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The Impact Of A K-8 STEM Program On Grades And Student Choice Of STEM And Advanced Mathematics And Science Coursework In High School

Astrid Rodrigues

THE IMPACT OF A K-8 STEM PROGRAM ON GRADES AND STUDENT CHOICE OF STEM AND ADVANCED MATHEMATICS AND SCIENCE COURSEWORK IN HIGH SCHOOL

Astrid Q. Rodrigues

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Astrid Q. Rodrigues

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Approved:

Elizabeth Minor
Chair, Dissertation Committee

Member, Dissertation Committee

James Fitzpatrick
Dean's Representative

Director, EDL Doctoral Program

Dean, National College of Education

December 17, 2021
Date Approved

ABSTRACT

The demands of today's workforce call for schools to prepare their students to have problem-solving skills and be critical thinkers and collaborative colleagues. Science, Technology, Engineering, and Mathematics (STEM) learning has been known to cultivate, excite, and promote critical thinking and problem-solving skills in students from an early age.

This study explored the high school course selection of students who had participated in a compulsory Kindergarten to 8th grade (K-8) STEM program, called Project Lead the Way (PLTW), while in middle school. Specifically, the study compared the number of STEM and advanced mathematics and science courses that students who were exposed to this program took while in high school. It also examined the impact of PLTW on these students' mean grades in STEM, mathematics, and science courses.

An analysis of the course enrollment revealed that participating in PLTW coursework for one or two quarters in middle school did not result in students increasing the number of STEM, advanced mathematics, and science courses taken in high school. However, the results also showed that participating in PLTW courses for one or two quarters in middle school was associated with an increased likelihood that students characterized as English Language Learners (ELL) took more STEM courses in high school. Additionally, an analysis of the academic outcomes for students who completed one or two quarters of PLTW coursework prior to entering high school achieved higher academic grades than their historic predecessors' grades on mathematics and science courses taken in high school.

From these findings, the researcher recommends that the state create a K-12 policy that addresses access to STEM coursework for all its students. The researcher also recommends that each district in the state creates a district policy to ensure every student has an opportunity to engage in STEM opportunities from pre-Kindergarten through high school. This study provides evidence for the continued support of heuristic approaches to learning through a compulsory K-12 STEM program in schools.

PREFACE

Science, Technology, Engineering, and Mathematics (STEM) education has been gaining national attention for the last three decades. This attention has developed from the shortage of U.S. students pursuing STEM careers, as well as a shortage in the U.S. workforce in successfully filling jobs designed for and demanding those well-trained in STEM fields. In an effort to adequately support future workforce development, the U.S. Department of Education has started to create STEM visions and invest in specific projects to fund STEM initiatives in public education. As public school district leaders continue to consider how to prepare students with college, job, and career readiness, school district leaders must continue to think ahead and align to industry needs of the future workforce. The premise of this program evaluation was to investigate the impact of a K-8 STEM program in motivating students to pursue STEM and advanced mathematics and science coursework in high school. The researcher also sought to find the impact a K-8 STEM program has on ELL students, as well as on the mean mathematics and science grades of high school students.

The researcher completed her undergraduate in Electronic Engineering and has always had a passion for STEM. Throughout her career she served in a variety of instructional and administrative capacities in public schools. As a high school science teacher, the researcher was aware of the lack of basic science skills and engagement of students not exposed to STEM coursework in elementary school. As the administrative supervisor of the STEM program in the middle school, the researcher was aware of the engagement and enthusiasm that the district's STEM program brought to its middle school students. This first-hand experience prompted the researcher to explore and quantify the impact of a K-8 STEM program on the high school course selections and mean grades of students exposed to a STEM program in middle school.

The researcher analyzed the high school course selection data of high school students to determine the impact of a K-8 STEM program on mean grades and high school course selection. Through this research, the researcher identified barriers of the program in its first few years of implementation and provided practical and intentional strategies to correct and maximize further the impact of the program on student course selection in high school and their mean grades. This research is important to administrators, educators, and key community stakeholders as it provides insight into the effectiveness and the impact of a K-8 STEM program in elementary schools.

Through this research study, the researcher reaffirmed the critical nature of calculated and strategic planning of educational initiatives. In addition, the researcher observed the significance of supporting professional growth with job-embedded and continuous professional learning opportunities. Both administrators and teachers must be trained and have a robust knowledge and understanding of STEM programs in order to effectively implement the program and support its implementation. Moreover, sufficient study and experience is needed to acquire the background, skills, knowledge, and strategies to enact a high-quality K-8 STEM education for all students.

As a result of this research project, the researcher identified the barriers that must be overcome to improve the STEM program in her district; hence, recommends that all students have equal access to a K-8 STEM program while in middle school, as this was not the case when the K-8 STEM program was first implemented in this middle school. The researcher also recommends improving the implementation of such programs as she supervised during the study, and promoting K-8 STEM programs in other elementary schools in the state.

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Lastly, and above all, I would thank Jesus Christ for the peace and purpose that comes in knowing Him, for His continued provision and peace when I needed it, for leading me through difficult seasons along the way, and for sustaining my family throughout this journey.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

We live in a technological environment where the only constant is change. In order to keep up with the rapid developments in the information and technology age, individuals must be agile, adaptable, and innovative. For individuals to adapt and innovate, they must also possess creativity, critical thinking, research, questioning, problem-solving, and collaboration skills. According to Harvard University (2011), since before the first American schools opened, some of the biggest challenges taken up by teachers included teaching students how to solve problems. At the end of the 20th and beginning of the 21st century, the rapidly changing demands of American industry in the information age and government pressure created demands from both government and industry to better prepare American students for a world transforming at an increasing pace (Harvard University, 2011).

In the United States, the National Science Board (NSB; 2010) reported a strong correlation between students who take advanced science and mathematics courses in high school and their enrollment and success in four-year college institutions. Likewise, there is also a strong enrollment correlation between high school students who do not take advanced courses and subsequently do not enroll in four-year college institutions; even those who do enroll often need remedial support courses. This research supports the need for elementary students' early exposure to STEM initiatives. By introducing elementary students to a science, mathematics, and technology-integrated curriculum, based on interactive problem-solving activities, interest in these types of STEM career fields will increase (Katehi et al., 2009), and fill jobs now requiring such training in the U.S. workforce. In fact, the NSB recommends early exposure to STEM opportunities for all students, thus the opportunity for students to engage in inquiry-based learning, peer collaboration, and open-ended, real-world problem-solving (NSB, 2010).

Although a number of schools have started to realize the importance of early exposure to STEM initiatives, most schools have not realized the critical importance of this. In this study, the researcher investigated the implementation of the K–8 STEM program, Project Lead the Way (PLTW) in middle school and the impact of this program on the number of STEM, advanced mathematics and science courses selected by the students in high school, as well as the science and mathematics grades they earned in these courses.

The researcher's school district used in this study was located in a western suburb of Chicago. Forty-two percent of the students enrolled in the district qualified for free or reduced-price lunches. The district has students from pre-Kindergarten through eighth grade. The school district prides itself on the diversity of its students. Forty-seven percent were of Hispanic origin, 24% of Asian origin, 20% Caucasian, and 6% African American. The researcher's district strives to offer excellent educational programs to all students and holds high expectations for students and staff, including the ideal that every student is capable of meeting or exceeding those expectations with the right support. The researcher's district has committed to providing all students with a guaranteed and viable, research-based curriculum. Equally important to the district is providing staff with relevant training, ongoing coaching and support to guarantee the implementation of assessments and instruction within a standards-driven curriculum. The researcher's district also views student engagement as an important part of student learning and has trained every staff member on Kagan (2009) engagement strategies. The researcher's district also strives to create a collaborative culture through the development of high-performing teams in each grade level. Teachers and administrators in the researcher's district continually analyze results and refine programs to foster all students' continued learning and growth.

The researcher's district has always sought to prepare its students for the high school and beyond. In the last few years, it has increased collaboration with the high school district administration so as to gain an understanding of how it can better prepare its students for the rigors of high school. In response to the increase in collaboration, middle school teachers in the researcher's district have worked to boost the self-confidence and perseverance of middle school students through rigorous coursework and the introduction of STEM coursework for all middle school as well as elementary school students.

The researcher's district has also strived to provide all its students with equitable access to all the programs offered in the district. As mentioned above, the district has a diverse body of students and a large number of students who are categorized as ELL students. The district has emphasized the need for all its students to have access to all its programs such as the Challenge Program as well as the same STEM program for all its students, including its linguistically and culturally diverse students. Exposing ELL students to culturally relevant STEM-focused education and role models in STEM at early ages can increase their interest in STEM fields and eventual participation in the STEM workforce, leading to increased academic performance and long-term broader economic opportunities (Lynch et al., 2018). Realizing the importance of ensuring that all students must have equal access to STEM programs in the district, administrators in the district work collaboratively to ensure that the master schedule allows all students to have access the STEM program in the district. The district is one of the few districts in the area that offers a compulsory STEM program to all its students from Kindergarten to 8th grade.

Purpose of PLTW Evaluation

Given that the American economy and industry needs significantly more highly qualified and skilled STEM workers, American educators must focus on increasing college access, retention, and persistence among traditionally underrepresented groups pursuing STEM education in college (Dancy, 2010). There is a dearth of culturally and linguistically diverse students and professionals in STEM fields nationwide (Beasley & Fischer, 2012). The problem emerges partially from a lack of access and exposure to STEM content in the primary and secondary grades for students of underserved communities (Flynn, 2016).

A literature review conducted by the National Research Council (NRC; 2014), on the impact of integrated STEM education on learning outcomes, determined that STEM education has crucial benefits for students and educators. According to this review, learning outcomes of STEM education for students are specified as (i) increasing academic achievement, (ii) improving the 21st-century skills, (iii) augmenting the number of students who are taking courses in STEM fields, continuing education, and graduating, (iv) increasing the STEM workforce, (v) developing interest in STEM and also STEM identity, and (vi) improving the ability to convey understanding between the STEM domains. The development of these skills through the implementation of a STEM program motivates students to pursue STEM courses in high school, thus preparing them for a career in STEM.

The researcher's district realizes the imperative of boosting the critical-thinking and problem-solving skills of all students with the expectation that these result in an increase in the self-confidence of students and thereby encourage them to pursue challenging STEM careers. At the time of the study, the researcher's district offered a K-8 STEM program to all its students. The researcher's district uses the Project Lead the Way (PLTW) curriculum for their K-8 STEM program. The PLTW program was first introduced in 2014 to middle school students in the researcher's district. The researcher's background in Electronic Engineering resulted in her being assigned to supervise this program and working closely with the teachers implementing this program at the middle school. The researcher observed that middle school students of the district explored these courses with much enthusiasm.

After a few years, the program was introduced to students at the intermediate building (Grades 4 and 5) and subsequently brought to both primary buildings, for Kindergarten to 3rd-grade students. Until recently, at the elementary grades, students received this program once a week for 40 minutes, while at the middle school, students rotated through two STEM courses for one quarter of the school year. In the PLTW program at the middle school, students worked with their peers to design and build solutions to real-life problems using the design process.

For this study, the researcher investigated the effectiveness of the district's K-8 PLTW program in helping students to pursue STEM and advanced mathematics and science coursework in high school. Prior research has revealed PLTW as an impactful pedagogy that helps change students' attitudes towards STEM, offering a positive influence on students' choice related to STEM careers (Tai, 2012). Thus, elementary school districts in the area could use the results of this study to review their coursework and determine how they could provide their students with opportunities to engage in the development of problem-solving and critical-thinking skills, as well as to develop in students the confidence to pursue advanced coursework in high schools.

Rationale

Twenty-first century careers require specific modes of schooling to prepare students with different skills than those fostered in the past. Graduates are expected to be persistent critical thinkers who work well with each other, solve problems collaboratively, communicate well, and manage time and work efficiently. In order for graduates to develop these skills, educators must expose students early on to projects and classroom experiences that allow them to interact with each other instead of classroom experiences where they remain passive recipients of knowledge. Moreover, research across all classrooms, not just STEM classrooms, has shown that creating an environment in which students construct knowledge, work socially and collaboratively to address problems has significant cognitive and achievement outcomes for students (Chi, 2009).

The NSB (2010) recommends early exposure to STEM opportunities for all students and the opportunity for students to engage in inquiry-based learning, peer collaboration, and open-ended, real-world problem-solving, with the objective of increasing the number of students who want to pursue coursework in STEM fields. Despite this recommendation, most districts in Illinois do not offer STEM-related programs from Kindergarten, only offering such programs starting at middle and high school levels. Flynn (2016) notes a lack of access and exposure to STEM content in the primary and secondary grades, especially for students of underserved communities. Given the urgent need to increase the number of students that meet the demands of the workforce, educational institutions must make changes to course offerings to increase students' positive attitudes and motivations toward STEM-related coursework.

As the supervising administrator of the PLTW program in the middle school, the researcher has observed students thoroughly engage in this kind of hands-on program. The researcher has observed students challenge the thinking of their peers, collaborate with each other, and develop such 21st-century skills since the school's adoption of this program. Very few school districts in the United States offer STEM programs to all students right from Kindergarten. Through this study, the researcher investigated whether or not students who participate in STEM programs in middle school years could develop the motivation to choose STEM and advanced mathematics and science coursework in high school. The researcher also investigated whether or not taking STEM coursework in middle school has an effect on the students' grades in STEM and advanced mathematics and science courses taken in high school.

In addition, the researcher investigated if language proficiency is an indicator of STEM coursework selection in high school. Students who are not language-proficient typically take the English Language proficiency assessment (ACCESS) every year, those not fulfilling the assessment minimum are characterized as ELLs. A majority of students observed to be not proficient in English in this study were of non-English speaking cultures: 47% of the students in the researcher’s district were Hispanic and 24% of Asian origin. Underrepresentation of Latinos in STEM degrees and occupations is a reality, even though Latinos are one of the largest minorities in the United States. This underrepresentation prevents the diversification and implementation of strategies that can increase Latino immersion or participation in global markets (Hanson, 2013).

It is crucial, then, to attract more minority students to STEM careers, starting at early grade levels. In order to do so, STEM courses must be made more accessible and relate to students’ daily lives. School communities and teachers are critical in changing minority students’ perceptions of STEM classes. This change can be accomplished by generating more STEM-related environments for students (Moller et al., 2015). The researcher’s district exposes all its students to STEM-related environments in their elementary years and the researcher sought to discover if this exposure has had any impact on the number of STEM courses taken by students in high school.

Implementing any new instructional program always comes with its set of challenges. When starting a new initiative, a big challenge that school districts need to overcome is the cost associated with the start of the new program. The cost of the PLTW program and the consumable materials constitutes an important factor to budget for, so that the school district could successfully implement the PLTW curriculum in every grade. Another issue associated with the implementation of the STEM program was time, a scarce resource at schools. If school is called off due to a snow day, students scheduled to participate in STEM class typically have no opportunity to make up the class. STEM coursework requires hands-on interaction and cannot be delivered to students via a remote learning platform, thus formed a major hurdle in the implementation of this program during the COVID-19 pandemic.

The researcher observed that the Board of Education of the district were supportive of the PLTW program and continued to allocate resources toward the purchase of the consumable materials or software updates required for the program. They also continued to invest in teacher training and ongoing support required for a successful implementation of the program. The researcher also observed that rescheduling PLTW classes missed due to snow days or school assemblies was more difficult, especially at the middle school level.

According to NSB (2010), the continued economic prosperity of the United States depends on a skilled workforce, particularly at the leading edge of science and technology. Although mastery of a STEM discipline requires over a decade of intensive study after high school, the interest or disinterest in STEM germinates early in K-12 education, maybe even in early childhood (NSB, 2010). Despite the NSB's recommendation to expose elementary students to STEM in elementary schools, very few school districts have STEM programs starting from Kindergarten. Thus it is critical to see if a K-8 STEM program had an impact on student choice of coursework at the high school level. While a few studies exist on the benefits of STEM programs at the middle school level, a lack of research remains around STEM programs at the early elementary level. The results of this study could be used to advocate for policy change around early exposure to STEM programs for all students. The researcher's district could also use the results of this study to evaluate the return on investment in K-8 STEM education for all its students.

Goals

According to a research study conducted by Rethwisch et al. (2012), with over 26,000 students, students who participated in PLTW coursework had higher mathematics and science achievements, as measured by the Iowa Test of Basic Skills. In another study, conducted by Bottoms and Uhn (2007), PLTW students were significantly more likely to complete at least four years of mathematics and score high on National Assessment of Educational Progress-referenced exams, as compared to career or technical students.

The researcher explored the benefits of K-8 STEM programs so that other elementary districts in Illinois could leverage such programs with the objective of providing equitable opportunities to all students irrespective of race, socioeconomic backgrounds, or language proficiency. As an administrator with a background in Engineering and overseeing the STEM program in the district, the researcher has seen first-hand the important role that such STEM programs can play in building the critical thinking skills and perseverance in elementary aged students. The researcher also recommends an increased duration of such programs, as this could result in an increase in the number of students interested in STEM careers. Eventually, these efforts will help address the shortage of skilled workers in STEM careers in our country.

Definition of Terms

ELL: English Language Learners are students who have yet to pass the English Language State assessment, ACCESS.

K-8: Kindergarten through eighth grade

STEM: Science, Technology, Engineering, and Mathematics

PLTW: Project Lead the Way, a STEM education program that had been adopted by the researcher's district.

PLTW Gateway: The PLTW program for students in Grades 6 through 8, adopted by the researcher's district.

PLTW Launch: The PLTW program for students in Grades Pre-K through 5 adopted by the researcher's district.

Research Questions

The primary research question for the study was: To what extent do students who participate in a compulsory K-8 STEM program participate in STEM and advanced mathematics and science coursework in high school?

Secondary research questions were:

1) To what extent does language acquisition predict the likelihood of voluntary enrollment in STEM coursework in high school?
2) To what extent does participation in a STEM program in middle school affect mathematics grades in high school?
3) To what extent does participation in a STEM program in middle school affect science grades in high school?
4) To what extent does participation in a STEM program in middle school affect STEM grades in high school?

Conclusion

All students deserve a high-quality education; however, some students inadvertently miss out on this kind of education due to their race, gender, English proficiency level, zip code and socioeconomic status. STEM programs that provide all students with an opportunity to problem-solve, collaborate, think critically, and develop higher-order thinking skills should not be reserved for a privileged few. In the 21st century, all students deserve to have the opportunity to participate in STEM programs beginning in Kindergarten. The vast majority of underrepresented students “lose interest in and develop negative attitudes toward science by the time they complete middle school” (Barton, 2002, pp. 1-2), and the aspirations of females and underrepresented students for STEM careers are limited by their low levels of academic preparation early in their schooling (Riegle-Crumb et al., 2010). It is thus imperative that teachers, school leaders, and policymakers prioritize implementing STEM programs for all students to participate in at the earliest possible stage in the K-12 educational system. It is also important for educators to instill in elementary students the love of problem-solving and innovation, and to inspire in them the passion for science and technology, so that they may persevere with advanced coursework in high school and beyond, and to eventually pursue STEM careers with enormous growth potential in the near future.

CHAPTER TWO

LITERATURE REVIEW

This chapter examines the literature and research surrounding the central question of the study: “To what extent do students who participate in a compulsory K-8 STEM program participate in STEM and advanced mathematics and science coursework in high school?” It also examines the literature and research surrounding the secondary research questions: “To what extent does language acquisition predict the likelihood of voluntary enrollment in STEM coursework in high school?” and “To what extent does participation in a STEM program in middle school affect mathematics, science, and STEM grades in high school?” This chapter will also provide readers with a historical overview of STEM education, examine STEM education in elementary schools, and discuss the impact of PLTW on elementary-aged students.

The accumulated research of this literature review is drawn from relevant books, websites, academic journal reports, research articles, and other dissertations. This review is important to my program evaluation as it aims to identify relevant perspectives and effective implementations of STEM education. In order to improve program implementation, it is important to consider what has been successful and unsuccessful in previous STEM implementations. Additionally, the suggested strategies and actions (see Chapter 6) to improve existing STEM programs should be based on research-based practices.

Historical Overview of STEM Education

On October 5, 1957, the launch of the Russian satellite Sputnik created a sense of urgency in the United States. That launch ushered in new political, military, technological, and scientific developments. America did not want to fall behind Russia in the Space Race and wanted to maintain its position as a global leader in any and all innovative ventures. Thus, in his address to the American people on science in National Security, President Eisenhower (1957) stated:

> According to my scientific friends, one of our greatest, and most glaring deficiencies is the failure of us in this country to give high enough priority to scientific education and to the place of science in our national life . . . . We need scientists in the 10 years ahead. They say we need them by thousands more than we're now presently planning to have . . . . The task is a cooperative one. Federal, state, and local governments, and our entire citizenry must all do their share. We should, among other things, have a system of nation-wide testing of high school students; a system of incentives for high aptitude students to pursue scientific or professional studies; a program to stimulate good-quality teaching of mathematics and science; provision of more laboratory facilities; and measures, including fellowships, to increase the output of qualified teachers. (para. 33)

Eisenhower's address was instrumental in creating the National Aeronautics and Space Administration (NASA) in 1958. It also marked the beginning of STEM education, although the formal name was not developed until many years later. In 1983, the National Commission on Excellence in Education published a report entitled "A Nation at Risk" (1983), which among other things contributed to the ever-growing assertion that American schools were failing.

> Our Nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world. This report is concerned with only one of the many causes and dimensions of the problem, but it is the one that undergirds American prosperity, security, and civility. We report to the American people that while we can take justifiable pride in what our schools and colleges have historically accomplished and contributed to the United States and the well-being of its people, the educational foundations of our society are presently being eroded by a

> rising tide of mediocrity that threatens our very future as a Nation and a people. What was unimaginable a generation ago has begun to occur—others are matching and surpassing our educational attainments. (para. 2)

This report magnified the flaws of public education and touched off a wave of local, state, and federal reform. The report recommended that state and local schools strengthen their graduation requirements, adopt a rigorous curriculum, and improve the preparation of teachers. The American Association for the Advancement of Science (AAAS) sought to advance science education from Kindergarten to 12th grade by creating Project 2061 (Project 2061: American Association for the Advancement of Science, 1985). Project 2061 continues to provide a coherent set of K-12 learning goals that serve as a foundation for state and national science education frameworks and standards, including the Next Generation Science Standards (NGSS).

Since they were sparked by the Space Race of 1957, educators in American schools and colleges are still being asked to prepare students for the rigors of a work industry that requires workers who can problem-solve, collaborate with their peers, and generate innovative ideas and solutions for the problems of the future. President Barack Obama launched the Educate to Innovate campaign in 2009, to move American students from the middle to the top of the pack in science and mathematics achievement over the next decade. The priorities of this campaign were to increase STEM literacy, improve the quality of mathematics and science teaching, and expand STEM education and career opportunities for underrepresented groups (White House Archives, 2009). This campaign played a pivotal role in the history of science, technology, engineering, and mathematics, or what we call STEM today. Collectively, the U.S. Department of Education selected STEM as an educational priority to match the campaign's initiatives. In addition, the

Obama administration also launched the Change the Equation campaign in 2010. Change the Equation was a specific campaign to engage intentionally with the business community to become more involved with STEM education. In its first year, Change the Equation expanded proven STEM education programs to sites across the country, developed a new toolkit for CEO local action, called "Vital Signs," collecting key metrics that empower CEOs to advocate in communities where they are the largest employers for STEM reform, and created a new blueprint for how companies can create and invest in STEM programs (White House Archives, 2009).

Many high schools have been responding to the demands of the workforce and taking advantage of the grants that the federal government has provided. Increasingly, STEM-focused high schools are being used to prepare students for college STEM majors and launch them into STEM careers. The aim of inclusive STEM-focused high schools is to provide students with opportunities to prepare for and participate in careers in STEM fields (Lynch et al., 2015). Yet a new focus on STEM education at the elementary levels suggests that the importance of STEM education is much broader than a preparation for workforce needs in high school or college. The report Successful K-12 STEM Education, from the National Research Council (NRC; 2011), pointed to the importance of providing all students with a coherent STEM education, starting in Kindergarten or earlier. A second report, Monitoring Progress Toward Successful K-12 STEM Education (NRC, 2013), addressed the need for research and data that can be used to monitor progress in the K-12 STEM education system overall, and to make decisions for its improvement.

According to Osborne et al. (2003), a pervasive STEM focus at the elementary level also helps capture student interest in STEM before such interests tend to drop, and it provides a valuable opportunity to connect science learning with important literacy skills. As we continue to seek solutions to improve the education of all our students, it is important to consider the evolution of STEM education so we can continue to improve success outcomes.

STEM Education in Elementary Schools

As a result of the increased awareness for STEM awareness initiatives, programs have been developed for high school students in order to recruit and prepare them for four-year degree programs in STEM disciplines (Lynch et al., 2014). Efforts to motivate students to pursue STEM disciplines have also trickled down to the middle-school level where academic and curricular “pipelines” have been developed to provide pathways for students interested in STEM-focused careers (Lyon et al., 2012). Increased awareness of the value of a STEM curriculum within the elementary school continues to grow. Additionally, the newly-released NGSS standards provide a unique K-12 engineering education focus, not previously a part of science education. They represent a commitment to integrate engineering design into the structure of science education by raising engineering design to the same level as scientific inquiry when teaching science disciplines at all levels, from Kindergarten to Grade 12. There are both practical and inspirational reasons for including engineering design as an essential element of science education.

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

Embedding engineering practices into the NGSS standards provides students with a foundation in engineering design, allowing them to better engage in and aspire to solve the major societal and environmental challenges they will face in the decades ahead.

The NGSS Framework also projects a vision of engineering design in the science curriculum, and of what students can accomplish from early school years to high school:

> In some ways, children are natural engineers. They spontaneously build sand castles, dollhouses, and hamster enclosures, and they use a variety of tools and materials for their own playful purposes. . . . Children's capabilities to design structures can then be enhanced by having them pay attention to points of failure and asking them to create and test redesigns of the bridge so that it is stronger (NRC, 2012, p. 70).

By the time these students leave high school, they can "undertake more complex engineering design projects related to major global, national, or local issues" (NRC, 2012, p. 71).

It is never too early to expose children to STEM or engineering practices. According to Moomaw (2012), young children between ages five and eight are already at a prime age for learning STEM content. Primary-school-aged children are very inquisitive and have a unique desire to thoroughly explore their surroundings. They continuously question and want to know "why" things happen as they do in their world (DeJarnette, 2018). This natural curiosity of young learners, combined with their keen interest in the world around them, positions them at a crucial stage for learning about STEM content. Arne Duncan (U.S. Secretary of Education under the Obama Administration) stated that by introducing young children to science early, they become more familiar with it and build confidence in their abilities to conduct inquiry. Jones (2011) states that 75% of all children learn by doing and through inquiry. Research has also shown that early exposure to STEM initiatives and activities positively impacts elementary students' perceptions and dispositions towards STEM (DeJarnette, 2016). Such research establishes compelling reasons for providing STEM-education opportunities for early elementary students. By exposing children to STEM disciplines during the elementary years through hands-on, interactive, and problem-solving activities, research indicates that children's interest in STEM career fields increases, establishing an educational pathway for the future (Katehi et al., 2009).

Cotabish et al. (2013) conducted a study to assess elementary students' science process skills, content knowledge, and concept knowledge after one year of participation in an elementary STEM program. The STEM program used an inquiry-based, rigorous science curriculum, along with intensive professional development for staff. The results of the study revealed that students who participated in their STEM program had a statistically significant gain in their understanding of science processes and content knowledge as compared with students in the comparison group. Due to the importance placed on the STEM disciplines and the calls from policy-makers to build a pipeline for science and mathematics talent, such programs must be created so that elementary students have exposure to STEM opportunities from an early age. Another study, conducted by Ugras (2018), revealed a significant difference between STEM attitudes, scientific creativity, and motivational beliefs of students who participated in an eight-week STEM program. Furthermore, the students stated that the STEM education improved their creativity and motivation toward the courses and contributed to their career choices.

Little is understood about how young English language learners (ELLs) respond to engineering-centered literacy and design activities and whether that response ultimately leads to content understanding. In their study on younger ELL learners, Pantoya and Aguirre-Munoz (2017) sought to understand the extent to which the use of engineering-centered activities emphasizing academic conversations during age appropriate tasks lead to increased knowledge of technology and the engineering design process for linguistically diverse students in Kindergarten, first and second grade. Learning gains were observed for ELLs who received engineering-centered literacy activities. These results provide evidence of the impact of the integration of academic conversation, and narrative texts to improve student learning. Given the cultural and linguistic background of these ELLs, the results revealed the potential for these instructional strategies to promote broader STEM participation. In another study of Latinx students in grades 3 to 5, Roncoroni et al. (2021) assessed the feasibility, acceptability, and impact on STEM career interest of an evidence-based, after-school STEM program for elementary school Latinx children from Spanish-speaking families. The results showed that attendance and satisfaction with the program were high and students' STEM career interest showed a statistically significant increase between pre- and post-program.

With the limited number of youth pursuing STEM careers, even though STEM job growth is on the rise, it is imperative that school leaders continue to prioritize STEM education and pursue opportunities that provide all elementary students, including those that are culturally and linguistically diverse with exposure to STEM activities.

Impact of Project Lead the Way (PLTW) on Students

Employment within STEM occupations is predicted to increase to over 10 million in 2029 (U.S. Bureau of Labor Statistics, 2021). Yet policy-makers and scholars are concerned that a small STEM labor pool will not meet the demands of job growth. In 2012, the President's Council of Advisors on Science and Technology (PCAST) reported a projected deficit of one million STEM graduates needed for U.S. jobs over the decade to follow. Even more, it was reported that "fewer than 40% of students who enter college intending to major in a STEM field complete a STEM degree" (PCAST, 2012, p. 7, para. 3).

In order to increase the number of STEM graduates, a closer look at the source of the issue is needed. The PCAST council reported that "in 2005, 57% of the students enrolled in 4-year colleges and universities were enrolled in pre-college algebra, trigonometry, or other pre-calculus courses" (PCAST, 2012, p. 28). These courses are below the required introductory courses necessary for a STEM degree. Additionally, these college courses tend to merely review high school mathematics, and often rely on rote memorization and a procedural approach to understanding the mathematics. This leaves college students "with the impression that the field is dull and unimaginative, and that they can extend this judgment to all STEM disciplines" (PCAST, 2012, p. 14, para. 1). This may cause undergraduate students who are deciding their major to dismiss the possibility of STEM, as well as pushing students intending to major in a STEM discipline to consider a different major. For underrepresented minorities, the problem does not stop there. In addition to remedial or introductory STEM courses being uninteresting, many minority students cite "an unwelcoming atmosphere from faculty in STEM courses as a reason for their departure" (PCAST 2012). According to Palmer et al. (2011), providing students of color with the support they need, such as peer group support, involvement in

STEM-related activities, and strong high school preparation, could encourage them to pursue and persist in STEM disciplines.

To make remedial and introductory STEM courses relevant and interesting, as well as to establish learning communities within the classroom, drastic pedagogical changes need to be made. The traditional lecture-style approach to teaching must shift to that of a student-centered approach. Research suggests that “what students learn is greatly influenced by how they learn, and many students learn best through active, collaborative, small group work” (Springer et al., 1999, p. 21). This can be accomplished in part by using forms of active learning. This diversification of teaching methods is necessary to reach all students (PCAST, 2012).

As a result of a decline in the percentage of U.S. students pursuing STEM degrees, improving STEM education throughout K-12 has become a national focus. In theory, integrating pre-college engineering and technology curriculum throughout STEM ought to motivate students to engage with STEM and, in turn, this enhanced interest ought to improve their mathematics and science abilities (Hess et al., 2016). One such pre-college engineering and technology curriculum is Project Lead the Way (PLTW).

PLTW is a non-profit organization that has developed a project-based pre-college engineering and technology curriculum for K-12 students. As of 2015, PLTW was by far the largest pre-engineering curriculum throughout the United States, with a presence in over 6500 schools nationally. Since its conception in 1997, PLTW rapidly expanded and grew, to the point where it now covers all states and the District of Columbia. One of the core claims from PLTW is that by including real-world STEM problems into the pre-college curriculum, these disciplinary topics will become interesting to students. PLTW’s

“Pathway to Engineering” curriculum offers a sequence of courses that students may take during their high school years, and many university programs allow students who complete this curriculum the opportunity to earn college credit. PLTW also offers tracks for students to specialize in Biomedical Science or Computer Science. Prior to high school, PLTW also offers a “Gateway” curriculum targeted at middle school students and a “Launch” curriculum targeted at elementary students.

PLTW is one of many pre-college engineering programs and, according to the website (2021), it has programs in more than 12,200 schools across the country. Also according to the PLTW website (2021), the PLTW Launch program is designed for students in Pre-Kindergarten through fifth grade. The program empowers students to adopt a design-thinking mindset through compelling activities, projects, and problems that build upon each other and promote students relating to the world around them. As students engage in hands-on activities in computer science, engineering, and biomedical science, they become creative, collaborative problem-solvers ready to take on any challenge (PLTW, 2021).

A research study based on interviews of nearly 120 scientists found that positive experiences with science played a central role in their decision to focus on science (Maltese & Tai, 2010). These types of positive experiences varied from encouragement from instructors to topics in science courses that captivated students’ imaginations. Another study, which examined nearly 5,000 students from a nationally representative longitudinal data set that tracked students though high school and into college, found that positive classroom experiences, such as relating the course content to students’ lives, were strongly associated with the completion of a college degree in STEM (Maltese &

Tai, 2011). In light of these findings, a well-designed and well-implemented curriculum introducing K-12 students to STEM-related careers has the potential to have an impact on long-range outcomes. PLTW coursework has been observed to engage students in real-world problems that require critical thinking and collaboration, and it is likely that students who have exposure to these courses in elementary and middle school level are motivated to take such courses in high school.

Pike and Robbins (2014) note a study from the Center for Urban and Multicultural Education at Indiana University-Purdue University Indianapolis, which examined data about nearly 60,000 graduates, including nearly 4,000 who participated in PLTW, from the Indiana Department of Education and the National Student Clearinghouse. Researchers were looking for evidence that participation in the high school program had an impact on college enrollment, and persistence toward a degree, and pursuit of STEM majors. Results from this study indicated that PLTW participation in high school significantly increased the likelihood that students would major in a STEM discipline, particularly engineering. Although similar data is not available for PLTW coursework at the elementary level, it is likely that participating in PLTW coursework in elementary and middle school years may also increase students' perseverance, lead them to grow passionate about mathematics and science, and encourage them to take advanced coursework in mathematics and science when they enter high school.

According to a dissertation by Paslov (2007), which focused on the experiences and perceptions of eighth-grade female PLTW students, her results indicated that both males and females displayed positive attitudes towards mathematics as a result of participating in PLTW. Further, both groups performed better in mathematics as a result of PLTW. In light of these findings, it is likely that students who participate in PLTW coursework in middle school have a positive attitude towards mathematics and science, are motivated to take STEM and advanced mathematics and science coursework, and will score higher grades in STEM, mathematics, science coursework in high school.

According to a dissertation by Sorge (2014), PLTW did an especially effective job of improving minority and female interest in STEM coursework. Females at PLTW schools were more likely to persist than boys, while gender was not a predictor for students at non-PLTW schools (Sorge, 2014). 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).

Rethwisch et al. (2012) used Iowa's statewide longitudinal data system to follow multiple cohorts of PLTW participants and nonparticipants from 8th grade into secondary education. Their findings indicated statistically significant evidence that PLTW increases mathematics or science scores on the Iowa Test of Educational Development by 5 points after controlling for selection bias.

Conclusion

This chapter provided readers with a historical overview of STEM education in American schools and reviewed the importance of providing STEM education to elementary-school-aged students. The impact of STEM education programs such as PLTW was also included in the literature review.

Despite the rapid and still ongoing growth of PLTW, scholarly literature pertaining to the efficacy of PLTW curriculum remains rather sparse. By analyzing the course selection data of high school students who had exposure to PLTW coursework in their middle school years, the researcher sought to add to this body of literature. Furthermore, the data from this program evaluation has the potential to bring awareness to the resounding issue of providing high-quality integrated STEM education and informing decision-makers about the critical need for more STEM education opportunities for all learners. Chapter 3 will provide the reader with information on the methodologies used for this study.

CHAPTER THREE

METHODOLOGY

Research Design Overview

Every program should be periodically evaluated to determine its merit, value, or significance. Evaluating a program includes determining the effectiveness of a program, the extent of implementation, the extent to which the program's goals were achieved, or determining the benefits of the program, if at all. Patton (2008) observes that evaluations typically describe and assess what was intended (goals and objectives), what happened that was unintended, what was actually implemented, and what outcomes and results were achieved. The evaluator can then discuss the implications of these findings, sometimes including items for future action and recommendations. The importance and potential utility of a good program evaluation remain in determining what has to be done to get appropriate results with meaningful use in improving the effectiveness of a program, as well as for making larger changes in policy and programming.

The researcher intended to answer this study's research questions by gathering course selection data of high school students and analyzing this data to determine if students who participated in the PLTW program at the researcher's district, went on to participate in STEM and advanced courses in mathematics and science in high school. The researcher believed this data would help determine if students participating in a K-8 STEM are more interested in taking STEM and advanced mathematics and science courses in high school. The researcher was able to compare the course selection data of students who participated in the K-8 STEM program offered by the researcher's district with the course selection data of students with no opportunity to participate in the K-8 STEM program in the researcher's district because the program was implemented in the researcher's district in 2014.

To analyze the course selection data of high school students, the researcher obtained a very large data set from the high school. The data set contained student demographic data and the courses each student had taken while in their freshman, sophomore, junior and senior years in high school. The data set also contained the grades each student in the classes of 2018, 2019, and 2020 had received for each course they had taken in high school. The researcher used statistical methods, including linear regression and One-Way Analysis of Variance (ANOVA) test to find the answers to the study's research questions and to determine if the results were statistically significant. James et al. (2008) contend that quantitative methods address many questions and have the advantage of providing information from larger groups of individuals than can be collected solely with qualitative methods.

Quantitative methodology helped the researcher to analyze the course selection data of high school students and to determine if students who have participated in a K-8 STEM program are more likely to take STEM and advanced mathematics and science courses. By analyzing cohort data, the researcher determined if students who have participated in a STEM program for a longer time were more likely to take STEM or advanced mathematics and science courses. By analyzing this data, the researcher could correlate the effectiveness and impact, if any, of the district's K-8 STEM program in building the confidence of students in the areas of STEM, mathematics, and science, and encouraging them to take advanced coursework in STEM, mathematics, and science.

Participants

The researcher gathered course-selection data of high school students who had graduated from the researcher's district. The researcher gathered the high school course selection data from the classes of 2018, 2019, and 2020. The class of 2018 had no exposure to a K-8 STEM program and was considered the control group of the study. The class of 2019 were exposed to one quarter of STEM coursework, while the class of 2020 participated in a STEM program for a semester. The type of participants included general education students, students who had an Individualized Education Plan (IEP), students with a 504 plan, or students characterized as ELLs.

Data Gathering Techniques

The researcher requested the high school to provide course-selection data of the classes of 2018, 2019, and 2020. The data included the courses each student in the classes of 2018, 2019, and 2020 had taken in high school.

To analyze the impact of PLTW on the number of advanced mathematics courses taken in high school, the researcher first organized the data into three categories: basic mathematics courses, intermediate-level mathematics courses, and advanced mathematics courses offered at the high school. After reviewing research and other studies conducted in this area, the researcher considered mathematics courses such as Pre-Algebra, Algebra 1, and Algebra 2 as basic mathematics courses; Geometry Honors and Pre-Calculus Honors were considered intermediate-level mathematics courses; and AP Calculus and AP Statistics were considered advanced mathematics courses. The categorization of mathematics courses is shown in Table 1.

Table 1

Categorization of Mathematics High School Courses

Basic Mathematics Courses	**Intermediate Mathematics Courses**	**Advanced Mathematics Courses**
Pre-Algebra	Algebra 2 with Trigonometry	AP Calculus AB
Algebra	Algebra 2 with Trigonometry Honors	AP Calculus BC
General Math	Geometry Honors	AP Statistics
Foundations of math	Pre Calculus Honors	AP Computer Science
Integrated Algebra/Geometry	Math Modeling and Applications	
Algebra 2		
Algebra 3		

To analyze the impact of PLTW on the number of advanced science courses taken in high school, the researcher first organized the data into three categories: basic, intermediate, and advanced science courses. After reviewing the course descriptions, the researcher considered science courses such as Biology, Chemistry and Physics as basic science courses, Biology Honors and Chemistry Honors as intermediate-level science courses, and AP Biology and AP Chemistry as advanced science courses. Table 2 shows the categorization of a representative sample of the science courses.

Table 2

Categorization of Science High School Courses

Basic Science Courses	Intermediate Science Courses	Advanced Science Courses
Biology	Earth/Environmental science honors	AP Seminar
Chemistry	Chemistry Honors	AP Physics
Physical Science	Physics Honors	AP Chemistry
Life and Physical Science	Anatomy and Physiology Lab	AP Biology
Environmental science		AP Environmental Science
Astronomy		

To analyze the impact of PLTW on the number of STEM courses taken in high school, the researcher first organized the data into STEM and non-STEM courses. After reviewing the course descriptions, the researcher considered courses related to business, accounting, child development, culinary arts, woodworking as non-STEM courses, while courses such as Digital Electronics and Principles of Engineering were considered STEM courses. The categorization of a few of the STEM courses is shown in Table 3.

Table 3

Categorization of STEM and Non-STEM High School Courses

STEM courses	Non-STEM courses
Marketing - Sports and Entertainment	Principles of Engineering
Introduction to Business	Electronic Technology
Consumer Economics	Digital Electronics
Culinary Arts	Engineering Design & Development
Accounting	Engineering Graphics 1 (Mechanical)
Principles of Business and Finance	Computer Science
Career Awareness	Computer Programming Visual Basic
Woodworking	Computer Applications
Parenting and Child Development	Computer Programming/Java

Ethical Considerations

An important consideration of the program evaluation is to protect the anonymity of participants and the school district. The participants and the school district involved in the program evaluation were guaranteed anonymity and confidentiality. The researcher obtained permission from the school district to use the extant data and kept the data secure at all times. There were minimal risks involved in this program evaluation as the goal was to gather information to determine the impact of a K-8 STEM program on the high school course choice and grades of students. The benefit of this program evaluation was to understand the effectiveness of a K-8 STEM program on student grades and high school course selection in STEM and advanced mathematics and science, to further awareness and advocacy.

Two ethical considerations that the researcher kept in mind while evaluating the effects of the district's STEM program were (1) to keep personal bias aside and (2) to be honest about reporting the data as it was. The researcher has always had a passion for STEM and thus may have biased in evaluating data, or ignored data that disproves the effectiveness of a STEM program. Therefore, the researcher worked closely with her dissertation chair to ensure that personal biases did not impact the results of the research. The researcher also sought to remain aware of a possible bias in results affecting her district.

Data Analysis Techniques

The researcher gathered and analyzed quantitative data for an accurate, in-depth understanding of the research questions. The researcher analyzed the data using SPSS, a statistical analysis tool. The researcher compared the number of STEM and advanced mathematics and science courses taken by students not participating in a STEM program at the middle school to the number of STEM and advanced mathematics and science, courses taken by students who participated in the district's STEM program for one quarter and for two quarters.

Additionally, the researcher compared the means of the science and math grades of students in the classes of 2018, 2019, and 2020. The students in the class of 2018 had no exposure to PLTW coursework in middle school; the class of 2019 had exposure to one quarter of PLTW coursework in middle school; and the class of 2020 had exposure to PLTW coursework for two quarters in middle school. The researcher sought to determine if exposure to two PLTW modules was more impactful to the means of the math and science grades of students in high school as compared to exposure to just a single PLTW course. To determine if the means were statistically significant and not the result of chance, and to determine if there was an effect or relationship between exposure to PLTW coursework and the mean grades, the researcher used a One-Way Analysis of Variance (ANOVA) test. The ANOVA test was chosen for its ability to identify statistically significant differences between the means of three or more independent groups.

In order to determine if the STEM grades of students in high school could be predicted by the amount of exposure to middle school PLTW coursework the student had, or the number of STEM courses that the student took in high school, the researcher analyzed the STEM grades of high school students using linear regression analysis. The linear regression test was chosen for its ability to predict the value of one variable based on the value of other variables.

Conclusion

The researcher gathered course selection data of high school seniors, juniors, and sophomores to determine if students who participated in a STEM program were more likely to take STEM or advanced mathematics and science coursework in high school. The researcher used a statistical analysis tool, SPSS to analyze the data and minimize personal biases while reporting the results. The next chapter will report on the results of the data analysis.

CHAPTER FOUR

RESULTS

Due to rapid changes and technological advances in industry and the global economy, many experts have recognized the need to bolster the engineering workforce to position the United States as a competitive participant in the global market (NSB, 2016). The need for professionals in STEM fields continues to grow at a comparable rate to meet the demands of this high-tech global economy (Dejarnette, 2016). The researcher attempted to find out if students who participated in PLTW coursework in middle school were more likely to engage more in STEM coursework and get motivated to take STEM and advanced mathematics and science coursework in high school. Taking STEM and advanced mathematics and science coursework in high school could provide them with better academic preparation, needed for students intending to pursue a STEM major in college. According to Tai et al. (2006), the strongest determinants of students entering a STEM major in college are students' prior academic preparation and their attitudes toward science and math in high school. The researcher also sought to discover if there was an increase in the mathematics, science, and STEM grades of students who took STEM coursework in middle school.

Analysis of Impact of K-8 STEM Program

With a focus on preparing students for 21st-century society and ensuring that students develop the "skill demands" required to prosper in the information age, and "to succeed as providers, learners, and citizens" (Wagner et al., 2006, p. 103), Wagner (2008) proffered his own "seven survival skills" for the 21st century: (1) critical thinking and problem solving; (2) collaboration across networks and leading by influence; (3) agility and adaptability; (4) initiative and entrepreneurship; (5) effective oral and written communication; (6) accessing and analyzing information; and (7) curiosity and imagination. With this set of skills, it is easy to see the role of STEM coursework, such as PLTW, as a value-added concept to teaching and learning, acting as another valuable learning tool for individualized student growth when it is integrated thoughtfully by teachers with strong support from school administrators. Such coursework is important in schools "because of the nature of the skills needed in today's knowledge economy" (Wagner, 2006, p. 3).

As part of the PLTW evaluation, Wagner et al.'s (2006) 4 C's (contexts, culture, conditions, and competencies) were used as a diagnostic tool to generate a snapshot of the current assets and challenges in the researcher's district, in relation to the PLTW program. This diagnostic tool is called the As-Is Diagram (Appendix A). The As-Is diagram outlines the contexts, culture, conditions and competencies of the PLTW program at the time when the class of 2018, 2019 and 2020 participated in the PLTW program in the researcher's district.

As-Is Context

Every program within a school or district operates within social, historical, and economic contexts and must meet demands and expectations in each context, both formal as well as informal. We must also understand all this contextual information so as to inform and shape the work needed to transform the culture, conditions, and competencies of any program (Wagner et al., 2006). With the realities of today's economy, which demand a new set of skills, teachers must also learn to teach these to all students.

Wagner’s (2008) seven new basic skills stress that all students must be able to think critically, compare and analyze information from various sources, problem-solve, ask good questions, communicate effectively, and, importantly, collaborate with their colleagues across the world. Schools must provide students with opportunities to build these skills so as to prepare them for post-secondary success.

Realizing these needs, the researcher’s district decided to adopt the PLTW program, initially for its middle school students and then subsequently for all students in the district. The PLTW modules are designed to encourage students to collaborate with their peers while solving real-world problems and to encourage them to think outside the box. The program was initially met with some opposition from a few stakeholders, as it was slated to replace the culinary arts program at the middle school. However, realizing the growing need for equipping our students with 21st-century STEM skills, the district adopted the program for all the students in the district.

Currently, every student in the district receives PLTW coursework every week. Students in the K-5 buildings receive 40 minutes of PLTW coursework per week, while most students at the middle school currently receive a PLTW course for a semester during the school year. The only exceptions to this are students in the Class of 2018, 2019 and 2020 who elected to take Spanish in 7th and 8th grade as the middle school master schedule did not allow for these students to be able to take PLTW coursework as well as the Spanish elective. The district has invested many resources to ensure that PLTW staff have all the resources they need. In 2017, realizing the need for introducing our students to coding skills, the district adopted an additional PLTW course in the area of coding for our students in the 7th and 8th grade. The district is currently the only district in the surrounding area that uses a comprehensive K-8 STEM program.

As-Is Culture

For change to be effective, it is important to have staff members who believe in the program and who are open to taking risks. Wagner et al. (2006) define culture as “the shared values, beliefs, assumptions, expectations, and behaviors related to students and learning, teachers and teaching, instructional leadership and the quality of relationships within and beyond the school” (p. 102). Most staff members in the district realize the importance of building the critical thinking and collaborative skills of our students, and preparing them for today’s workforce. They believe that PLTW coursework helps our students build these skills and have seen students blossom and thrive as they gain confidence in themselves by participating in these engaging courses. All PLTW staff are committed to providing all students, including those who have special needs, with the opportunity to participate in grade-level PLTW courses with appropriate accommodations and support. PLTW staff work with the case managers of students with significant needs to come up with materials and lessons that can meet the needs of these students. In addition, staff commonly work with the PLTW staff to make up any PLTW missed class time due to school activities such as assemblies and field trips.

As-Is Conditions

It is imperative that school districts create the right conditions, or “the external architecture surrounding student learning, the tangible arrangements of time, space, and resources” (Wagner, 2006, p. 101), for initiatives to be successful and sustainable. The researcher’s district Superintendent has been supportive of the PLTW program. The data analyzed in this study consisted of course selection data of students who had graduated from high school in 2018, 2019, and 2020. The class of 2018 had no exposure to PLTW coursework at the elementary level. The class of 2019 was the first group of students that participated in PLTW coursework, for a quarter in middle school, while the class of 2020 participated in PLTW coursework for two quarters while at the middle school.

At the time of the study and currently, PLTW was offered to all students from Kindergarten to 8th grade. All of the buildings in the researcher's district have a STEM laboratory, which are well equipped with infrastructure that lends itself to the curriculum. The laboratories are also well designed and have many storage solutions for the materials required for PLTW. Students can keep their projects in cubbies, as most projects take multiple weeks to complete. At the end of every school year, PLTW staff order consumable materials required for the next school year. Every week, PLTW staff are provided with time to collaborate with their district counterparts. Collaboration is usually between PLTW staff from different buildings. The Superintendent and the Board of Education support the program and have also taken the time to engage in a few PLTW activities during board meetings. Prior to the pandemic, one of the former board members has volunteered in one of the PLTW classrooms once every week. This support and visibility is crucial to the success of the program in the district.

As-Is Competencies

For the purpose of K-8 PLTW program evaluation, competencies are defined as "the repertoire of skills and knowledge that influences student learning" (Wagner et al., 2006, p. 98). Every PLTW staff member has attended PLTW rigorous training organized by PLTW prior to teaching any PLTW coursework. In addition, our PLTW staff also attends ongoing professional development offered through PLTW. According to Wagner et al. (2006), competencies are most effectively built when professional development is focused, job-embedded, continuous, constructed, and collaborative (p. 98). Realizing the importance and need for continuous collaboration between PLTW staff at the different grade levels, the district provides all PLTW staff with weekly collaboration time. PLTW staff members meet to brainstorm technology issues that they face, and discuss how they can ensure that the PLTW curriculum is developmentally appropriate for our students. They also discuss subtle changes they should make to the program to best meet the needs of our students. The elementary PLTW teachers meet for an hour every Monday morning while the middle school PLTW teachers have two common plan periods every day. In addition, all PLTW staff in the district have time to collaborate with each other twice a month, after students have been dismissed for the day.

For any program to be successful in a district, it is important to analyze the 4 C's and determine ways to improve the context, culture, conditions, and competencies of the staff. District administrators realize the importance of providing a STEM education to all its students and continue to support the program. District staff also are invested in the program. However, since the program has recently been introduced into the district, no analysis of data has proved the effectiveness of this program. An analysis of the 4 C's has helped the researcher learn that a few students in middle school have no exposure to STEM coursework at the beginning of the implementation. Based on the results of the data analysis, the researcher has proposed changes to the middle school schedule so that every student in the middle school has exposure to STEM coursework (context and conditions). The researcher also posits whether longer exposure to STEM courses would increase the likelihood of students selecting STEM and advanced courses in mathematics and science in high school. Based on the results of this data analysis, the researcher plans to work with district administrators to determine next steps to move forward with a plan to provide STEM staff with additional professional development needed to further improve the effectiveness of this program.

Findings

The researcher's district offers a comprehensive K-8 PLTW program to all students in this district. The researcher sought to determine the extent to which students who participate in this STEM program at the middle school participate in STEM, advanced mathematics and science coursework in high school. Secondary to the impact on advanced course selection, the researcher sought to find out if English language acquisition can predict the likelihood of voluntary enrollment in STEM coursework in high school. Additionally, the researcher sought to discover if participation in a STEM program at the middle school impacts the grades of mathematics, science, and STEM courses taken by these students in high school.

The researcher collected high school course selection data for the classes of 2018, 2019, and 2020. The data set consisted of the high school course selection data for all four years for the classes of 2018, 2019, and 2020. Since the program began at the middle school in 2014, the students in the class of 2018 did not have the opportunity to participate in any PLTW coursework while at the middle school. Thus, the class of 2018 was considered the baseline for this study. The class of 2019 had the opportunity to participate in one quarter of PLTW coursework at the middle school, while the class of 2020 participated in two quarters of PLTW coursework during their middle school years.

Impact of PLTW on the Number of STEM Courses Taken in High School

To analyze the impact of PLTW on the number of STEM courses taken in high school, the researcher first organized the data into STEM and non-STEM courses. The researcher considered courses such as Consumer Economics and Introduction to Business as non-STEM courses, while courses such as Digital Electronics and Principles of Electronics were considered STEM courses. The percentage results are shown in Table 4.

Table 4

Number and Percentage of STEM and Non-Stem Courses Taken by the Classes of 2018, 2019, and 2020 in High School

Graduation Year	2018		2019		2020	
	Number	Percentage	Number	Percentage	Number	Percentage
Number of students with non-STEM courses	45	31%	45	33%	48	32%
Number of students with STEM courses	102	69%	93	67%	103	68%

The results indicate that only 103 (68%) students took courses classified as STEM courses in 2020, as compared to 102 (69%) students in 2018. The researcher interpreted the data to mean that taking only one or two quarters of PLTW coursework in middle school has little impact on the number of STEM courses selected by students in the high school.

The researcher also tested for differences by gender but there were no substantive differences observed.

Impact of PLTW on the Number of Advanced Mathematics Courses Taken in High School

Algebra 1 is used as a benchmark to ascertain high school students' trajectory along the mathematics pipeline, as defined by Burkam and Lee (2003), which consists of eight levels of mathematics course-taking experiences of 47 mathematics courses or classifications, further categorized into four sub-categories (non-academic, low academic, middle academic, and advanced academic) to define students' rigorous mathematics course-taking experiences in secondary education. More recently, to gain a better understanding of the achievement gap among the most advanced mathematics students, Minor (2016) conducted a study that focused specifically on students whose highest mathematics course in high school included advanced mathematics courses such as trigonometry, pre-calculus, and calculus.

To analyze the impact of PLTW on the number of advanced mathematics courses taken in high school, the researcher first organized the data into three categories: basic mathematics courses, intermediate-level mathematics courses, and advanced mathematics courses offered at the high school. After reviewing previous research, the researcher considered mathematics courses such as Pre-Algebra, Algebra 1 and Algebra 2 as basic mathematics courses, Geometry Honors and Pre-Calculus Honors as intermediate level Mathematics courses, and AP Calculus and AP Statistics as advanced mathematics courses. Table 5 shows the results of the percentage of students taking these classes.

Table 5

Number and Percentage of Basic, Intermediate, and Advanced Mathematics Courses Taken by Classes of 2018, 2019 and 2020 in High School.

Graduation Year	2018		2019		2020	
	Number	Percentage	Number	Percentage	Number	Percentage
Number of students with basic mathematics courses	42	19%	65	32%	87	40%
Number of students with intermediate level mathematics courses	130	60%	111	53%	92	42%
Number of students with advanced math courses	45	21%	32	15%	40	18%

The results show that only 40 (18%) students took courses classified as advanced mathematics courses in 2020, as compared to 45 (21%) students in 2018. The researcher interpreted the data to mean that taking only one or two quarters of PLTW coursework in middle school has little impact on the number of advanced math courses selected by students in the high school.

The researcher also tested for differences by gender but there were no substantive differences observed.

Impact of PLTW on the Number of Advanced Science Courses Taken in High School

To analyze the impact of PLTW on the number of advanced science courses taken in high school, the researcher first organized the data into 3 categories: basic, intermediate, and advanced science courses. The researcher considered science courses such as Biology, Chemistry and Physics as basic science courses, Biology Honors and Chemistry Honors as intermediate level science courses, and AP Biology and AP Chemistry as advanced science courses. The percentages of students taking these classes are shown in Table 6.

Table 6

Number and Percentage of Basic, Intermediate and Advanced Science Courses Taken by Classes of 2018, 2019, and 2020 in High School

Graduation Year	2018		2019		2020	
	Number	Percentage	Number	Percentage	Number	Percentage
Number of students with basic science courses	109	50%	94	46%	128	59%
Number of students with intermediate level science courses	52	24%	54	26%	35	16%
Number of students with advanced science courses	55	26%	56	28%	54	25%

The results indicate that only 54 (25%) students took courses classified as advanced science courses in 2020, as compared to 55 (26%) students in 2018. The researcher interpreted the data to mean that students taking only one or two quarters of PLTW coursework in middle school has little impact on the number of advanced science courses they select in high school.

The researcher also tested for differences in the means of the number of Advanced Science courses taken by males as compared to the means of the number of Science courses taken by females. The results are shown in table 7 below.

Table 7:

Mean of the number of Advanced Science courses taken by males and females

	N	Mean	Std. Deviation	Std. Error Mean
Male	282	3.4701	0.5518	0.0328
Female	259	3.5946	0.6601	0.0410

The researcher used the independent samples T-test and found a substantive difference at the $p < 0.05$ level in the means of the two groups analyzed ($p = 0.018$). The researcher rejected the null hypothesis and noted that a difference appeared in the means of the number of Advanced Science courses taken by males as compared to the means of the number of Advanced Science courses taken by females. The results are shown in the table below.

Table 8:

Independent Samples Test to determine statistical significance

	F	Sig.	t	Df	Sig (2-tailed)	Mean difference	Std. Error Difference
Equal variance assumed	5.614	0.018	-2.386	539	0.017	-0.1244	0.0521
Equal variance not assumed			-2.368	504.62	0.018	-0.1244	0.0525

As noted in table 7 and 8, even though there is a difference in the number of Advanced Science courses taken by males and females in high school, both males and females earn about 3.5 credits of Advanced Science coursework. Substantively there is not much of a difference between the number of courses taken by males and females, however, it is observed that females took slightly more Advanced Science coursework than males.

Impact of PLTW on the Number of STEM Courses Taken by English Language Learners (ELLs) in High School

The researcher considered ELLs as those students who had not passed the English Proficiency State Assessment, ACCESS. There is very little research on the impact of a STEM program on the attitudes towards STEM of ELLs. Lie et al. (2019) explored the association among student and teacher demographics, and student learning of engineering content and attitudes towards STEM after participation in an elementary or middle school engineering-based science curricula. They found it particularly encouraging that no differences in attitudes toward engineering were detected among various student demographics, including ethnicity, ELL status, and students with special needs, after participation in an elementary or middle school engineering-based science curricula. This led the authors to suggest that the implementation of a design-based curriculum played a role supporting a positive outlook in engineering among students of different ethnic backgrounds.

The researcher sought to discover if students characterized as ELLs, and exposed to STEM coursework in middle school, chose to take more STEM courses in high school, as compared to students characterized as ELLs who had no exposure to STEM coursework in middle school. Table 9 shows the percentage results.

Table 9

Number and Percentage of Non-STEM and STEM Courses Taken by ELL Students

Graduation Year	2018		2019		2020	
	Number	Percentage	Number	Percentage	Number	Percentage
Number of ELL students with no STEM course selection	6	67%	9	56%	3	25%
Number of ELL students with at least one STEM course	3	33%	7	44%	9	75%

The results indicate that, for the Class of 2018, out of nine ELL students only three students chose to take STEM courses at the high school. However, for the Class of 2020, nine of the 12 ELL students chose to take STEM courses at the high school. Although the sample size is small, the researcher interpreted the data to mean that taking

PLTW coursework in middle school had a substantial impact on the number of STEM courses selected by ELL students in the high school.

Impact of PLTW on Student Grades of Mathematics Courses Taken in High School

The researcher also sought to find out if taking STEM coursework in middle school had any impact on the mathematics grades of courses taken by high school students. The researcher calculated the mean of the mathematics grades that students received in high school and then calculated and compared the mean of all students in the classes of 2018, 2019, and 2020. The students in the class of 2018 had no exposure to STEM coursework in middle school and were considered the baseline group. The class of 2019 participated in PLTW coursework for one quarter of the year, while the class of 2020 participated in PLTW coursework for two quarters in middle school.

Table 10

Mean Mathematics Grades of All Students in Classes of 2018, 2019, and 2020

	Class of 2018	Class of 2019	Class of 2020
Mean mathematics grades of all students	3.35	3.35	3.54

As shown in Table 10, the mean of the mathematics grades of all students in the class of 2020 was higher than the mean of all mathematics grades of the classes of 2018 and 2019. The researcher interpreted the data to mean that taking two quarters of PLTW coursework in middle school has an impact on the mean grades of mathematics coursework taken by students in high school.

In order to determine if there was statistical evidence that the means of the mathematics grades of students of the classes of 2018, 2019, and 2020 were significantly different, the researcher used a One-Way Analysis of Variance (ANOVA) test. The ANOVA test was chosen for its ability to identify statistically significant differences between the means of three or more independent groups. The researcher assumed the null hypothesis, i.e., no significant difference in the means of the mathematics grades of students who participated in STEM coursework in middle school and students who did not participate in STEM coursework in middle school. The results of the ANOVA test are shown in Table 11.

Table 11

ANOVA Test Results for Mean Mathematics Grades

	Sum of Squares	df	Mean Squares	F	Sig.
Between Groups	4.342	2	2.171	4.801	.009
Within Groups	255.497	565	.452		
Total	259.821	567			

The ANOVA test revealed significant differences at the $p < 0.05$ level in the means of the independent groups analyzed ($p = 0.009$). The researcher rejected the null hypothesis and noted that a difference appeared in the means of mathematics grades of students who took STEM coursework in middle school and students who did not take STEM coursework in middle school. To determine the statistical difference in the means of each pair of groups, the researcher utilized the Bonferroni post-hoc test. The results of this test are shown in Table 12.

Table 12

Multiple Comparisons of the Means of Mathematics Grades in Classes of 2018, 2019, and 2020

(I) Graduation Year	(J) Graduation Year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
2018	2019	.00248	.06901	1.000	-.1632	.1682
	2020	-.18458*	.06873	.022	-.03496	-.0195
2019	2018	-.00248	.06901	1.000	-.1682	.1632
	2020	-.18706*	.06964	.022	-.3542	-.0198
2020	2018	.18458*	.06873	.022	.0195	.3496
	2019	.18706*	.06964	.022	.0198	.3543

* The mean difference was significant at the 0.05 level.

The results of the Bonferroni test revealed a significant difference in the means of the mathematics grades of students in the class of 2020, as compared to the means of the mathematics grades of students in the class of 2018, the class that took no STEM coursework in the middle school. Similarly, a significant difference appeared in the means of the math grades of students in the class of 2020, as compared to the means of the mathematics grades of students in the class of 2018. The researcher interpreted this to mean that taking STEM coursework in middle school has an impact on the mathematics grades of students in high school. The mean mathematics grades of the students who did not take PLTW coursework in middle school was 3.35, while the mean mathematics grades of students who took PLTW coursework in middle school was 3.54.

Impact of PLTW on Grades of Science Courses Taken in High School

The researcher also sought to find out if taking STEM coursework in middle school had any impact on the science grades of courses taken by high school students. The researcher calculated the mean of the science grades that students received in high school and then both calculated and compared the mean of all students in the classes of 2018, 2019, and 2020. The students in the class of 2018 had no exposure to STEM coursework in middle school and were considered the baseline group. The class of 2019 participated in PLTW coursework for one quarter of the year, while the class of 2020 participated in PLTW coursework for two quarters while in middle school.

Table 13

Mean Science Grades of all Students in Classes of 2018, 2019, and 2020

	Class of 2018	Class of 2019	Class of 2020
Mean science grades of all students	3.32	3.31	3.43

As shown in Table 13, the mean of the science grades of all students in the class of 2020 was higher than the mean of science grades of all students in the classes of 2018 and 2019. The researcher interpreted the data to mean that taking two quarters of PLTW coursework in middle school has some impact on the mean grades of science coursework taken by students in high school.

In order to determine if there was statistical evidence that the means of the science grades of students of the classes of 2018, 2019 and 2020 was significantly different, the researcher used an ANOVA test. The researcher assumed the null hypothesis, i.e., no significant difference in the means of the science grades of students who participated in STEM coursework in middle school and students who did not participate in STEM coursework in middle school. The results of the ANOVA test are shown in Table 14.

Table 14

ANOVA Results for Mean Science Grades

	Sum of squares	df	Mean Squares	F	Sig.
Between Groups	.338	2	.169	7.750E+27	.000
Within Groups	.000	538	.000		
Total	.338	540			

The ANOVA test revealed significant differences at the $p < 0.05$ level in the means of the independent groups analyzed ($p = 0.000$). The researcher rejected the null hypothesis and noted the difference in the means of science grades of students who took STEM coursework in middle school and students that took no STEM coursework in middle school. To determine the statistical difference in the means of each pair of groups, the researcher utilized the Bonferroni post-hoc test. The results of this test are shown in Table 15.

Table 15

Multiple Comparisons of the Means of Science Grades in Classes of 2018, 2019, and 2020

(I) Graduation Year	(J) Graduation Year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
2018	2019	.00860*	.00000	.000	.0086	.0086
	2020	-.04866*	.00000	.000	-.0487	-.0487
2019	2018	-.00860*	.00000	.000	-.0086	-.0086
	2020	-.05726*	.00000	.000	-.0573	-.0573
2020	2018	.04866*	.00000	.000	.0487	.0487
	2019	.05726*	.00000	.000	.0573	.0573

* The mean difference was significant at the 0.05 level.

The results of the Bonferroni test revealed a significant difference in the means of the science grades of students in the class of 2020, as compared to the means of the science grades of students in the class of 2018, the class that took no STEM coursework in the middle school. Similarly, a significant difference appeared in the means of the science grades of students in the class of 2020, as compared to the means of the science grades of students in the class of 2018. The researcher interpreted this to mean that taking STEM coursework in middle school has an impact on the science grades of students in high school. The mean science grades of the students who did not take PLTW coursework in middle school was 3.32 while the mean science grades of students who took PLTW coursework in middle school was 3.43.

Impact of PLTW on Grades of STEM Courses Taken in High School

The researcher also sought to find out if taking STEM coursework in middle school had any impact on the STEM grades of courses taken by the students in high school. Part of the requirements for high school graduation requirements is that students must complete one semester of Applied Arts coursework, which can be chosen from Business, Family and Consumer Science, or Technology and Engineering. The researcher considered courses from Family and Consumer Science as non-STEM courses, and considered most courses in Technology and Engineering as STEM courses. Although students were only required to take a single STEM course, many students took more than one STEM course. The researcher sought to discover if taking PLTW coursework in middle school for one or two quarters had an impact on the STEM grades of the students in high school. The researcher also investigated whether the number of STEM courses that students took in high school had any impact on their grades in STEM coursework. The students in the class of 2018 had no exposure to STEM coursework in middle school and were considered the baseline group. The class of 2019 participated in PLTW coursework for one quarter of the year while the class of 2020 participated in PLTW coursework for two quarters while in middle school.

In order to determine if the STEM grades of students in high school could be predicted by the amount of exposure to middle school PLTW coursework the student had, or the number of STEM courses that the student took in high school, the researcher analyzed the STEM grades of high school students using linear regression analysis. The linear regression test was chosen for its ability to predict the value of one variable based on the value of other variables. The researcher assumed the null hypothesis, i.e., that there would be no significant difference in the means of the STEM grades of students who participated in STEM coursework in middle school and students who did not participate in STEM coursework in middle school. The researcher also assumed the null hypothesis that there would be no significant difference in the means of the STEM grades of students who took more than one STEM course in high school. The results of the linear regression are shown in Tables 16, 17, and 18.

Table 16

Model Summary for Linear Regression

Model	*R*	*R Square*	*Adjusted R Square*	*Std. Error of the Estimate*
1	.020	.000	-.010	1.13198

Table 17

ANOVA Test Results for Mean STEM Grades

Model	*Sum of Squares*	*df*	*Mean Squares*	*F*	*Sig.*
1 Regression	.152	3	.051	.040	.989
Residual	372.881	291	1.281		
Total	373.033	294			

Dependent Variable: STEM_Grade_Mean
Predictors: (Constant), No_STEM_Courses, Class 2019, Class 2020

Table 18

Unstandardized and Standardized Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
Model	*B*	*Std. Error*	*Beta*	*t*	*Sig.*
1 (Constant)	3.708	.152		24.338	.000
Class 2019	.049	.161	.020	.307	.759
Class 2020	.031	.160	.013	.195	.846
No. of STEM courses	.008	.057	.008	.139	.890

Dependent Variable: STEM_Mean_Grade

Multiple linear regression was used to predict the mean STEM grades in high school, based on the exposure to PLTW coursework in middle school and the number of STEM courses taken in high school. Table 16 shows the impact of exposure to PLTW coursework in middle school and number of STEM courses in high school on the mean STEM grades in high school. The R^2 value of .00 revealed that the predictors did not explain a variance in the mean STEM grades with $F(3,291) = .04$, $p = .99$. The findings also revealed that the amount of PLTW coursework taken by the class of 2019 had no significant effect on the mean of the high school STEM grades (B = .02, $p > .05$). Similarly, the amount of PLTW coursework taken by the class of 2020 had no significant effect on the mean of the high school STEM grades (B = .01, $p > .05$). Additionally, the number of STEM courses taken at high school had no significant effect on the mean of the high school STEM grades (B = .01, $p > .05$)

Interpretation

Overall, the researcher interpreted the data results to mean that taking a quarter or two quarters of PLTW coursework at the middle school level has no significant impact on the number of STEM, advanced mathematics and science courses selected by students at the high school. The results could mean that students must have additional exposure to PLTW coursework at the elementary and middle school level so as to develop the perseverance and passion to endure through advanced mathematics and science, as well as STEM coursework in high school. The researcher posits whether students with exposure to PLTW courses from Kindergarten would be more likely to select STEM, advanced mathematics and science courses when they reach high school.

Additionally, the researcher noted that some of the high school STEM coursework is offered at a separate location. Students interested in these courses must spend 2.5 hours of their day at this alternate location, possibly explaining why students prefer to stay at their home school where the choice for STEM coursework is limited rather than to pursue additional STEM coursework offered at a different location. Moreover, there is a limit on the number of students who can take STEM coursework, which may account for students not being able to choose STEM coursework at the high school level. Other factors affect student course selection at the high school level, such as certain courses being reserved for only junior or senior students, or scheduling conflicts.

In another study finding, the number of ELL students who took STEM courses in high school tripled when compared to the number of ELL students with no exposure to PLTW coursework while in middle school. This led the researcher to the conclusion that ELLs benefitted from taking STEM courses while in middle school, and that this had an impact on their course selection choices made in high school. It is likely that ELL students developed positive attitudes towards hands-on STEM courses such as PLTW while participating in PLTW coursework in middle school, thus felt confident that they could be successful in these courses in high school, leading them to take PLTW coursework in high school.

The researcher also interpreted the data results to mean that taking one or two quarters of PLTW has an impact on the mathematics and science grades taken in high school. According to the PLTW Gateway website (2021), each PLTW Gateway unit engages the students in activities that build knowledge and skills in computer science and engineering, and then challenges them to apply what they have learned to real-world problems such as cleaning oil spills and programming traffic lights.

The researcher also arrived at the conclusion that taking PLTW courses in middle school leads students to develop problem-solving skills and to persevere in their coursework, and that this may have an impact on the mathematics and science grades of courses taken in high school. Although taking PLTW coursework in middle school did not have an impact on the number of STEM, advanced mathematics and science courses taken in high school, it did have an impact on the mathematics and science grades received by the students in high school. The researcher believes that students who have been exposed to PLTW coursework from elementary school will likely take STEM, advanced mathematics and science courses in high school because taking PLTW courses in elementary school will help build their perseverance and problem-solving abilities from an early age. The researcher recommends continued support for all students to have exposure to PLTW coursework in elementary school and middle school, and for further data analysis to be conducted for long-term effects of PLTW coursework on mathematics, science, and STEM grades of students in high school.

Judgments

The researcher sought to discover if students who participated in STEM coursework in middle school were more likely to take STEM, advanced mathematics and science coursework in high school. An analysis of the data determined that participating in STEM coursework for one or two quarters in middle school does not result in an increase in the number of STEM, advanced mathematics and science courses taken by students in high school. Nevertheless, a new study might determine if students who participate in STEM coursework for more than three years at the middle school or have taken STEM coursework from Kindergarten go on to take STEM, advanced mathematics and science, or STEM coursework in high school. According to Dejarnette (2016), scientific, problem-based activities should not be reserved for middle school and high school classrooms. Elementary students have the cognitive abilities to engage in STEM content and problem-solving activities, which in turn will whet their appetite for more. Not only do STEM lessons and activities excite young learners, but they also build their confidence and self-efficacy in relation to their own abilities to be successful in more advanced mathematics and science courses in high school years (Dejarnette, 2016).

One of the secondary research question asked if students who participated in STEM coursework in middle school were more likely to earn high grades in STEM, mathematics and science coursework that they took in high school. An analysis of the data determined that participating in STEM coursework for one or two quarters in middle school resulted in a statistically significant increase in the mean grades of the students in mathematics and science. However, the analysis also revealed that participating in STEM coursework for one or two quarters in middle school did not result in a statistically significant increase in the mean grades of the students in STEM coursework taken in high school.

The researcher would recommend a study determining if middle school teachers perceived that students who participated in STEM coursework developed curiosity, imagination, critical thinking, and problem-solving skills to a larger extent as compared to students who did not participate in STEM coursework at the middle school. While the researcher did not interview PLTW teachers at the middle school, a future study might determine if PLTW teachers saw a difference in the critical-thinking, problem-solving skills, and perseverance of students who have been exposed to PLTW coursework from the early elementary years. It is possible that the benefits of PLTW coursework are not quantifiable in the number of advanced math, science, or STEM coursework taken by students in high school, but can be observed in the critical thinking, problem-solving skills of students who have had exposure to PLTW coursework since early elementary school.

Conclusion

The researcher utilized Wagner et al.'s (2006) 4 C's As-Is diagnostic tool to evaluate the current assets and contributing factors that hindered the potential impact of PLTW coursework on student high school course selection. The utilization of this tool readily assisted the researcher in more accurately defining the needs of the PLTW program in the researcher's district. Problems can be identified and eradicated with the effective usage of the 4 C's framework.

By collecting and analyzing high school coursework selection data of students who had taken PLTW coursework in middle school, the researcher determined the impact of two quarters of PLTW coursework on high school students' course selection, as well as their grades in mathematics, science, and STEM courses taken in high school. In the next chapter, the researcher will outline the vision for the PLTW program in the district, where all students can engage with their peers collaboratively and have access to rigorous PLTW coursework.

CHAPTER FIVE

TO-BE FRAMEWORK

The researcher investigated the effectiveness of the district's PLTW program in encouraging students to persist in STEM and advanced mathematics and science coursework in high school. According to the NSB (2010), the continued economic prosperity of the United States depends on a skilled workforce, particularly at the leading edge of science and technology. Although mastery of a STEM discipline requires over a decade of intensive study after high school, the interest or disinterest in STEM germinates early in K-12, maybe even in early childhood (NSB, 2010). The researcher's middle school introduced the PLTW program to students in 2014. The program was gradually expanded to include additional grade levels and currently is a K-8 STEM program. While the researcher observes the many strengths of the current program, there is room for improvement. This chapter outlines the context, culture, conditions, and competencies that can be improved so as to move the PLTW program in the researcher's district from the As-Is condition of the program to the To-Be or ideal PLTW program that the researcher envisions for the district. The implementation of these specific changes will create the ideal PLTW program that the researcher envisions, one that instills a passion for STEM in the minds of every young learner in the district.

Envisioning the Success To-Be

In order to maximize the potential effects of PLTW, we currently need improvements in certain areas. Once the researcher identified areas of improvement in

Wagner et al.'s (2006) outline, she devised the To-Be diagram (Appendix B) in order to present recommendations and requirements. The To-Be diagram outlines the future context, conditions, competencies, and culture of the PLTW program that the researcher envisions so that the PLTW program has the most impact on student academic outcomes and high school course selection.

To-Be Context

The ideal context envisioned by the researcher is one where every student in the district, including those in pre-K, receive PLTW coursework every week. The researcher advocates for STEM to also be introduced at the Pre-K building, so that our youngest learners can develop an appetite for STEM activities at an early age. The researcher envisions the district as one of the few where STEM is offered to all students irrespective of their gender, socio-economic status, or language proficiency.

To-Be Culture

The researcher envisions that all staff members in the district realize the importance of building students' critical thinking and collaborative skills, and for preparing them for today's workforce. The researcher also views all PLTW staff as committed to providing all students, including those students with special needs, with the opportunity to participate in grade level PLTW courses, also providing appropriate accommodations and support. Additionally, PLTW staff would work with the case managers of students with special needs to generate ideas for materials and lessons that can help these students experience success in these courses. In addition, in the ideal culture, staff in all buildings work with the PLTW staff to make up any PLTW class time missed due to school activities, such as assemblies and field trips.

To-Be Conditions

It is crucial that districts provide the support necessary to continue to prepare students to be active, creative, knowledgeable, and ethical participants in our global society (U.S. Department of Education, 2017). Under the ideal conditions for the PLTW program to thrive in the researcher's district, the researcher envisions that the PLTW program is offered to all students from Pre-K to 8th grade. The researcher envisions that every building in the researcher's district has a STEM laboratory and these laboratories are well equipped with infrastructure that lends itself to the curriculum. The laboratories are also well designed and have plenty of storage solutions for the materials required for PLTW. Students will have the opportunity to keep their projects in cubbies, as most projects take multiple weeks to complete. PLTW staff will continue to have the time to collaborate on their program with other PLTW staff in the district, and with the PLTW staff at the high school. The Superintendent and the Board of Education will continue to support the program and find opportunities to engage in PLTW activities or occasionally volunteer in a PLTW classroom; support and visibility is crucial to the success of the program in the district.

To-Be Competencies

For any new program to truly thrive, the foundation for transformation lies within the competencies of those who work closely with the students and have the most impact on them—namely, the teachers. According to Wagner et al. (2006), competencies are most effectively built when professional development is focused, job-embedded, continuous, constructed, and collaborative (p. 98). The researcher envisions that PLTW staff would seek to improve their instructional practice by seeking to attend ongoing professional development offered through PLTW. They would also seek ways to engage in continuous collaboration with PLTW staff in neighboring districts, and with the high school, with the objective of improving their instruction, student learning, and develop a passion for STEM in the minds of our young learners.

According to Goris (2020), parental educational level is a significant factor for a child's choice of future career. This study's district is very diverse and many students in the district will be first-generation college students. The researcher advocates for PLTW staff inviting all parents to participate in STEM activities during evening events, such as family STEM night, with the objective of broadening their parents' perspectives so that they may encourage all their children, especially their daughters, to persist with PLTW coursework in high school and beyond. Prior to the pandemic, such activities were prevalent in the district's intermediate building. The researcher would advocate for such events to occur in every school, so that every parent in the district has the opportunity to engage in STEM activities.

Conclusion

The chapter above describes the context, culture, context, conditions, and competencies crucial to the creation of a robust PLTW program that inspires a sense of curiosity and a passion for STEM in the district. The next chapter outlines some of the strategies and actions necessary to move the PLTW program from the As-Is condition of the PLTW program to the To-Be or ideal PLTW program that the researcher envisions for the district.

CHAPTER SIX

STRATEGIES AND ACTIONS

Despite NSB's recommendation to expose elementary students to STEM in elementary schools, very few school districts have STEM programs as early as Kindergarten. This section represents the researcher's conceptualization of changes needed in the areas of context, culture, conditions, and competencies. These changes are necessary to foster the effective implementation of an organizational change plan within the study school with the purpose of improving student achievement. The researcher recommends developing the following strategies to provide every child in the district with the opportunity to engage in PLTW activities from Pre Kindergarten to 8th grade. In addition, the researcher would advocate for extracurricular activities, such as K-8 STEM clubs, which currently exist only at the middle school building, Grades 5 to 8. The researcher would also advocate for professional development activities such as coaching and collaboration with neighboring STEM districts, and the high school, as such collaborative activities currently do not exist. The researcher proposes the following strategies and actions to move from the conditions of the PLTW program that were prevalent when the students whose data was analyzed took PLTW in the district to the To-Be or ideal future conditions of the STEM program in the district as envisioned by the researcher. The Strategies and Actions Diagram is shown in Appendix C.

Strategy 1: Increase the Amount of Hours that Elementary Students Receive STEM Coursework at the Elementary and Middle School Level

In thinking about the context of this program, currently, the pre-K program in the district does not offer PLTW coursework to their students. The researcher would advocate for the addition of this coursework at the pre-K level. According to Dejarnette (2016), not only do STEM lessons and activities excite young learners, but they also build their confidence and self-efficacy in relation to their own abilities to be successful in more advanced mathematics and science courses in later school years.

Although K-5 students in the district have a single 40-minute PLTW class every week, the researcher has observed that too often students are prevented from participating in this class because of school holidays or assemblies. The researcher would work with the elementary and middle school principals in the district to seek out opportunities for increasing the amount of time that K-4 students can participate in PLTW coursework in her district. By scheduling additional time during the week for PLTW coursework in the elementary grades, all students would receive at least one PLTW class per week, despite school holidays and assemblies. The researcher would assess the effectiveness of the plan to increase PLTW time for all students by comparing the number of minutes that all students in the district currently receive PLTW classes to what they will receive in the future.

Strategy 2: Provide Opportunities for Elementary Students to Participate in After-school STEM Clubs

Currently, after-school STEM clubs only exist at the middle school level, thus only students in Grades 5 to 8 can participate in these clubs. The researcher would extend this opportunity to elementary students in the district with the objective of whetting their appetite for STEM coursework at an early stage, and in a playful setting. If the economy goes into a downward spiral and unemployment increases, the researcher anticipates that funding allocated to public schools will be constrained and budgets under pressure. In such a case, the researcher would identify opportunities for government grants used to fund after-school programs so as to provide opportunities for all students to participate in STEM activities. This strategy also involves initiating the application process for such grants so as to use these funds to promote after-school STEM clubs at the K-4 level.

Strategy 3: Increasing Mathematics, Science, and STEM Career Awareness with Career Fairs at the Elementary and Middle Schools

Career development theorists have long recognized the importance of early childhood in human career development. Super (1980) was one of the first to articulate a career development theory that emphasized the impact of childhood activities, role models, and achievements on the young person's vocational self-concept. His Life-Span, Life-Space Approach to Career Development describes the ages from birth to 14 years as a period of vocational growth in which successful home, school, and social experiences lead to a positive vocational self-concept. A positive vocational self-concept allows a child to later meet his or her career potential. Betz and Hackett (1981) also emphasized the importance of role models in career development. They introduced the concept of career self-efficacy, in which a person develops confidence in his or her ability to choose a career and having success in that career. Role models are important in the development of career self-efficacy, particularly role models similar to the person choosing them. The researcher recommends creating opportunities for middle school students to interact with students in the high school, so they can share their high school experiences with coursework selection, including advanced mathematics, science, and STEM coursework.

The researcher recognizes that the students in her school district come from various socio-economic backgrounds, races, and cultures. Many students have had few positive role models in their lives that can introduce them to the concept of a steady job or encourage them to seek out and persist in STEM and science careers. This is especially important in later elementary and middle school, when students are beginning to learn more about their interests and think about what they would like to do as they grow older. Strategy 3 proposes a later elementary and middle school career fair that represents a wide variety of science and STEM careers, so that students have opportunities to interact with professionals from the field and learn more about STEM and science careers at an early age.

Strategy 4: Engaging Various Stakeholders and Community Members at Evening Events Such as Family STEM Night

Numerous studies have identified parental involvement in education as an important way to facilitate positive youth development (Jeynes, 2009). Strategy 4 involves evening events, such as family STEM nights at the elementary schools, where parents can participate in STEM activities along with their child. Participation in after-school, summer, and other informal STEM programs is viewed as critical to obtaining positive outcomes for learners (cf. Chubin et al., 2008; National Academy of Sciences, 2007). Documented benefits for participants in informal STEM programs include an increase in positive attitudes and interest in science and technology (Hayden et al., 2011), and a stronger understanding of STEM concepts and processes (McGee-Brown et al., 2003). For this strategy, the researcher would work with both teachers and community members to develop a plan for all families to engage in STEM-related activities during an evening event such as Family STEM night, inviting parents and students to participate in this event.

Strategy 5: Job-embedded and Continuous Professional Development for PLTW Staff

For any new program to truly thrive, the foundation for transformation lies within the competencies of those who work closely with the students and have the most impact on them, namely, the teachers. Wagner et al.'s (2006) competencies are most effectively built when professional development is focused, job-embedded, continuous, constructed, and collaborative (p. 98), and, currently, PLTW staff in the district meet weekly to collaborate with each other. Strategy 5 would increase job-embedded and collaborative professional development by scheduling time for the PLTW staff to observe PLTW classrooms in the district, as well as in neighboring districts.

According to Hattie (2009), not all forms of professional development are equal in their impact on teacher knowledge and instructional practice. The type of instruction found most effective on teacher knowledge and behavior is observation of actual classroom methods (p. 120). Strategy 5 includes PLTW staff collaborating with the high school PLTW staff with the objective of discussing how the elementary and middle school teachers can better prepare their students for persisting with STEM coursework at the high school. The researcher would collaborate with the principals of neighboring districts to determine a time when PLTW teachers can observe each other's classrooms and debrief after the observation. PLTW trainers would coach our PLTW staff every quarter to obtain specific, non-evaluative feedback on staff practices. The researcher would also continue to evaluate the effectiveness of the strategy by frequently observing the PLTW teachers and engaging in candid conversations with them to determine if the instructional practices of the PLTW teachers are improving due to an increase in specific professional development and collaboration with other PLTW staff.

Conclusion

The purpose of these five strategies and actions is not only to strengthen the Wagner's (2006) arenas of change (context, conditions, competencies, and culture), but also to ensure engaging and meaningful lessons every day for every student. In the 21st century, all students deserve the opportunity to participate in STEM programs right from early childhood. It is imperative that teachers, school leaders, and policymakers make early childhood and elementary STEM programs a priority, by implementing STEM programs that all students can participate in at the earliest possible stage in a K-12 educational system. Time is always a constraint, but administrators have to prioritize generating ideas on ways to ensure that all children have exposure to a quality STEM program.

Ensuring that the teachers deliver a rigorous program also calls for continuous professional development for these teachers. Without the change necessary to make the To-Be STEM vision a reality, the opportunities that STEM presents will go unrealized, and teachers will not be able to make significant contributions to the environment necessary to prepare students for the demands of the 21st century. It is therefore crucial for educators to instill the love of problem-solving and innovation in our elementary students, inspire in them the passion for science and technology, so that they may persevere with advanced coursework in high school and beyond. These actions, in turn, will inspire them to eventually pursue STEM careers that have enormous growth potential in the near future.

The next chapter will discuss implications from the findings of this study and discuss changes to policy the researcher recommends based on those findings.

CHAPTER SEVEN

IMPLICATIONS AND POLICY RECOMMENDATIONS

The policy issue surrounding my K-8 PLTW program evaluation and integrated throughout the strategies for organizational change is the clear need for the creation of a policy advocating for increased STEM opportunities for all students from pre-Kindergarten through high school graduation. This policy would advocate for an increase in STEM opportunities beyond any mathematics and science requirements, and would be specifically related to STEM coursework.

Currently, in Illinois, there is no statute, policy, practice, or bylaw addressing STEM education. In 2009, when the U.S. Department of Education came out with the Race to the Top initiative, Illinois had implemented initiatives to ensure that school districts would be prepared to offer students a top-notch education, one that prepares them for success in college, career, and life in the 21st century. Although these initiatives were terminated, the Illinois Department of Education's website currently has a plan for strengthening the career and technical education of its students under the Perkins V state plan. However, the purpose of the plan is to develop the academic knowledge and employability skills of secondary and post-secondary students who elect to enroll in Career and Technical Education (CTE) programs of study. The plan does not specifically mention ways to provide all students with opportunities to engage in STEM coursework. STEM coursework is also not a part of the graduation requirements in Illinois, although students can use STEM coursework to meet their elective requirement for graduation.

The nation now needs “STEM innovators,” those individuals who have developed the expertise to become leading STEM professionals and potentially the creators of significant breakthroughs or advances in scientific and technological understanding (NSB, 2010). Utilizing Vision 2030 (NSB, 2020) and other related research, such as Charting a Course for Success: America’s Strategy for STEM Education (Committee on STEM Education of the National Science & Technology Council, 2018), the researcher’s state could create a policy on STEM education. Additionally, the researcher recommends that Illinois also provide technical assistance, guidelines, and monetary assistance for all public school districts to implement STEM education to all its students.

Currently, many high school and middle school students do not have the opportunity to take STEM coursework in middle or high school. Even fewer elementary students have access to this opportunity. The creation of a K-12 policy will even out the playing field so that every student, irrespective of their zip code will have the opportunity to participate in STEM coursework from Kindergarten through 12th grade. All K-12 students should have access to a STEM curriculum throughout their school career; STEM education can no longer be considered as an elective course if we want to create a workforce that meets the needs of our country. If the United States is to ensure a strong economy and national security, it is vital that a significant share of future scientific breakthroughs and world-changing innovations be made here (NSB, 2020).

The researcher thus proposes a policy at both the state and local levels to address the access of a STEM curriculum to all K-12 students. The policy would articulate and promote all public school districts to create and maintain STEM education policy that ensures equitable access and opportunities to all students, irrespective of their language proficiency or race. The policy developed by the researcher's state would provide detailed guidance on STEM coursework and standards that students need to master in each year of their K-12 education.

Since there is no current STEM policy in the state, generating a STEM policy is a necessity to prepare our students for tomorrow's workforce. Under the current state policy, a student may graduate from a K-12 public school without having any exposure to a STEM curriculum, as it is currently not a graduation requirement nor required curriculum at in any grade level. This is not only a disservice to the students, but the state is also not doing its part to prepare its students for post-secondary success. According to NSB (2020), increasing the STEM skills and opportunities for all Americans will require local, state, and federal governments, public and private educational institutions, community organizations, and industry to step up their efforts. The United States needs "all hands on deck" to modernize its education system, reinvest in public elementary, secondary, and postsecondary education, and support the reskilling or upskilling that workers will need throughout their careers.

A STEM policy will serve to outline the number of hours that students need to engage in STEM related activities. Moreover, if this policy provides all public schools with an official mandate of required STEM instruction, school districts will then place a focus on it and emphasize K-12 STEM instruction for all its students. According to Ralston et al. (2013), the pipeline concept of funneling students to middle schools with STEM programs, and then moving those students to high schools with PLTW courses, has been effective and models an outreach program with tremendous potential to increase both the quality and quantity of students electing to study STEM fields. Currently, the researcher’s elementary school district is one of the few in the area that provides a K-8 STEM (PLTW) program for all of its students. The high school district has recently adopted the PLTW curriculum for its students. Having such a policy in all state school districts would provide all students in the state with access to equitable STEM opportunities at the K-12 level. The policy would also provide districts with research-based practices that can increase STEM opportunities for students, as well as recommendations for providing professional development opportunities for its educators.

The proposed policy will provide all K-12 public school districts with an awareness of the importance of STEM education and would serve as a strategic catalyst for change in the area of STEM education. It would provide the much-needed support for the implementation of the organizational changes that the researcher has outlined in the “Strategies and Actions” section of Chapter 6.

Policy Statement

Thus the researcher recommends that the state create a K-12 policy that addresses equitable access to STEM coursework for all its students. Additionally, the researcher recommends that each district creates district policy that ensures every student has an opportunity to engage in STEM opportunities from Kindergarten through high school.

Analysis of Needs

Based on the findings in this STEM program evaluation, the researcher’s policy recommendation addresses the adaptive challenge of ensuring equitable opportunities for STEM education for all K-12 students. The following sections address the analysis of needs through the educational, economic, social, political, legal, moral, and ethical standpoints. This analysis will provide insights into the impact of STEM education for all K-12 students.

Educational Analysis

In the PLTW program evaluation, the researcher identified a need for an increase in STEM engagement opportunities, such as PLTW coursework at the K-12 level. With the proposed policy in place, school districts in the researcher's state will look for opportunities to engage all students in a STEM-based curriculum, such as PLTW. This policy will also require school districts to provide their staff and administrators with professional development on the adopted STEM curriculum.

The researcher also identified job-embedded and continuous professional development of all PLTW staff as a strategy (see Chapter 6). For any program to truly thrive, the foundation for transformation lies within the competencies of those who work closely with the students and have the most impact on them, namely, the teachers. Through this program evaluation, the need for continuous professional development of teachers and administrators became evident. With this policy in place, district administrators can intentionally plan and create ongoing and sustainable STEM professional development opportunities, including opportunities for staff to collaborate with staff from neighboring districts so as to address the needs of all staff.

Economic Analysis

Only about a quarter of K-12 funding is currently provided by the state government; thus school districts must rely on their local sources for a bulk of their funds. Consequently, any changes in policy have enormous financial implications for school districts. The economic analysis of my proposed STEM policy has two unique issues: (1) the health and well-being of the U.S. economy as it relates to the future workforce, and (2) the fiscal implications of mandating a STEM curriculum for all K-12 students. Both issues have short-term and long-term implications that must be considered.

According to NSB (2020), worldwide demand for STEM-capable workers keeps growing, driven by international opportunities and competition, and by rapid increases in the number of jobs that require STEM skills, including in lines of work that historically required no science and engineering knowledge. This demand will only become more urgent. By 2026, science and engineering jobs are predicted to grow by 13%, compared with 7% growth in the overall U.S. workforce. For the nation to preserve its lead in fundamental research and empower its businesses and enterprises to compete globally, it must stay on the leading edge of the practice of science and engineering or STEM fields. It is imperative that school districts provide all students with STEM education; this is a critical strategy to ensure students have the desired skill sets and are viable candidates for future employment.

The second policy issue to consider is the fiscal impact of mandating STEM education to all K-12 students. Any new program implementation comes with a fiscal impact, such as personnel requirements, the cost for purchasing a new curriculum, as well as providing staff and administrators with professional development on the curriculum. Along with the policy, the state should also appropriate some dollars toward the implementation of this policy. Both the state and public school districts will need to review their budget allocations to find funding categories that help offset additional costs related to implementing a K-12 STEM program for all students.

Social Analysis

The social analysis of my proposed policy concerns teacher preparedness, collaboration and implementation. Typically, the STEM teacher is the only STEM teacher in the building and consequently these teachers have limited interactions with other colleagues, which can lead to low morale and motivation. In order to promote an effective implementation of a K-12 STEM program, STEM teachers must collaborate with each other and share best practices that have been proven to work for their students' progress and learning in STEM coursework. Even if the STEM teacher is the only teacher in the building, it is important to provide them with time to collaborate with STEM teachers in the other elementary buildings. The proposed policy would help increase the interactions between STEM teachers and other professionals, either in the same or in neighboring districts, thus increasing the likelihood of effective implementation of the STEM curriculum.

Political Analysis

Durodoye (2019) notes that education has never been nonpartisan. Buffeted by economic, political, and social influences, educators and various stakeholders have taken sides to provide institutionalized instruction to child and adult learners. Despite divergent views, the ultimate goal of serving students has remained paramount. The political analysis of my STEM policy is multifaceted and has implications on the national, state, and local levels.

Due to the Tenth Amendment of the U.S. Constitution, even though the federal government has no direct control over public education, national political leaders create public policy by tying initiatives to federal dollars. According to Kersten (2017), states—

more specifically school districts—that want federal funding are required to meet certain federal requirements. For example, under the requirements of Every Student Succeeds Act (ESSA), every state in the nation must complete ESSA plans if the state intends to utilize federal funds from the Title programs (U.S. Department of Education, ESSA, 2020). The plans must include academic enrichment for students, support for students with special needs, language learner interventions programs for students at risk, as well as for homeless students.

Next, there are political implications at the state level, because each school district receiving federal funding must create a plan to account for how the federal dollars will be spent. Once the state's Department of Education reviews the district plans, public school districts are allowed to allocate and spend the Title money as articulated in their local plans.

Finally, at the local level, the political landscape has the possibility of shaping many of these decisions based on the priorities and needs of the public school district. Tying both federal and state funding to STEM opportunities for all K-12 students is instrumental in advocating for STEM opportunities for K-12 students. Local districts might use such monies for procuring STEM supplies or for providing their staff with continuous professional development. In order to mitigate competing political agendas, the creation of a state policy for STEM education would force bipartisan collaboration for the betterment of our local, national, and global society.

Legal Analysis

According to Palestini and Palestini (2012), the degree of authority that local systems have over educational matters depend on the wording of the state's constitution and laws. The prevailing belief is that public schools are controlled locally, but the fact of the matter is that in many respects, even in curriculum and instruction, local control does not prevail. In many instances, especially when the state is heavily involved in financing education, the state has more meaningful power over educational policy than does the local school system. This means that each public school district needs to align its policy with the State's STEM policy so as to ensure they receive state funding for their STEM initiatives.

The legal implication of the proposed policy directly addresses the issue of equity in STEM. Currently, there are only a few sections of PLTW courses in the high school district. If students want to take additional PLTW courses, they must take these courses at another campus. Only students in their junior and senior years can take classes at another campus and they must be on that campus for half the school day. This requirement leads to inequitable opportunities for students who want to take PLTW courses. Thus the current structure to access STEM opportunities is vastly inequitable and alienates students who may still need to take additional courses at their home campus. The proposed STEM policy would allow the public school district of the study to re-examine current practices and provide an opportunity to make STEM education more accessible to all students on the same campus.

Moral and Ethical Analysis

Educational leaders must always try to ensure that all students in their district, irrespective of their language proficiency or skin color, have equal access to all programs and opportunities that prepare them for post-secondary success. According to the NSB (2010), the continued economic prosperity of the United States depends on a skilled workforce, particularly at the leading edge of science and technology. Students of color continue to experience problems accessing higher education and in persisting in finishing their high school degree, especially in STEM (NSB, 2010). Mitchell (2011) observes that the underrepresentation of minorities in STEM is multifaceted and exists at several levels, including individual (emotional stability and assertiveness), family (educational level and financial support), educational (academic rigor and classroom climate), workplace (wages and promotion), and social (policy and awareness). Subsequently, action strategies and solutions must address each of these levels to adequately repair the "leaky pipeline," or the process by which URM (underrepresented minority) students leave STEM fields.

The proposed STEM policy would mean that all school districts provide STEM opportunities for all students. A K-12 STEM education will provide students with the necessary skills and knowledge for increased college and career readiness. According to the National Academies of Sciences, Engineering, and Medicine (2016), in an increasingly interconnected global economy the future competitiveness of the United States depends on the nation fostering a workforce with strong capabilities and skills in science, technology, engineering, and mathematics (STEM). Educational efforts should align with U.S. industry needs and workforce development to help create viable, employable candidates for the future.

Implications for Staff and Community Relationships

Implications of the recommended policy for staff relationships show the opportunity to improve staff relationships and remove any perceived barriers. Currently, because often (and in the researcher's district) the STEM teacher is the only STEM teacher in the building, their limited interactions with other STEM colleagues lead to low teacher morale and motivation. In order for an effective implementation of a K-12 STEM program, it is imperative for STEM teachers to collaborate and share their best practices, those proven to work with past students. As part of the Strategies and Actions (listed in Chapter 6), the researcher would advocate for expert trainers from PLTW to coach PLTW staff in the district every quarter with the objective of providing staff with specific, non-evaluative feedback on their practice. According to Neuman and Cunningham (2009), the pairing of peer coaching and professional development creates optimal changes in teacher instruction, contributing to higher student achievement. These Strategies and Actions would help increase the interactions for STEM teachers with other professionals, either in the same or in neighboring districts, thus increasing the likeliness of effective implementation of the STEM curriculum and the removal of potential barriers that the single STEM teacher faces.

Implications for community relationships will foster mutually beneficial partnerships. School districts with strategic goals that align with the work force ultimately benefit the community at large, as the public school district contributes in creating productive and responsible citizens who potentially live and work within the community. As a public school district creates and participates in the STEM ecosystem, more opportunities arise for students to see their parents working in STEM jobs, thus be more naturally inclined to take STEM courses while at school.

The implications for a district-wide K-8 STEM program concerning parents and families include an increase in parental involvement and more positive school-home interactions. As part of Strategies and Actions, the researcher advocates for evening events such as family STEM nights where parents can participate in STEM activities along with their child. Documented benefits for participants in informal STEM programs include an increase in positive attitudes and interest in science and technology (Hayden et al., 2011) and a stronger understanding of STEM concepts and processes (McGee-Brown et al., 2003). The researcher would work with teachers and community members to develop a plan for all families to engage in STEM-related activities during an evening event, such as Family STEM night, and where parents and students participate together. Such activities result in increased parental involvement in their child's educational process as well as positive school-home interactions.

Conclusion

In conclusion, these policy recommendations provide the catalyst for public school districts to provide equitable integrated STEM opportunities for all K-12 students. The intent of this policy is to bring collective understanding of the urgent need of K-12 STEM education for all students so that schools are able to train students and prepare them for the demands of the workforce. As demonstrated with the educational, economic, social, political, legal, moral, and ethical analysis, K-12 STEM education should be a priority within public education, for our nation's well-being, economic health, and innovation depend on our ability to adapt in this ever-changing world.

CHAPTER EIGHT

CONCLUSION

There has been tremendous pressure on educators to prepare all students for the today's world and for careers that need critical thinkers and problem-solvers. While teaching all students to read, write, and perform mathematical calculations remains important, we must also expose them to a curriculum that helps them develop their critical-thinking and problem-solving skills in collaboration with their peers. STEM education has become important in worldwide discussions in the last three decades as countries try to meet the technological demands of maintaining larger populations and changing industries. The needs of industry demand workforce development; thus student acquisition of STEM skills is crucial as these skills will be required for a majority if not all jobs in the next few years. STEM education brings relevance to student learning and allows students to apply the content they learn to find authentic solutions to real-world problems. It is imperative that school leaders, district administrators, and all educators work collaboratively to ensure that all students receive a high quality STEM program from pre-Kindergarten to high school, one where students are challenged to work collaboratively with their peers in supportive learning environments. These programs also teach them life-long skills of critical thinking, collaboration, and problem-solving.

Discussion

Through the study's evaluation, the researcher has sought to find the impact of a K-8 STEM program on high school course selection, and on mathematics, science, and STEM grades of high school students. The study's findings suggest that participating in a

STEM program such as PLTW in middle school had negligible impact on the number of STEM and advanced mathematics and science coursework taken by students in high school. However, the data analysis revealed that ELL students were more likely to take STEM coursework in high school as compared to non-ELL students. Additionally, the data analysis revealed that students exposed to a quarter or a semester of PLTW coursework in middle school earned higher grades in mathematics and science in high school.

In the proposed recommendations, I advocate for the creation of a policy that provides all students the opportunity to participate in STEM programs from pre-Kindergarten to high school. I also recommended defined strategies and actions needed for organizational change to maximize the STEM impact on student achievement. As outlined and discussed throughout this study, the prevalent issues identified by the data collection and analysis include (1) the need for a STEM program for all students, (2) continuous job-embedded professional development for all PLTW staff, (3) activities that further the mathematics, science, and STEM career awareness for all students, and (4) involvement of the community and families in engagement programs, such as STEM night.

This process addressed my initial goal of deepening our understanding the impacts of a K-8 STEM program on STEM and advanced mathematics and science course selection choices for high school students, and their subsequent grades for these courses. The overall findings of the study demonstrate a positive impact on student achievement outcomes in mathematics and science for high school students. The findings also suggest that ELLs were more likely to take STEM coursework in high school if they had taken STEM courses in middle school. The findings also uncovered barriers and challenges in the implementation of PLTW, and suggest a need for more collaboration between members of PLTW staff in implementing PLTW coursework and with the high school, both within the district as well as with neighboring elementary districts.

An additional but overarching finding was the lack of state-level policy for STEM education for all students in the state. Because there is no present mandate for STEM education, public school districts in the researcher's state are not required to offer any STEM opportunities to its students.

The researcher also proposed specific strategies and actions to address the barriers and challenges mentioned above. These five strategies outlined a comprehensive organizational change plan for an effective implementation of the STEM education program in the researcher's district. The strategies sought to (1) increase the amount of hours that elementary students receive PLTW curriculum at the elementary level; (2) provide opportunities for elementary students to participate in after school STEM clubs; (3) increase mathematics, science, and STEM career awareness with career fairs for later elementary and middle school students; (4) engage various stakeholders and community members at evening events such as family STEM nights; and (5) plan for continuous job-embedded professional development opportunities for PLTW staff in the district.

These strategies and actions, will strengthen the proposed STEM policy of creating a state-level policy mandate that ensures all K-12 students in public school districts have equitable access to STEM coursework. This STEM policy would serve as a catalyst to bring awareness to the purpose and importance of STEM education. It will also create accountability for public school districts to prepare students for the needs of the U.S. workforce. Along with the STEM policy, the strategies and action plans will provide a framework for change that helps to guide a successful STEM implementation. This STEM policy will also help to address the issues outlined in the culture, context, conditions, and competencies of my K-8 PLTW evaluation.

Leadership Lessons

Through this program evaluation, I learned two important leadership lessons. First, the importance of investing in human capital; any program is as good as the teachers who deliver the instruction. It is critical to ensure that staff who deliver STEM programs have received appropriate training, are able to collaborate with their counterparts, and share ideas and engage in job-embedded professional development opportunities. According to Murphy and Torre (2014), effective collaboration is mutual, purpose-driven work, learning centered, and focused on the instructional. It is driven by the tenets to evidence-based inquiry and directed toward improved teacher practice and student achievement via teacher learning. Providing teachers with the time to collaborate with their counterparts allows them to problem-solve issues, reflect on their practice and share best practices with each other. However, collaboration requires time and it is important for instructional leaders to plan the master schedule so as to provide STEM teachers with collaboration time. Through collaboration, the PLTW teachers have the opportunity to learn, understand, and refine the PLTW curriculum to meet the needs of their students. They have individually bought into the strategic implementation of the program.

Another leadership lesson involves the importance of looking for opportunities to expand a program based on changes in staffing, such as retirements and selecting staff that result in a better fit between the needs of the students and the STEM expertise of the teachers. When PLTW was initiated at the middle school of this study, students had access to only one quarter of PLTW coursework in 7th and 8th grades. Staff retirements had recently allowed the district to expand the program and bring in additional PLTW courses, so that students could receive twice the amount of PLTW coursework in a year. When the program was expanded to the intermediate building, the teachers selected had the teaching skills and natural enthusiasm for STEM, thus were observed to bring that these into the classroom to pass on to their students. The careful assignment of teachers to classes is unquestionably a critical leadership function (Blase & Kirby, 2009, p. 68). Teachers are at the forefront of the implementation, and without teacher efficacy such initiatives are likely to be unsuccessful. Therefore, school leaders leading change must consider the implications of efficacy on the overall success of a program and on student achievement.

Conclusion

President Obama's campaign Educate to Innovate initiated the motivation to help American youth achieve globally at the highest levels in STEM disciplines, but the flames must now be fanned. It is critical for public school educators to collaborate with the federal government, businesses, higher education, as well as nonprofit groups, to provide American youth with STEM exposure through programs such as PLTW. Every pre-K to 12th grade student should have equitable access to a high-quality STEM education that prepares them for the job market and for careers in this field. In light of the finding of this study that indicated students with only some exposure to STEM in middle school were less likely to take advanced coursework in mathematics, science, and STEM, the researcher would like to recommend that the impact of a K-8 STEM program be considered by evaluating the courses selected by students with exposure to PLTW coursework from Kindergarten. Since the analysis of the data indicated that PLTW coursework has an impact on STEM courses selected by ELL students, it is important to continue to provide such opportunities to ELL students with the objective of increasing their perseverance and motivation to take up careers in STEM. According to National Center of Education Statistics (2021), only14% of STEM degrees were conferred to Hispanics in 2019-20. Culturally and linguistically diverse students have few role models in STEM careers, hence, providing them with opportunities to explore STEM activities in elementary school is critical to ensuring that these students develop the enthusiasm and perseverance needed to continue taking STEM coursework in high school and ultimately succeed in STEM careers.

According to the Elementary and Secondary STEM education report recently released by the NSB (2021), K-12 STEM education plays a critical role in introducing students to STEM topics, preparing them to enter STEM majors and STEM jobs. The opportunity for America to achieve high ranking status in STEM disciplines in labor markets lies in the hands of our youth; thus we as their educators in public school districts must work to provide every student in America with equitable access to a STEM program from pre-Kindergarten to 12th grade. If we focus our efforts to make every improvement to our students' STEM education, our youth will not only excel but thrive in the global economy.

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APPENDIX A

As-Is Diagram

Context	Culture	Conditions	Competencies
K-8 elementary district - 5 buildings, 1 pre-K building, 2 K-3 buildings, 1 4-5 building and 1 6-8 building PLTW was introduced to ensure that our students were able to gain critical thinking, analytical, problem solving, communicative, and collaborative skills that would be essential for them to survive in today's workforce. PLTW staff receive materials required for students Provides opportunities for students to collaborate with each other The only district in the area that uses PLTW for K-8 STEM	PLTW staff believe that PLTW increases student engagement PLTW staff believe that PLTW positively impacts collaboration and problem-solving skills in students All students can be successful in PLTW coursework with necessary supports All staff work with PLTW staff to make up any missed PLTW class time.	PLTW staff have a PLTW classroom at each building PLTW classrooms have furniture that lends itself to the curriculum (storage areas etc) PLTW staff have access to the required materials New PLTW staff are trained. PLTW staff have time to organize materials PLTW staff have time to collaborate with PLTW staff from other buildings	PLTW staff have been trained. PLTW staff ensure that the curriculum is developmentally appropriate for K-8 students. PLTW staff have time allocated for vertical articulation PLTW specials have fixed instructional time in the schedule Superintendent and the Board of Education supports the program

APPENDIX B

To-Be Diagram

Context	Culture	Conditions	Competencies
- One pre-K building, two K-4 buildings, one 5-8 building -All K-8 students can elect to take PLTW coursework - Pre-K students also receive PLTW coursework - K-4 students receive PLTW more than once a week. -	- All staff believe that PLTW positively impacts collaboration and problem-solving skills in students - All students are successful in PLTW coursework with necessary supports - All staff visit the PLTW classroom frequently to see students designing a robot or completing a challenge.	- PLTW staff have a PLTW classroom at each building - PLTW classrooms have furniture that lends itself to the curriculum (storage areas etc) - PLTW staff have access to the required materials - New PLTW staff are trained. - PLTW staff have time to organize materials - PLTW staff have to collaborate with each PLTW staff from other buildings	- PLTW staff know the district vision for PLTW - Coaching of PLTW staff - Future Superintendents continue to support the program - PLTW staff collaborate with staff from neighboring elementary districts who also use PLTW coursework. - PLTW staff collaborates with high school staff (vertical articulation)

APPENDIX C

Strategies and Actions Diagram

Strategies	Actions
Increase in the amount of time that elementary students receive STEM coursework at the elementary and middle school level	- Collaborate with the Principals of the elementary and middle school to develop a schedule which allows for an increase in PLTW time. - Collaborate with the Principal of the middle school to determine how all students can have the choice to take PLTW and are not limited by schedule conflicts. - Communicate the plan to staff as well as the community.
Provide opportunities for elementary students to participate in after school STEM clubs	- Obtain funding through federal grants to provide all elementary students with an after-school STEM club where students can develop a scientific mindset and work to find scientific solutions to various real-life issues. - Obtain funding for a Pre-K STEM program - Communicate the plan to staff as well as the community.
Increasing mathematics, science, and STEM Career Awareness by organizing Career Fairs at the middle school	- Work with teachers to plan a Career fair for all students - Invite alumni and community members to present to students - Communicate with families, students and community members.
Engaging all stakeholders & community members	- Work with teachers to plan a STEM evening for all families. - Purchase materials needed for the family STEM evening. - Invite local community members to participate in the event - Communicate with families, students and community members.
Increased Professional development for PLTW staff	- Communicate the plan with staff with the objective of obtaining their buy-in. - Work with the administrators of neighboring districts to schedule time for PLTW staff to collaborate with each other as well as observe each other’s classrooms. - Obtain resources such as substitutes so that staff have the time to observe each other's classrooms. - Schedule coaching cycles with PLTW trainers