researcher was to determine if there was a difference in student perceptions of STEAM programs and careers and performance on the MAP state tests between students who took middle school PLTW Gateway courses and those who did not.

Chapter Four: Results

Overview

As noted in Chapter Three, the Researcher conducted a quantitative study of PLTW Gateway program outcomes by analyzing responses to a Researcher-generated survey of high school students' STEAM knowledge and attitudes. The Researcher collected 57 consent and assent forms and sent out 57 surveys to the respondents from the two high schools. Fifty-seven students responded to the survey through the *Qualtrics* platform, and the 57 surveys completed served as a convenience sample for applying the *t*-test for difference of two means to NH1 through NH4. Thirty of the participants who took the survey answered yes when asked if they completed one or more PLTW Gateway courses in middle school. Twenty-seven of the participants who took the survey answered no when asked if they completed one or more PLTW Gateway courses in middle school. Thirty-nine respondents to the survey identified as female while 18 respondents identified as male. The Researcher then conducted a *t*-test for difference of two means, applying the *t*-test to question pairs 4 and 11, 5 and 12, 6 and 13, 7 and 14, 8 and 15, 9 and 16, and 10 and 17, applying the results of the *t*-tests to the appropriate null hypotheses 1 through 4.

The Researcher also analyzed middle school students' academic performance on the MAP state standardized assessment from four middle schools over three years that the PLTW Gateway program served students. The Researcher collected MAP scores for a population that included all students, 5,441 total scores, in the four school district middle schools over the three years included in the study and then applied stratified sampling to obtain data sets.

Null Hypotheses Results

Null Hypothesis 1. There is no difference in knowledge of STEAM education programs between students who participate in PLTW Gateway and students who do not participate in PLTW Gateway.

Survey question 4. I heard about STEAM careers and concepts before taking PLTW Gateway in middle school.

Survey question 11. I heard about STEAM careers and concepts before taking any courses in middle school.

The Researcher conducted a *t*-test for difference of two means to see if the students who took PLTW Gateway had a difference in their knowledge of STEAM education programs compared to students who did not take PLTW Gateway courses. The Researcher applied the *t*-test for difference of two means to survey questions 4 and 11, comparing means of participant responses on the Likert scale survey. A preliminary test of variances revealed that the variances were equal. The analysis revealed that knowledge of STEAM education programs for students who took PLTW Gateway courses (M = 3.82, SD = 1.09) was significantly different from knowledge of STEAM education programs for those students who did not take PLTW Gateway courses (M = 3.12, SD = 1.36); $t(51) = 2.08$, $p = 0.043$, $\alpha = .05$. The Researcher rejected the null hypothesis and concluded that the students who took PLTW Gateway did show a difference in knowledge of STEAM programs higher than the students who did not take PLTW Gateway based on the results of survey questions 4 and 11. *T*-test results are displayed in Table 13.

Table 13

t-Test: Two-Sample Assuming Equal Variances; H1: Question Pair 4 & 11

	Q4	*Q11*
Mean	3.82	3.12
Variance	1.19	1.86
Observations	28	25
Pooled Variance	1.50	
Hypothesized Mean Difference	0	
df	51	
t Stat	2.08	
P(T<=t) one-tail	0.021	
t Critical one-tail	1.68	
P(T<=t) two-tail	0.043	
t Critical two-tail	2.01	

Null Hypothesis 2. There is no difference in perceptions of STEAM education programs between students who participate in PLTW Gateway and students who do not participate in PLTW Gateway.

Survey question 5. PLTW Gateway class in middle school changed my view of STEAM careers and concepts.

Survey question 12. Other factors or courses in middle school besides PLTW Gateway changed my view of STEAM careers and concepts.

The Researcher conducted a *t*-test for difference of two means to see if the students who took PLTW Gateway had a difference in their perceptions of STEAM education programs compared to students who did not take PLTW Gateway. The Researcher applied the *t* -test for difference of two means to survey questions 5 and 12, comparing means of participant responses on the Likert scale survey. A preliminary test of variances revealed that the variances were equal. The analysis revealed that perceptions of STEAM education programs for students who took PLTW Gateway (M = 3.68, SD = 0.86) was significantly different from perceptions of STEAM education programs for those students who did not take PLTW Gateway (M = 3.08, SD = 0.95); $t(51) = 2.40$, $p = 0.020$, $\alpha = .05$. A second set of questions in the survey also applied directly to H2. The Researcher rejected the null hypothesis and concluded that the students who took PLTW Gateway did show a difference in perceptions of STEAM programs higher than the students who did not take PLTW Gateway, based on a comparison of question pair 5 and 12. *T*-test results are displayed in Table 14.

Table 14

t-Test: Two-Sample Assuming Equal Variances; H2: Question Pair 5 and 12

	Q5	*Q12*
Mean	3.68	3.08
Variance	0.74	0.91
Observations	28	25
Pooled Variance	0.82	
Hypothesized Mean Difference	0	
df	51	
t Stat	2.40	
P(T<=t) one-tail	0.010	
t Critical one-tail	1.68	
P(T<=t) two-tail	0.020	
t Critical two-tail	2.01	

The Researcher also analyzed survey question pair 6 and 13 as they applied to Null Hypothesis 2.

Survey question 6. I thought that a STEAM career would be too difficult for me before taking PLTW Gateway in middle school.

Survey question 13. I thought that a STEAM career would be too difficult for me before taking any courses in middle school.

The Researcher conducted a *t*-test for difference of two means to see if the students who took PLTW Gateway had a difference in their perceptions of STEAM education programs compared to students who did not take PLTW Gateway. The Researcher applied the *t*-test for difference of two means to survey questions 6 and 13, comparing means of participant responses on the Likert scale survey. A preliminary test of variances revealed that the variances were equal.

Table 15

t-Test: Two-Sample Assuming Equal Variances; H2: Question Pair 6 & 13

	Q6	*Q13*
Mean	3.07	2.92
Variance	1.11	0.66
Observations	28	25
Pooled Variance	0.90	
Hypothesized Mean Difference	0	
df	51	
t Stat	0.58	
P(T<=t) one-tail	0.282	
t Critical one-tail	1.68	
P(T<=t) two-tail	0.564	
t Critical two-tail	2.01	

The analysis revealed that perceptions of STEAM educational programs for students who took PLTW Gateway (M = 3.07, SD = 1.05) was not significantly different from perceptions of STEAM education programs for those students who did not take PLTW Gateway (M = 2.92, SD = 0.81); $t(51) = 0.58$, $p = 0.564$, $\alpha = .05$. The Researcher failed to reject the null hypothesis and concluded that the students who took PLTW Gateway did not show a difference in perceptions of STEAM educational programs higher than the students who did not take Gateway PLTW, based on question pair 6 and 13. *T*-test results are displayed in Table 15.

The Researcher also analyzed survey question pair 8 and 15 as they applied to Null Hypothesis 2.

Survey question 8. Taking PLTW Gateway in middle school influenced my decision to take more PLTW in high school.

Survey question 15. Taking PLTW Gateway in middle school influenced my decision to take more PLTW in high school.

The Researcher conducted a *t*-test for difference of two means to see if the students who took Gateway PLTW Gateway had a difference in their perceptions of STEAM education programs compared to students who did not take Gateway PLTW. The Researcher applied the *t*-test for difference of two means to survey questions 8 and 15, comparing means of participant responses on the Likert scale survey. A preliminary test of variances revealed that the variances were not equal. The analysis revealed that perceptions of STEAM education programs for students who took PLTW Gateway (M = 3.75, SD = 1.04) was significantly different from perceptions of STEAM education programs for those students who did not take PLTW Gateway (M = 2.84, SD = 0.69); $t(24) = 3.79$, $p < 0.001$, $\alpha = .05$. The Researcher rejected the null hypothesis and concluded that the students who took Gateway PLTW did show a significant difference in perceptions of STEAM programs higher than the students who did not take Gateway PLTW, based on a comparison of question pair 8 and 15. *T*-test results are displayed in Table 16.

Table 16

t-Test: Two-Sample Assuming Equal Variances; H2: Question Pair 8 & 15

	Q8	Q15
Mean	3.75	2.84
Variance	1.08	0.47
Observations	28	25
Pooled Variance	0.80	
Hypothesized Mean Difference	0	
df	51	
t Stat	3.71	
P(T<=t) one-tail	0.001	
t Critical one-tail	1.68	
P(T<=t) two-tail	0.001	
t Critical two-tail	2.01	

Null Hypothesis 3. There is no difference in student interest in STEAM careers after high school between students who participate in PLTW Gateway and students who do not participate in PLTW Gateway.

Survey question 7. After taking PLTW Gateway in middle school, I have more of an interest in a STEAM career.

Survey question 14. After taking courses in middle school besides PLTW Gateway, I have more of an interest in a STEAM career.

The Researcher conducted a *t*-test for difference of two means to see if the students who took PLTW Gateway had a difference in their interest in STEAM careers after high school compared to students who did not take PLTW Gateway. The Researcher applied the *t*-test for difference of two means to survey questions 7 and 14, comparing means of participant responses on the Likert scale survey. A preliminary test of variances revealed that the variances were equal. The analysis revealed that interest in STEAM careers after high school for students who took PLTW Gateway (M = 3.82, SD = 1.09) was significantly different from interest in STEAM careers after high school for those students who did not take PLTW Gateway (M = 2.88, SD = 1.36); $t(51) = 2.79$, $p = 0.007$, $\alpha = .05$. The Researcher rejected the null hypothesis and concluded that the students who took PLTW Gateway did show a significant difference in level of interest in STEAM careers higher than the students who did not take Gateway PLTW, based on question pair 7 and 14. *T*-test results are displayed in Table 17.

Table 17

t-Test: Two-Sample Assuming Equal Variances; H3: Question Pair 7 & 14

	Q7	*Q14*
Mean	3.82	2.88
Variance	1.19	1.86
Observations	28	25
Pooled Variance	1.50	
Hypothesized Mean Difference	0	
df	51	
t Stat	2.79	
P(T<=t) one-tail	0.004	
t Critical one-tail	1.68	
P(T<=t) two-tail	0.007	
t Critical two-tail	2.01	

The Researcher also analyzed survey question pair 9 and 16 as they applied to Null Hypothesis 3.

Survey question 9. I feel better prepared for a STEAM career because I took PLTW Gateway

Survey question 16. I feel better prepared for a STEAM career because I took courses other than PLTW Gateway

The Researcher conducted a *t*-test for difference of two means to see if the students who took PLTW Gateway had a difference in their interest in STEAM careers after high school compared to students who did not take PLTW Gateway. The Researcher applied the *t*-test for difference of two means to survey questions 9 and 16, comparing means of participant responses on the Likert scale survey. A preliminary test of variances revealed that the variances were equal. The analysis revealed that interest in STEAM careers after high school for students who took PLTW Gateway (M = 4.11, SD = 0.79) was significantly different from interest in STEAM careers after high school for those students who did not take PLTW Gateway (M = 3.56, SD = 0.65); $t(51) = 2.74$, $p = 0.008$, $\alpha = .05$. The Researcher rejected the null hypothesis and concluded that the students who took PLTW Gateway did show a significant difference in level of interest in a STEAM careers higher than the students who did not take Gateway PLTW, based on question pair 9 and 16. *T*-test results are displayed in Table 18.

Table 18

t-Test: Two-Sample Assuming Equal Variances; H3 & H4: Question Pair 9 & 16

	Q9	*Q16*
Mean	4.11	3.56
Variance	0.62	0.42
Observations	28	25
Pooled Variance	0.53	
Hypothesized Mean Difference	0	
df	51	
t Stat	2.74	
P(T<=t) one-tail	0.004	
t Critical one-tail	1.68	
P(T<=t) two-tail	0.008	
t Critical two-tail	2.01	

The Researcher also analyzed survey question pair 10 and 17 as they applied to Null Hypothesis 3.

Survey question 10. I am likely to pursue a STEAM career

Survey question 17. I am likely to pursue a STEAM career

The Researcher conducted a *t*-test for difference of two means to see if the students who took PLTW Gateway had a difference in their interest in STEAM careers after high school compared to students who did not take PLTW Gateway. The Researcher applied the *t*-test for difference of two means to survey questions 9 and 16, comparing means of participant responses on the Likert scale survey. A preliminary test of variances revealed that the variances were equal. The analysis revealed that interest in STEAM careers for students who took PLTW Gateway (M = 3.75, SD = 1.32) was not significantly different from interest in a STEAM career for those students who did not take PLTW Gateway (M = 3.64, SD = 1.38); $t(51) = 0.30$, $p = 0.77$, $\alpha = .05$. The Researcher failed to reject the null hypothesis and concluded that the students who took

Gateway PLTW did not show a significant difference in level of interest in a STEAM career higher than the students who did not take Gateway PLTW, based on question pair 10 and 17. *T*-test results are displayed in Table 19.

Table 19

t-Test: Two-Sample Assuming Equal Variances; H3 & H4: Question Pair 10 & 17

	Q10	Q17
Mean	3.75	3.64
Variance	1.75	1.91
Observations	28	25
Pooled Variance	1.82	
Hypothesized Mean Difference	0	
df	51	
t Stat	0.30	
P(T<=t) one-tail	0.384	
t Critical one-tail	1.68	
P(T<=t) two-tail	0.768	
t Critical two-tail	2.01	

Null Hypothesis 4. There is no difference in interest in STEAM careers after high school between female students who participate in PLTW Gateway and female students who do not participate in PLTW Gateway.

Survey question 7. After taking PLTW Gateway in middle school, I have more of an interest in a STEAM career.

Survey question 14. After taking courses in middle school besides PLTW Gateway, I have more of an interest in a STEAM career.

The Researcher conducted a *t*-test for difference of two means to see if the female students who took Gateway PLTW had a difference in their interest in STEAM careers after high school compared to female students who did not take Gateway PLTW. The Researcher applied the *t*-test for difference of two means to survey questions 4 and 11, comparing means of participant responses on the Likert scale survey. A preliminary test of variances revealed that the variances were equal. The analysis revealed that interest in STEAM careers after high school for female students who took PLTW Gateway (M = 3.58, SD = 1.02) was not significantly different from interest in STEAM careers after high school for those female students who did not take PLTW Gateway (M = 3.5, SD = 0.79); $t(35) = 0.26$, $p = 0.794$, $\alpha = .05$. The Researcher failed to reject the null hypothesis and concluded that the female students who took Gateway PLTW did not show a difference in interest in STEAM careers higher than the female students who did not take Gateway PLTW, based on question pair 7 and 14. *T*-test results are displayed in Table 20.

Table 20

t-Test: Two-Sample Assuming Equal Variances; H3 & H4: Question Pair 7 & 14

	Q7	*Q14*
Mean	3.58	3.5
Variance	1.04	0.62
Observations	19	18
Pooled Variance	0.83	
Hypothesized Mean Difference	0	
df	35	
t Stat	0.26	
P(T<=t) one-tail	0.397	
t Critical one-tail	1.69	
P(T<=t) two-tail	0.794	
t Critical two-tail	2.03	

The Researcher also analyzed survey question pair 9 and 16 as they applied to Null Hypothesis 3.

Survey question 9. I feel better prepared for a STEAM career because I took PLTW Gateway

Survey question 16. I feel better prepared for a STEAM career because I took courses other than PLTW Gateway

The Researcher conducted a *t*-test for difference of two means to see if the female students who took Gateway PLTW had a difference in their interest in STEAM careers after high school compared to female students who did not take Gateway PLTW. The Researcher applied the *t*-test for difference of two means to survey questions 9 and 16, comparing means of participant responses on the Likert scale survey. A preliminary test of variances revealed that the variances were equal. The analysis revealed that interest in STEAM careers after high school for female students who took PLTW Gateway (M = 3.95, SD = 0.78) was not significantly different from interest in STEAM careers after high school for those female students who did not take PLTW Gateway (M = 3.5, SD = 0.71); $t(35) = 1.83$, $p = 0.077$, $\alpha = .05$. The Researcher failed to reject the null hypothesis and concluded that the female students who took Gateway PLTW did not show a significant difference in level of interest in a STEAM career higher than the female students who did not take Gateway PLTW, based on question pair 9 and 16. *T*-test results are displayed in Table 21.

Table 21

t-Test: Two-Sample Assuming Equal Variances; H3 & H4: Question Pair 9 & 16

	Q9	*Q16*
Mean	3.95	3.5
Variance	0.61	0.5
Observations	19	18
Pooled Variance	0.56	
Hypothesized Mean Difference	0	
df	35	
t Stat	1.82	
P(T<=t) one-tail	0.038	
t Critical one-tail	1.69	
P(T<=t) two-tail	0.077	
t Critical two-tail	2.03	

The Researcher also analyzed survey question pair 10 and 17 as they applied to Null Hypothesis 3.

Survey question 10. I am likely to pursue a STEAM career

Survey question 17. I am likely to pursue a STEAM career

The Researcher conducted a *t*-test for difference of two means to see if the female students who took Gateway PLTW had a difference in their interest in STEAM careers after high school compared to female students who did not take Gateway PLTW. The Researcher applied the *t*-test for difference of two means to survey questions 10 and 17, comparing means of participant responses on the Likert scale survey. A preliminary test of variances revealed that the variances were equal. The analysis revealed that interest in STEAM careers after high school for female students who took PLTW Gateway (M = 3.68, SD = 1.25) was significantly different from interest in STEAM careers after high school for those students who did not take PLTW Gateway (M = 3.72, SD = 1.32); *t*(35) = -0.09, *p* = 0.929, α = .05. The Researcher failed to reject the null hypothesis and concluded that the female students who took Gateway PLTW did not show a significant difference in level of interest in a STEAM career higher than the female students who did not take Gateway PLTW, based on question pair 10 and 17. *T*-test results are displayed in Table 22.

Table 22

t-Test: Two-Sample Assuming Equal Variances; H3 and H4 Question Pair 10 and 17

	Q10	*Q17*
Mean	3.68	3.72
Variance	1.56	1.74
Observations	19	18
Pooled Variance	1.65	
Hypothesized Mean Difference	0	
df	35	
t Stat	-0.09	
P(T<=t) one-tail	0.464	
t Critical one-tail	1.689572	
P(T<=t) two-tail	0.929	
t Critical two-tail	2.03	

Null Hypothesis 5. There is no difference in Science MAP scores of students who participated in PLTW Gateway and Science MAP scores of students who do not participate in PLTW Gateway.

The Researcher conducted a *t*-test for difference of two means to see if the students who took Gateway PLTW had a difference in Science MAP scores compared to students who did not take Gateway PLTW. A preliminary test of variances revealed that the variances were equal. The analysis revealed that the science MAP scores for students who took PLTW (M = 2.27, SD = 0.74) were not significantly different from those of the science MAP scores of students who did not take PTLW Gateway (M = 2.53, SD = 0.73); *t*(30) = -1.405, *p* = 0.17, α = .05. The Researcher failed to reject the null hypothesis and concluded that the students who took Gateway PLTW did not have a difference on the Science MAP test compared to the students who did not take Gateway PLTW. *T*-test results are displayed in Table 23.

Table 23

t-Test: Two-Sample Assuming Equal Variances; H5: MAP Science

	PTLW SCI	*Non PLTW SCI*
Mean	2.27	2.53
Variance	0.547	0.533
Observations	30	30
Pooled Variance	0.54	
Hypothesized Mean Difference	0	
df	58	
t Stat	-1.405	
P(T<=t) one-tail	0.08	
t Critical one-tail	1.672	
P(T<=t) two-tail	0.17	
t Critical two-tail	2.002	

Null Hypothesis 6. There is no difference in MAP math scores of students who participate in PLTW Gateway and MAP math scores of students who do not participate in PLTW Gateway.

The Researcher conducted a *t*-test for difference of two means to see if the students who took Gateway PLTW had a difference in math MAP scores compared to students who did not take Gateway PLTW. A preliminary test of variances revealed that the variances were equal. The analysis revealed that the math MAP scores for students who took PLTW (M = 2.43, SD = 0.97) were not significantly different from those of the math Map scores of students who did not take PTLW Gateway (M = 2.23, SD = 1.04); $t(51) = 2.08$, $p = 0.043$, $\alpha = .05$. The Researcher rejected the null hypothesis and concluded that the students who took Gateway PLTW did have a difference on the math MAP test compared to the students who did not take Gateway PLTW. *T*-test results are displayed in Table 24.

Table 24

t-Test: Two-Sample Assuming Equal Variances; H6: MAP Math

	PLTW Math	Non-PLTW Math
Mean	2.43	2.23
Variance	0.944	1.082
Observations	30	30
Pooled Variance	1.01	
Hypothesized Mean Difference	0	
df	58	
t Stat	0.77	
P(T<=t) one-tail	0.22	
t Critical one-tail	1.672	
P(T<=t) two-tail	0.44	
t Critical two-tail	2.001	

Null Hypothesis 7. There is no difference in EOC Algebra I scores of students who participate in PLTW Gateway and EOC Algebra I scores of students who do not participate in PLTW Gateway.

The Researcher conducted a *t*-test for difference of two means to see if the students who took PLTW Gateway had a difference in Algebra 1 scores compared to students who did not take PLTW Gateway. A preliminary test of variances revealed that the variances were equal. The analysis revealed that the Algebra 1 scores for students who took PLTW (M = 3.70, SD = 0.47) were not significantly different from those of the Algebra 1 scores of students who did not take PTLW Gateway (M = 3.63, SD = 0.49); $t(30) = 0.540$, $p = 0.59$, $\alpha = .05$. The Researcher failed to reject the null hypothesis and concluded that the students who took PLTW Gateway did not have a difference on the Algebra 1 test compared to the students who did not take PLTW Gateway. *T*-test results are displayed in Table 25.

Table 25

t-Test: Two-Sample Assuming Equal Variances; H7: ALG EOC

	ALG EOC PLTW	*ALG EOC Non PLTW*
Mean	3.70	3.63
Variance	0.217	0.240
Observations	30	30
Pooled Variance	0.23	
Hypothesized Mean Difference	0	
df	58	
t Stat	0.54	
P(T<=t) one-tail	0.30	
t Critical one-tail	1.67	
P(T<=t) two-tail	0.59	
t Critical two-tail	2.00	

Summary

This quantitative study revealed PLTW Gateway students who responded to the study survey showed statistically significant differences in three of the four null hypotheses tested for STEAM attitudes. For Null Hypothesis 1 (survey question pair 4 and 11) the study revealed PLTW Gateway students showed knowledge of STEAM programs higher than the students who did not take PLTW Gateway. For Null Hypothesis 2 (survey question pairs 5 and 12, 6 and 13, and 8 and 14) the study revealed PLTW Gateway students showed a statistically significant difference in perceptions of STEAM programs higher than the students who did not take PLTW Gateway. For Null

Hypothesis 3 (survey question pairs 7 and 14, 9 and 16, and 10 and 17) the study also revealed PLTW Gateway students showed statistically significant differences difference in attitudes regarding STEAM careers higher than the students who did not take PLTW Gateway. However, for Null Hypothesis 4 (survey question pairs 7 and 14, 9 and 16, and 10 and 17) related to female students' attitudes regarding STEAM careers, no statistically significant difference was shown. Finally, Null Hypotheses 5, 6, and 7 showed no significant difference in math, Algebra I, and science scores between students who took a PLTW Gateway course and those who did not. This quantitative data showed PLTW Gateway to be similar to other STEAM programs examined in this study, providing students with experiences in the classroom that changed knowledge and perceptions of STEAM programs and careers, while having little impact on standardized math and science test scores. Chapter Five provides further analysis of this data and offers suggestions for future study related to PLTW programs specifically and STEAM programs more broadly.

Chapter Five: Discussion

Overview

The Researcher’s study emerged from his professional experience working in a middle school where a number of different STEAM education initiatives, including PLTW Gateway had been implemented over the several years previous to this writing. The Researcher also found that while an extensive amount of research existed in the areas of PBL, STEAM, math, and science pedagogy, little research existed specifically for PLTW, especially in the middle school setting. This specific research study focused on examining survey data to ascertain student attitudes regarding STEAM courses and careers, as well as student academic performance in the areas of science and math. The focus was to determine if implementing a PLTW Gateway program in a Midwestern suburban district of just over 10,000 students led to changes in student attitudes regarding STEAM careers along with changes in academic performance in the areas of science and math. The Researcher created a survey and distributed solicitations to participate in the survey to over 3,000 of the school district’s high school students. The Researcher ultimately received 57 completed surveys from district students. The Research also examined three years of state test data for science, math, and Algebra I. The entire population of student scores consisted of 5,411 separate scores from which 6 stratified random samples of 30 were drawn.

In order to examine specific academic achievement outcomes and attitudes regarding STEAM courses and STEAM careers among students who completed at least one semester in a middle school PLTW Gateway program, the Researcher examined a Likert style survey of 57 high-school-aged survey respondents submitted in the spring and fall of 2018, as well as three consecutive years (2015, 2016, and 2017) of historical MAP science, math, and Algebra I data. Through examining student survey data, this study attempted to determine if a statistically significant difference existed between students' perceptions of those who took at least one PLTW Gateway course and students' perceptions of those who did not take any such course. These survey questions related to student knowledge regarding STEAM school programs, attitudes regarding STEAM school programs, attitudes related to STEAM careers, and female student attitudes related to STEAM careers. Through examining historical MAP data, this study attempted to determine if a statistically significant difference existed in the areas of math, Algebra I, and science Missouri state assessments between the two groups studied: middle school students who took at least one PLTW Gateway course and middle school students who did not take any such course.

Discussion

Hypothesis 1. There is a difference in knowledge of STEAM education programs between students who participate in PLTW Gateway and students who do not participate in PLTW Gateway.

Through examining survey question pair 4 and 11, the Researcher attempted to determine whether a difference existed regarding students' knowledge of STEAM educational programs between the two groups studied: students who took at least one PLTW Gateway course in middle school and students who did not take any such course. However, when examining the data from the *t*-test for difference of independent means, the Researcher determined that knowledge of STEAM education programs for students who took PLTW Gateway could not be analyzed for significance because questions 4 and

11 were poorly worded (Fraenkel et al., 2015, p. 398). Although the *t*-test showed results for Q4 were significantly higher than results for Q11, it was impossible to determine from student answers whether knowledge of STEAM school programs came from classes students took before a PLTW course or the PLTW course itself. Question 4 asked students to rate from strongly disagree through strongly agree the following statement: I heard about STEAM careers and concepts before taking PLTW Gateway in middle school. Question 11 used the same rating scale for the statement: I heard about STEAM careers and concepts before taking any courses in middle school. The researcher determined that a higher rating on the Likert scale for Q4 indicated that students were more likely to have heard about STEAM before taking a PLTW course, not from taking the course. Another problem with question pair 4 and 11 was that Q11 may have led students to believe they were commenting on whether they heard about STEAM in elementary school instead of middle school. Therefore, question pair 4 and 11 could not be used by the Researcher to answer questions regarding knowledge of STEAM programs (Fraenkel et al., 2015, p. 398). Future teachers and administrators implementing a PLTW program as a STEAM initiative along with PLTW officials, however, should continue to survey student participants about students' knowledge of STEAM programs and its relationship to PLTW. As other survey questions related to STEAM attitudes and careers in the Researcher's study were more accurately worded, those questions provided more useful information to researchers and were more relevant to the purposes of this study. Question pair 4 and 11 was the only pair that applied to H1.

Hypothesis 2. There is a difference in perceptions of STEAM education programs between students who participate in PLTW Gateway and students who do not participate in PLTW Gateway.

Through examining survey question pair 5 and 12, the Researcher determined that perceptions of STEAM education programs for students who took PLTW Gateway were significantly higher than perceptions of STEAM education programs for those students who did not take PLTW Gateway. Unlike the problems that occurred for this study regarding Q4 and Q11, question pair 5 and 12 proved easy enough for students to understand so as to provide reliable results. Results for the *t*-test applied to Q5 and Q11 indicated to the Researcher that taking one PLTW Gateway course in middle school resulted in more positive attitudes of students towards STEAM education programs when compared to peers who did not take any PLTW Gateway course. Specifically, for this questions pair, the results showed that taking one PLTW Gateway course created a more favorable view of STEAM careers and concepts than never having taken a PLTW course. The mean score of 3.68 on question pair 5 and 12 for PLTW students was significantly higher than the mean of 3.08 for non-PLTW students. This conclusion supported other research indicating that PLTW had a positive impact, encouraging students to pursue further STEAM coursework in high school and college (Sorge, 2014). Mean scores for survey question pairs are displayed in Table 26.

Table 26

Survey Question Pair 5 & 12 Means

Mean Scores	PLTW	Non-PLTW
Question Pair 4 and 11	3.82	3.12
Question Pair 5 and 12	**3.68**	**3.08**
Question Pair 6 and 13	3.07	2.92
Question Pair 7 and 14	3.82	2.88
Question Pair 8 and 15	3.75	2.84
Question Pair 9 and 16	4.11	3.56
Question Pair 10 and 17	3.75	3.64

In contrast to results for survey question pair 5 and 12, results for survey question pair 6 and 13 did not support H2. The Researcher determined that perceptions of STEAM education programs for students who took PLTW Gateway were not significantly higher than perceptions of STEAM education programs for those students who did not take PLTW Gateway. This survey question pair asked students to comment on whether they believed a STEAM career would be too difficult for them before taking a PLTW course for PLTW students and if a STEAM career would be too difficult before taking any middle school course for non-PLTW students. The *t*-test showed no significant difference between the two groups. The Researcher proposed that this result might be explained by students' lack of certainty one way or another regarding the future difficulty of STEAM careers for both groups. The mean score for PLTW students was 3.07, while the mean for non-PLTW students was 2.92. This mean answer correlated to neither agree nor disagree on the study's Likert scale survey, indicating students were unsure as to the future difficulty of STEAM careers, not whether coursework in middle school affected their interest in future STEAM coursework. A mixed method study that included a focus group or open-ended question survey could have shed more light on student attitudes regarding the perceived difficulty of STEAM courses and/or careers. (Hess et al, 2016). Mean scores for survey question pairs are displayed in Table 27.

Table 27

Survey Question Pair 6 & 13 Means

Mean Scores	PLTW	Non-PLTW
Question Pair 4 and 11	3.82	3.12
Question Pair 5 and 12	3.68	3.08
Question Pair 6 and 13	**3.07**	**2.92**
Question Pair 7 and 14	3.82	2.88
Question Pair 8 and 15	3.75	2.84
Question Pair 9 and 16	4.11	3.56
Question Pair 10 and 17	3.75	3.64

Results for survey question pair 8 and 15 offered opportunities for similar analysis as pair 5 and 12. The Researcher determined that perceptions of STEAM education programs for students who took PLTW Gateway were significantly higher than perceptions of STEAM education programs for those students who did not take PLTW Gateway. Results for the *t*-test applied to Q8 and Q15 indicated to the Researcher that taking one PLTW Gateway course in middle school resulted in more positive attitudes of students towards STEAM education programs when compared to peers who did not take any PLTW Gateway course. This question pair asked students whether taking a PLTW Gateway course in middle school influenced their decision to take another PLTW course in the future. The mean answer for PLTW students was 3.75, the third highest mean for all survey questions. The mean answer for non-PLTW students was the lowest mean score for all survey questions, just 2.84. As discussed earlier in the limitations of this study, this low result for non-PLTW participants may have been due to confusion related to the wording of question 14, ‘Taking PLTW Gateway in middle school influenced my decision to take more PLTW in high school,' as these students did not take a PLTW Gateway course. However, the 3.75 mean answer for PLTW students did indicate to the Researcher that students who took at least one PLTW course were likely to take another in high school. Other research indicating that PLTW had a positive impact encouraging students to pursue further STEAM coursework in high school and college agreed with these findings for question pair 8 and 15 (Sorge, 2014). Mean scores for survey question pairs are displayed in Table 28.

Table 28

Survey Question Pair 8 & 15 Means

Mean Scores	PLTW	Non-PLTW
Question Pair 4 and 11	3.82	3.12
Question Pair 5 and 12	3.68	3.08
Question Pair 6 and 13	3.07	2.92
Question Pair 7 and 14	3.82	2.88
Question Pair 8 and 15	**3.75**	**2.84**
Question Pair 9 and 16	4.11	3.56
Question Pair 10 and 17	3.75	3.64

Finally, for Hypothesis 2 the results of two of the three survey question pairs indicated that students who took a PLTW Gateway course in middle school left the course with a more favorable view of STEAM coursework. The only survey question pair that did not support H2, pair 6 and 13, may have only revealed students' uncertainty regarding the difficulty of future STEAM careers rather than interest in future STEAM coursework. Therefore, the Researcher concluded that results for Hypothesis 2 agreed with other research that PLTW Gateway could have a positive influence on student attitudes regarding future STEAM coursework (Sorge, 2014).

Hypothesis 3. There is a difference in student interest in STEAM careers after high school between students who participate in PLTW Gateway and students who do not participate in PLTW Gateway.

Through examining survey question pair 7 and 14, the Researcher determined that interest in STEAM careers for students who took PLTW Gateway was significantly higher than interest in STEAM careers for those students who did not take PLTW Gateway. Results for the *t*-test applied to Q7 and Q14 indicated to the Researcher that taking one PLTW Gateway course in middle school resulted in more positive attitudes of students towards STEAM careers when compared to peers who did not take any PLTW Gateway course. Specifically, for this question pair, the results showed that taking one PLTW Gateway course created more interest in a STEAM career than never having taken a PLTW course. The mean score of 3.82 on question 7 was the second highest mean score in the entire survey portion of this study. Conversely, the mean score of 2.88 for non-PLTW students was significantly lower. This conclusion supported other research indicating that PLTW had a positive impact, encouraging students to pursue STEAM degrees in college and STEAM careers after high school (Porter, 2011; Sorge, 2014; Van Overschelde, 2013). Other studies on STEM/STEAM careers also revealed students showed increased interest in STEAM careers when introduced to STEM/STEAM specifically in middle school (Tai, 2012). Mean scores for survey question pairs are displayed in Table 29

Table 29

Survey Question Pair 7 & 14 Means

Mean Scores	PLTW	Non-PLTW
Question Pair 4 and 11	3.82	3.12
Question Pair 5 and 12	3.68	3.08
Question Pair 6 and 13	3.07	2.92
Question Pair 7 and 14	**3.82**	**2.88**
Question Pair 8 and 15	3.75	2.84
Question Pair 9 and 16	4.11	3.56
Question Pair 10 and 17	3.75	3.64

Additionally, through examining survey question pair 9 and 16, the Researcher determined that interest in STEAM careers for students who took PLTW Gateway was significantly higher than interest in STEAM careers for those students who did not take PLTW Gateway. Results for the *t*-test applied to Q9 and Q16 indicated to the Researcher that taking one PLTW Gateway course in middle school resulted in students feeling more prepared for a STEAM career when compared to peers who did not take any PLTW Gateway course. The mean score of 4.11 on question 9 was the highest mean score in the entire survey portion of this study. While the mean score of 3.56.for non PLTW students was also one of the higher scores in the survey, it was still statistically significantly lower than the score for Q16. The researcher thus concluded that both groups felt prepared for a STEAM career, but PLTW students felt better prepared. This conclusion supported other research indicating that PLTW had a positive impact, encouraging students to pursue STEAM degrees in college and STEAM careers after high school (Porter, 2011; Sorge, 2014; Van Overschelde, 2013). Other studies on STEM/STEAM careers also revealed students showed increased interest in STEAM careers when introduced to

STEM/STEAM specifically in middle school (Tai, 2012). Mean scores for survey question pairs are displayed in Table 30.

Table 30

Survey Question Pair 9 & 16 Means

Mean Scores	PLTW	Non-PLTW
Question Pair 4 and 11	3.82	3.12
Question Pair 5 and 12	3.68	3.08
Question Pair 6 and 13	3.07	2.92
Question Pair 7 and 14	3.82	2.88
Question Pair 8 and 15	3.75	2.84
Question Pair 9 and 16	**4.11**	**3.56**
Question Pair 10 and 17	3.75	3.64

Finally, for hypothesis 3, through examining survey question pair 10 and 17, the Researcher determined that interest in STEAM careers for students who took PLTW Gateway was not significantly higher than interest in STEAM careers for those students who did not take PLTW Gateway. Results for the *t*-test applied to Q10 and Q17 indicated to the Researcher that taking one PLTW Gateway course in middle school did not result in students indicating that they would be more likely to pursue a STEAM career when compared to peers who did not take any PLTW Gateway course. The mean score of 3.75 on question 10 was the third highest mean score in the survey portion of this study, while the mean score of 3.64 for non PLTW students was also one of the higher scores in the survey. The difference was, therefore, not statistically significantly lower than the score for Q10. The Researcher thus concluded that while both groups indicated some likelihood to pursue a STEAM career, taking a PLTW Gateway course in middle school did not influence students to pursue students at a higher rate than non-PLTW students. This conclusion for question pair 10 and 17 pertaining to H3 contradicted other research indicating that PLTW had a positive impact, encouraging students to pursue STEAM degrees in college and STEAM careers after high school (Porter, 2011; Sorge, 2014; Van Overschelde, 2013). However, the failure to reject the null for only question pair 10 and 17 may have been influenced by the study school district's other STEAM initiatives that focused on embedding STEAM principals and motivation in all core subjects. Some research highlighted in this study revealed embedding STEAM in core classes instead of stand-alone courses like PLTW as an effective strategy to improve interest in STEAM careers (Abbott, 2016; Michael & Alsup, 2016; Vennix et al., 2018; Yoon Yoon, 2014). Mean scores for survey question pairs are displayed in Table 31.

Table 31

Survey Question Pair 10 & 17 Means

Mean Scores	PLTW	Non-PLTW
Question Pair 4 and 11	3.82	3.12
Question Pair 5 and 12	3.68	3.08
Question Pair 6 and 13	3.07	2.92
Question Pair 7 and 14	3.82	2.88
Question Pair 8 and 15	3.75	2.84
Question Pair 9 and 16	4.11	3.56
Question Pair 10 and 17	**3.75**	**3.64**

Hypothesis 4. There is a difference in interest in STEAM careers after high school between female students who participate in PLTW Gateway and female students who do not participate in PLTW Gateway.

Through examining survey question pair 7 and 14, after disaggregating female results from the sample of 57 respondents**,** the Researcher determined that perceptions of STEAM education programs for female students who took PLTW Gateway were not significantly higher than perceptions of STEAM education programs for those female students who did not take PLTW Gateway. Results for the *t*-test applied to Q7 and Q14 indicated to the Researcher that taking one PLTW Gateway course in middle school did not result in more positive attitudes of female students towards STEAM careers when compared to female peers who did not take any PLTW Gateway course. This is contrary to the results of other researchers who found that PLTW had a positive impact on female students' attitudes regarding STEAM coursework (Sorge, 2014). All three of these studies focused on high school students. However, Paslov (2007) found similarly that PLTW Gateway improved female middle school students' view of STEAM school programs. The results of the Researcher's survey questions may have been impacted by the small size of the female sample: 39 respondents. Ultimately, the results of this study and Hypothesis 4 in particular did not show the positive impact that other studies of middle school PLTW programs showed (Paslov, 2007, Sorge, 2014).

Hypothesis 5. There is a difference in Science MAP scores of students who participated in PLTW Gateway and Science MAP scores of students who do not participate in PLTW Gateway.

Through examining historical MAP science data, the Researcher determined that there was no difference in science MAP scores of students who participated in PLTW Gateway and science MAP scores of students who did not participate in PLTW Gateway. Most of the research of PLTW programs highlighted in Chapter Two of this study agreed with the Researcher's conclusions related to H5, pointing out that PLTW had little impact on improving standardized test scores in math and science (Hess et al., 2016; Tran & Nathan, 2010; Wheeler, 2008). This conclusion was true for the Researcher's conclusions related to both H6 and H7, as well, and are discussed in more detail further on in Chapter Five.

Hypothesis 6. There is a difference in MAP math scores of students who participate in PLTW Gateway and MAP math scores of students who do not participate in PLTW Gateway.

Through examining historical MAP math data, the Researcher determined that there was no difference in math MAP scores of students who participated in PLTW Gateway and math MAP scores of students who did not participate in PLTW Gateway. Most of the research of PLTW programs highlighted in Chapter Two of this study agreed with the Researcher's conclusions related to H6, pointing out that PLTW had little impact on improving standardized test scores in math and science (Hess et al., 2016; Tran & Nathan, 2010; Wheeler, 2008). Because results for H6 were so similar to results for H5 and H7, those results are discussed after the specific discussion of H7.

Hypothesis 7. There is a difference in EOC Algebra I scores of students who participate in PLTW Gateway and EOC Algebra I scores of students who do not participate in PLTW Gateway.

Through examining historical EOC Algebra I data, the Researcher determined that there was no difference in EOC Algebra I scores of students who participated in PLTW Gateway and EOC Algebra I scores of students who did not participate in PLTW Gateway. Most of the research of PLTW programs highlighted in Chapter Two of this study agreed with the Researcher's conclusions related to H7, pointing out that PLTW had little impact on improving standardized test scores in math and science (Hess et al., 2016; Tran & Nathan, 2010; Wheeler, 2008).

So, for all three study hypotheses (H5, H6, and H7) related to PLTW Gateway's impact on specific math and science state assessments, this study's findings agree with the majority of research which found little evidence that PLTW improved student academic performance in the areas of math and science (Hess et al., 2016; Tran & Nathan, 2010; Wheeler, 2008). Additionally, the results of the study may have been limited by the master schedule used at all four middle schools in the study school district. The researcher noted that students in the study school district were forced by the master schedule to choose between PLTW and other electives, as the master schedule permitted students only one elective choice. Students who were interested in other electives, such as band, choir, or foreign language, did not have the opportunity to take PLTW Gateway courses and therefore not exposed to this program. Band students had historically scored well on state tests in the study school district and were not inclined to choose PLTW at the expense of band. However, the study school district recently added an additional elective course to the master schedule permitting band students to also take PLTW courses. Future researchers might benefit from a longitudinal comparison of PLTW's impact in the study school district before and after this change to the master schedule.

Based on the results summarized in Chapter Four, the Researcher recommends that the study school district, as well as other school districts, continue to implement PLTW Gateway and the entire PLTW program more broadly, as a means to motivate students to take further STEAM coursework in high school and college, as well as means to encourage more young people to pursue STEAM careers. Conversely, more study is still needed to determine if PLTW should be viewed by school districts or marketed by the PLTW organization as a pedagogy to improve math and science achievement. Implications and recommendations are laid out in more detail in the next section.

Implications

The results of this quantitative study have implications for school districts, the PLTW organization, and future researchers. School districts wanting to improve math and science scores should continue to focus on the curricula and instruction in those discreet subject areas particularly in middle schools. Both the results of this study and previous studies of PLTW indicated that PLTW more broadly and PLTW Gateway in particular had minimal impact on improving academic performance in the subject areas of science and math as measured on state assessments (Tran & Nathan, 2010; Stohlman et al., 2011; Wheeler, 2008). However, the results of this study concur with a large portion of the previous research in the recommendation that schools implement PLTW Gateway as a way to improve student attitudes regarding STEAM courses, as well as increase the likelihood that students will pursue STEAM careers.

The PLTW organization should continue to emphasize the program's benefits to schools and school districts seeking to improve student attitudes related to STEAM along with increasing student interest in STEAM careers. The PLTW organization should also continue to encourage and support more detailed studies, perhaps long-term ethnographic studies of its programs at all three grade levels (elementary, middle, and high) but especially middle school where there is still a need for more research (Hess et al., 2016). Finally, the PLTW organization may want to strengthen and update specific elements of their curriculum related to math and science instruction and then study the impact of those changes. Perhaps more focus on embedding math and science standards in the

PLTW curriculum could create a greater impact on math and science learning for PLTW students.

As for future researchers, there are still many questions worth exploring that this particular study was too narrow in focus to investigate. For instance, what impact do master scheduling decisions in middle schools have on enrollment in PLTW Gateway? Do students who take PLTW Gateway do better in high school math and science courses? The results of this study supported other research in that middle school students who took PLTW Gateway did not perform better on state math and science assessments than their non-PLTW Gateway peers. However, PLTW Gateway students did show improved attitudes and greater interest in STEAM and STEAM careers than their non-PLTW peers. Schools, the PLTW organization, and future educational researchers should continue to invest in PLTW programs, as well as future research in both the academic and attitudinal impacts of PLTW programs. Overall, the results of this study were not surprising, as they supported previous research confirming that PLTW is a more effective influencer of student attitudes regarding STEAM courses and STEAM careers than it is a tool for improving math and science performance.

Recommendations

As with much educational research and other studies with human subjects, this study contained limitations that other researchers should explore. One limitation was the quantitative nature of the study. Although the survey questions in this study attempted to ascertain student attitudes regarding STEAM courses and careers, the Researcher designed the study’s Likert survey himself which may have limited the effectiveness of the survey. A number of questions were confusing to students, and the survey results were in no way nationally norm referenced. Also, results for female students were contrary to most of the existing research in the literature (Sorge, 2014). The Researcher could not ascertain any reason for this discrepancy. The Researcher recommends that future research include qualitative measures, including detailed ethnographic studies of middle school students enrolled in PLTW Gateway courses in order to get a clearer picture of the elements of PLTW that influence student attitudes regarding STEAM courses and careers in a positive manner. Perhaps other researchers could use a standardize survey tool like the Engineering Identity Development Scale (EIDS) to measure student attitudes regarding STEAM (Yoon Yoon, 2014). The PLTW organization could also provide more useful information regarding PLTW's influence on student STEAM attitudes by either using a survey tool like the EIDS or one that they developed themselves, using their presence in every U.S. state, gather and align PLTW survey data regarding STEAM attitudes.

Conclusion

At the beginning of the 21st-century educational leaders around the United States recognized the need to provide programs and research designed to prepare students for rapidly changing career opportunities. Improving STEAM literacy and proficiency, therefore, became a major priority for schools all over the United States. Another priority also emerged to increase the number of students interested in pursuing STEAM careers. Among the myriad of programs and initiatives designed to improve STEAM proficiency and motivation to pursue STEAM careers, PLTW emerged as a viable option for many schools and school districts (Hess et al., 2016).

For school districts similar to the study school district, as well as districts in more urban and rural settings, PLTW appears to be a viable option for improving student attitudes and knowledge of STEAM coursework and STEAM careers. Despite this study's findings that PLTW Gateway does not significantly improve math and science performance when compared to non-PLTW student performance, PLTW Gateway does improve student attitudes regarding STEAM courses and careers. Thus, PLTW Gateway does meet the ever-present goal of educators, government officials, and business leaders of developing a well-trained workforce eager to pursue the careers of the 21st-century (Boyington, 2018; National Academies, 2007). It is the recommendation of this Researcher that his current school district, other school districts, and researchers throughout education continue to use the PLTW platform to improve STEAM proficiency and motivate students to pursue STEAM careers. But schools, researchers, and the PLTW organization should not stop there. All of these groups should work in concert to continue to deeply study PLTW's impact on student growth and preparedness for the challenges that lie ahead in the rest of the 21st-century and beyond.

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Appendix A

PLTW STEAM Career Survey

Dear Student,

The following survey is designed to collect information related to PLTW Gateway. This survey is voluntary, and you are receiving it due to your participation in at least one PLTW Gateway course in the last three years. The survey is also anonymous and will be used in this study to determine possible relationships between PLTW Gateway and STEAM course choices and careers. By completing this survey, you give permission for your answers to be included in this study.

1. Please provide the following information:

Male Female

2. Current grade level in school

9 10 11 12

3. Please indicate whether you took a PLTW Gateway course in a Mehlville School District middle school.

1. Yes 2. No

If you answered yes, please go on to survey question 4. If you answered no, please skip questions 4 through 10 and answer questions 11 through 17 on this survey.

Please rate the following statements related to career interest on a scale of 1 to 5:

1 Strongly Disagree 2 Disagree 3 Neither Agree nor Disagree

4 Agree 5 Strongly Agree

4. I heard about STEAM careers and concepts before taking PLTW Gateway in middle school.

5. PLTW Gateway class in middle school changed my view of STEAM careers and concepts.

6. I thought that a STEAM career would be too difficult for me before taking PLTW Gateway in middle school.

7. After taking PLTW Gateway in middle school, I have more of an interest in a STEAM career.

8. Taking PLTW Gateway in middle school influenced my decision to take more PLTW in high school.

9. I feel better prepared for a STEAM career because I took PLTW Gateway

10. I am likely to pursue a STEAM career.

11. I heard about STEAM careers and concepts before taking any courses in middle school.

12. Other factors or courses in middle school besides PLTW Gateway changed my view of STEAM careers and concepts.

13. I thought that a STEAM career would be too difficult for me before taking any courses in middle school.

14. After taking courses in middle school besides PLTW Gateway, I have more of an interest in a STEAM career.

15. Taking PLTW Gateway in middle school influenced my decision to take more PLTW in high school.

16. I feel better prepared for a STEAM career because I took courses other than PLTW Gateway

17. I am likely to pursue a STEAM career.

Vitae

Patrick Joseph Bellinger

Patrick Bellinger earned his undergraduate degree in Secondary Education with an emphasis in Social Studies from the University of Missouri-Columbia. After graduating, he accepted a position as a high school Social Studies teacher at Oakville High School, in the Mehlville School District. However, the following year he discovered his true educational passion, when an opportunity arose to teach middle school. Mr. Bellinger worked as a social studies teacher from 1994 through 2000 and as an English Teacher from 1998 through 2009. He received his master's degree from UMSL in Secondary Education with an emphasis in middle school education in 1998 and a second master's degree from Southwest Baptist University in Education Administration in 2003. In 2009, Mr. Bellinger became the Assistant Principal at Oakville Middle School in the Mehlville School District. He has proudly served Oakville Middle School in that capacity, leading the school through numerous achievements highlighted by numerous Gold and Silver Awards from MODESE statewide PBIS initiatives and both a State and National School of Character Award. Mr. Bellinger is the proud husband of Ronda for 25 years and the proud father of Grace and Olivia.