ABSTRACT

The “M” in STEM:
The Integration of High School Mathematics Standards in STEM Education

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This study is a curriculum analysis of a national high school STEM curriculum and the Texas state standards for high school mathematics. The STEM curriculum was analyzed to find the Algebra I, Algebra II, Geometry, and Precalculus concepts that were included and to determine if the high school mathematics was the primary or secondary focus of the activity. The findings suggested explicit connections to high school mathematics concepts, but many connections to middle school mathematics as well. This curriculum developed Algebra I and Geometry concepts and many high school level mathematical skills. For the activities that included high school mathematics, 56% had these concepts as the primary focus and 44% had the high school mathematics as the secondary focus. Implications and future studies are discussed, including the alignment of other STEM curricula, how the curriculum is implemented in the classroom, and when students should take STEM courses in high school.

The "M" in STEM: The Integration of High School Mathematics Standards in STEM Education

by

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CHAPTER ONE

Introduction of STEM Education

Introduction

Science, Technology, Engineering, and Mathematics (STEM) education has grown in popularity in recent years. Those who push for STEM education hope to spark students' interest in STEM careers but STEM education is ultimately driven by economic and vocational goals. Blackley and Howell (2015) noted this by stating, "STEM has been much heralded as a solution or preventative measure to avoid economic downturns in the future" (p 103). The rationales for STEM education include a change in workforce patterns and downward economic trends (Williams, 2011).

Both President George W. Bush and President Barack Obama passed initiatives to improve mathematics and science education in America, including the American Competitiveness Initiative, Educate to Innovate campaign, and Race to the Top (Handelsman & Smith, 2016; Mohr-Schroeder, Cavalcanti & Blyman, 2015; The White House, 2006). As part of the launch of the Educate to Innovate campaign, President Obama believed "reaffirming and strengthening America's role as the world's engine of scientific discovery and technological innovation is essential to meeting the challenges of this century" (The White House, 2009). More recently, the Federal Government has presented a 5-year strategic plan for STEM education with goals to build strong foundations of STEM literacy, increase diversity and equity in STEM, and prepare the future STEM workforce (Committee on STEM Education, 2018).

Although STEM education has received much attention in recent years, it originated decades ago. Historical events such as Sputnik and World War II pushed STEM education to grow in the United States (White, 2014). In World War II, scientists, engineers, and mathematicians worked together with the military to produce innovative products to ultimately win the war. Sputnik led to the creation of National Aeronautics and Space Administration (NASA), which has been responsible for many STEM education initiatives. STEM education was developed by the National Science Foundation (NSF) in the 1990's and was originally known as Science, Mathematics, Engineering, and Technology (SMET) (Sanders, 2008; White, 2014). The acronym was eventually changed to STEM after it received negative feedback from the original acronym, but many still did not know its meaning (Sanders, 2008). The goal of this education initiative "was to provide all students with critical thinking skills that would make them creative problem solvers and ultimately more marketable in the workforce" (White, 2014, p. 2). At first, it was interpreted as four separate disciplines, science, technology, engineering, and mathematics. It was not until 2007 that the four disciplines were integrated, changing the acronym from S.T.E.M. to integrated STEM education. (Blackley & Howell, 2015). According to Krajcik and Delen (2017), an integrated approach to STEM education better exemplifies how scientists and engineers work in the real world. Because the real world is not organized like the disciplines in school, bridges need to be built to prepare students for life outside of school (Perkins, 2014).

Defining STEM Education

Although the acronym is consistent, there are still inconsistent definitions and interpretations of STEM education. This leads to ambiguity for teachers when trying to implement this type of learning in the classroom (Blackley & Howell, 2015; Kelley & Knowles, 2016). In a joint position statement by The National Council of Supervisors of Mathematics (NCSM) and the National Council of Teachers of Mathematics (NCTM) (2018), it was noted that "underlying the confusion and inconsistency in school STEM programs is the lack of a clear vision of what STEM is and what STEM programs should include" (p. 2). Because STEM education developed from a non-educational rationale, the absence of a strong educational rationale inhibits its development (Williams, 2011). Blackley and Howell (2015) suggested there is a difference in STEM education between educational and vocational settings because STEM education is typically enacted as S.t.e.M in schools and is enacted as s.T.E.m outside of schools. This meant that in schools, the focus was put on learning science and mathematics; in the vocational setting, technology and engineering received a greater focus with science and mathematics being supporting roles.

Different interpretations and definitions of STEM education are found throughout research. Sanders (2008) defined STEM education as the teaching and learning between at least two of the STEM disciplines or between a STEM discipline and another non-STEM discipline. Other definitions include the effort to combine some of the STEM disciplines into a class unit or lesson and teaching STEM content in an authentic context to foster connections between the disciplines (Kelley & Knowles, 2016). Capraro and Nite (2014) believed problem-based learning and real-world applications are both indicators of STEM education. *Project Lead The Way (PLTW)*, a national STEM curriculum, emphasizes the importance of real-world learning experiences and developing key skills, such as problem solving and critical thinking, that will help students be successful in future careers (*PLTW*, 2019b). For this study, STEM education will be defined as the combining of at least two of the STEM disciplines in a unit or lesson with a goal to make connections between disciplines and to the real world. This study will focus on the "M" in STEM, or how the mathematics component is incorporated and integrated in STEM education. Is the mathematics component the primary or secondary focus? Is there a greater focus on developing mathematical concepts and skills or applying them?

Benefits of STEM Education

Regardless of the interpretation, researchers have suggested potential benefits and outcomes of STEM education. First, this type of learning "supports a constructivist pedagogy, authentic learning, and student-centeredness" (Blackley & Howell, 2015, p. 108). Because STEM education typically includes project-based learning and real-world applications, students can develop critical thinking skills, problem solving skills, and increase retention through this type of education (NCSM & NCTM, 2018; Stohlmann, Moore, & Roehrig, 2012). Stohlmann and colleagues noted "several benefits of STEM education include making students better problem solvers, innovators, inventors, self-reliant, logical thinkers, and technologically literate" (p. 29).

STEM education also allows students to extend their learning by connecting and applying the concepts to different disciplines. Kelley and Knowles (2016) suggested that "instead of teaching content and skills and hoping students will see the connections to real-life application, an integrated approach seeks to locate connections between STEM disciplines and provide a relevant context for learning the content" (p. 3). Integrated STEM activities include big ideas that are interrelated between the different subject areas, which allow for connections to be made between disciplines (Stohlmann et al., 2012). In their joint position statement, NCSM and NCTM (2018) see STEM education as a way to "connect and extend mathematics and science and incorporate engineering and technology to address relevant problems and tasks arising from life in the 21st century" (p. 2). The real-world applications aspect of these learning experiences help prepare students for post-secondary education and allow them to see what STEM professionals do in their jobs (Capraro, Capraro, & Morgan, 2013). By making connections, students are able to gain a deeper conceptual understanding of what they are learning. Integrated STEM education lays the foundation for understanding, problem solving, and innovation (Krajcik & Delen, 2017). Basham and Marino (2013) believed STEM learning experiences encourage students to move beyond low level cognitive tasks, such as memorization and repetition, to build a strong foundational understanding of the content. Overall, STEM education has been shown to have a positive impact on students' attitudes towards school, motivation, and achievement (Stohlmann et al., 2012).

Challenges of STEM Education

Although there are many potential benefits and outcomes, STEM education has its challenges as well. The current structure of curriculum and schools can be a barrier to STEM education (Blackley & Howell, 2015). Williams (2011) addressed the barrier in this way:

> It would require a very radical curriculum approach to take out all the time in the school day that is occupied by science, technology, and mathematics, and put back a sequence of learning activities that would represent an integrated approach to achieve the essential skills and knowledge of these three subjects, plus engineering. Support for a STEM approach to curriculum design must proceed with the understanding that school curriculum structures are very resistant to change. (p. 27)

In addition, the environment of standardized testing in schools today inhibits the progress of STEM education. When so much emphasis is put on standardized testing, teachers are forced to give priority to the tested subjects and content (Blackley & Howell, 2015). Regarding this, Blackley and Howell (2015) believed "the challenge is to reassure teachers that embracing integrated STEM education and preparation for standardized tests are not mutually exclusive" (p. 110).

Another challenge facing STEM education is the knowledge and preparation of teachers. Secondary teachers tend to specialize in a certain content area, so it is difficult for them to become experts in each of the STEM disciplines (Williams, 2011). Also, teachers may have gaps in their own content knowledge, so asking them to learn and teach another subject may create even more knowledge gaps for them and their students (NCSM & NCTM, 2018; Stohlmann et al., 2012). Without having an in-depth content knowledge, it is difficult to ensure connections between disciplines are explicit for the students. When the connections are implicit, students may miss them, which would not benefit the learning goals of STEM education (Honey, Pearson, & Schweingruber, 2014; Kelley & Knowles, 2016).

Lastly, there are concerns of an inequitable representation of each of the disciplines in STEM education. Because it is difficult to do justice to all four disciplines, there is a fear that one of them is getting overshadowed (English, 2015; Williams, 2011).

This leads to the concerns that mathematics is being overshadowed in STEM education. Chapter 2 provides an expanded discussion of the literature with the rationale for this study and the research questions guiding the study.

CHAPTER TWO

Mathematics and STEM Education

Mathematics is utilized in solving STEM problems, but it "goes beyond serving as a tool for science, engineering, and technology" (NCSM & NCTM, 2018, p. 3). STEM education has the ability to connect mathematics to real-world, authentic tasks, but the importance of developing mathematical skills can often be overshadowed. In order for the goals of STEM education to be met, Stohlmann (2018) suggested a need for an increased focus on ways to successfully implement integrated STEM education with an explicit focus on mathematics. Using mathematics solely as a tool does not necessarily help high school students understand grade level mathematics topics (Walker, 2017). Picha (2018) indicated, "Integrating mathematics isn't an easy thing to do well. Often it is math that is put in the passenger seat to lightly serve another subject, project, or task" (para. 5).

Because high school mathematics is a difficult discipline to integrate, another issue is that the mathematics included in STEM education may not address the intended level of mathematics. In their joint position statement, NCSM and NCTM (2018) believed that the mathematics included in STEM programs should include standards-based content for the intended grade levels. This is a difficult task to achieve for high schools due to the higher-level concepts needing to be integrated. Measurement, data analysis, geometry, and linear and quadratic equations are common topics included in high school STEM education, but there is a need to expand the mathematical content beyond these concepts (Stohlmann, 2018). Overall, “Mathematics needs to be elevated to the peaks of the STEM mountain range, and we must ensure it remains there with its contributions recognized and lauded” (English, 2015, p. 14).

Although STEM education has the opportunity to spark students’ interest, it should increase achievement in each discipline as well. Engineering, science, and technology are all avenues that can be utilized to strengthen students’ mathematical skills and deepen their conceptual understanding, but it is counterproductive to STEM education when unproductive mathematical practices are integrated (Picha, 2018). This is when the potential benefits of mathematics in STEM education are put in danger. Even if a student develops interest in STEM careers, they will not be successful as a STEM major in college if they are unable to do the mathematics. Picha (2018) believed decreasing math anxiety should be a goal of STEM education. However, one concern “comes from the realization that STEM education, the very thing that should be combatting this problem [math anxiety], seems to be focused on everything but the actual barrier” (para. 8). Beilock and Maloney (2015) believed addressing math anxiety would be beneficial to STEM education by increasing involvement and achievement. They noted improving the mathematics that is taught only addresses part of the issue. Their research suggests math anxiety causes students to avoid math-related careers. Thus, Beilock and Maloney believe STEM education should be designed to encourage the students with math anxiety, rather than motivate the students who already enjoy mathematics and science. STEM education should work towards improving achievement in the different disciplines for all students.

Effects on Mathematics Achievement

The goal of effective STEM education is to achieve both the benefits of STEM education and increase mathematics achievement. However, there is a disconnect between the potential benefits of STEM education and mathematics achievement. There is evidence that learning with integrated content allows students to gain a stronger conceptual understanding of the material (Honey et al., 2014). However, different factors including students' prior knowledge and achievement, levels of integration, and the outcomes that are measured can cause the effects to differ. Research has shown conflicting results regarding the relationship between STEM education and student achievement.

Bottoms and Uhn (2007) compared students enrolled in *Project Lead The Way (PLTW)* Engineering courses with *High Schools That Work (HSTW)* career/technical students. The engineering courses are part of the *PLTW* STEM curriculum for high school. In these courses, students assume the role of an engineer and include hands-on, real life experience (*PLTW*, 2019a). The *HSTW* program supports states to transform their public high schools by using research-proven strategies to raise student achievement (Southern Regional Education Board, n.d.). In this study, findings indicated that students who had completed at least three *PLTW* courses showed significant growth in achievement on the National Assessment of Educational Progress (NAEP) mathematics and science tests. The students in *PLTW* courses also scored higher than the *HSTW* career/technical students.

In contrast, Tran and Nathan (2010) investigated the effects STEM curriculum had on students' mathematics achievement. The study included 140 high schoolers; 70 of the students were enrolled in *PLTW* engineering courses, and 70 were not. The eighth and tenth grade NAEP mathematics scores of these students were analyzed for changes in mathematics achievement. Overall, the research suggested gains in mathematics achievement for all the students. However, the students in the *PLTW* classes showed smaller achievement gains than their peers who were not enrolled in these courses. With all the potential benefits of STEM education, the question remains: Why are all students in STEM education not increasing their mathematics achievement? Perhaps one reason relates to the topics and academic standards addressed in the curriculum.

STEM Curricula Alignment with Standards

Prior research has examined the relationship between STEM curricula and academic standards. In their study, Capraro and Nite (2014) analyzed four documents of national and state standards for indicators of STEM integration in middle school. The researchers aimed to see how well the current standards aligned with STEM integration and encouraged this type of learning. The NCTM *Principles and Standards for School Mathematics,* the *Texas Essential Knowledge and Skills (TEKS),* the *Common Core State Standards for Mathematics (CCSSM),* and the *Texas College and Career Readiness Standards (TCCRS)* were examined in the study. Indicators of STEM integration were coded, including real-world application, use of technology, and connecting mathematics to other domains. The results showed that the NCTM standards (NCTM, 2000) for middle school included the most obvious indicators of STEM integration. The indicators for these standards included many references to technology such as graphing calculators and computer software. The Data Analysis and Probability Standard suggested collaboration between mathematics and science teachers for real-life data collection opportunities. The *TEKS* for grades 5, 6, 7, and 8 (TEA, 2014) were analyzed and were relatively strong in STEM language, as they encouraged real-world applications. The process standards in the *TEKS* included the most explicit connections. The *CCSSM* (NGA Center, 2010) did not include any STEM integration indicators in the content strands, only in the Mathematical Practices. However, many of the example problems used a science context which encouraged STEM integration. Finally, the *TCCRS* (THECB, 2014) had the strongest integration between subjects. By focusing on middle school, this study still leaves questions about how the high school standards align with STEM integration.

The comparative study of curriculum organization conducted by Nathan, Tran, Phelps, and Prevost (2008) examined *PLTW Engineering* curriculum and academic algebra, geometry, and trigonometry textbook curricula to examine which had a stronger alignment with the high school NCTM standards (NCTM, 2000). The goal was to "identify potential points of synergy between the curriculum materials used in pre-engineering courses and the content covered in their academically oriented counterparts" (Nathan et al., 2008, p. 3). The study also examined how the different curricula support students' mathematical skills and understanding that would help prepare them for the future. This study looked at the three foundation courses of the *PLTW Engineering* curriculum, *Principles of Engineering, Introduction to Engineering Design,* and *Digital Electronics*, as they are the most widely taken *PLTW Engineering* courses. The analysis included the number of mathematics standards addressed in each course, as well as the relative emphasis of the standards over time. The results indicated that the *PLTW* curriculum covered far fewer standards-based mathematics topics compared to the academic curriculum. This led to the researchers posing questions about the type of learning experience that would occur when the two curricula were integrated. They also suggested that there is room for improvement between academic and vocational education courses. This study used the NCTM (2000) standards but did not include a comparison to state standards.

Lastly, Stohlmann and colleagues (2011) observed and learned what challenges and benefits middle school teachers and students experienced while using *PLTW Gateway to Technology* curriculum. One aspect of this study compared middle school *PLTW* curriculum to the Minnesota middle school mathematics and science state standards to find implicit and explicit connections between the curriculum and the standards. *PLTW* has a document indicating the alignment of their curriculum to the national standards. The researchers noted that the national standards are broader than most state standards, so the alignment may not be as strong as it appears. For this study, the researchers read the *PLTW* lessons looking for instances of mathematics and science concepts, then mapped them to the Minnesota state standards for sixth to eighth grade to check their alignment. Stohlmann and colleagues found that "*PLTW* did not have mathematics integrated explicitly in the curriculum, which may have impacted its ability to improve students' mathematical knowledge" (p. 4). They also noted that only three of the Minnesota mathematics standards were explicitly mapped to the *PLTW* lessons. The implicit connections required teachers to restructure the lessons, so the students would make the necessary mathematics connections. This study identifies a misalignment between STEM curriculum and state standards, but it does not answer questions about the alignment with high school standards because they were looking at middle school curriculum and standards. These studies and the issues they raise related to STEM curricula and standards alignment lead to the rationale for the current study.

Rationale

This study investigated the integration of high school mathematics in STEM curriculum. STEM education has the potential to allow students to make connections between concepts and grow in their mathematical understanding (Kelly & Knowles, 2016; Stohlmann et al., 2012) Because the review of literature shows a gap in research analyzing high school mathematics with STEM education, there is a need to find the disconnect between STEM education and mathematics achievement. One step is to compare the alignment of STEM curriculum and high school mathematics standards. This study examined what grade level of mathematics concepts are included in a high school STEM curriculum and identified whether the mathematics concepts and skills were a primary or secondary focus of the lesson. Some current STEM curricula are aligned to national standards, but as Stohlmann and colleagues (2011) noted, the national mathematics standards are much broader than the state standards. "Thus, the integration of the STEM disciplines in the curriculum may not be as strong as the national standards listed make it appear" (Stohlmann et al., 2011, p. 4). While there are several different high school STEM curricula, *Project Lead The Way (PLTW)* was chosen for this study in order to explore research and future questions regarding this curriculum.

This study will seek to answer the following questions:

1. In what ways does *Project Lead The Way (PLTW)* as a high school STEM curriculum align to state high school mathematics standards in Texas?
2. What percentage of the alignment has high school mathematics as the primary focus and what percentage has it as a secondary focus?

STEM Education in Texas

According to the Texas Education Agency (TEA), Texas has more than 8,000 schools and educates approximately 5 million students (TEA, 2016). The *Texas Essential Knowledge and Skills (TEKS)* are used as the teaching standards in the state. Students begin taking the State of Texas Assessments of Academic Readiness (STAAR) test in third grade. In high school, students are required to pass the End of Course (EOC) exams for Algebra 1, Biology, English I, English II, and U.S. History. In 2018, only 55% of student scores were on or above grade level for the Algebra I EOC (TEA, 2018a). When looking at scores for all grades of mathematics, this number fell to 50%. This suggests there is still room for improvement for students in mathematics.

To aid in this, Texas has put an emphasis on STEM education in recent years by opening Texas Science, Technology, Engineering, and Mathematics (T-STEM) academies. According to TEA, there are 94 designated STEM academies and 9 planning campuses in Texas (TEA, 2018b). These schools are "rigorous secondary schools focusing on improving instruction and academic performance in science and mathematics-related subjects and increasing the number of students who study and enter STEM careers" (TEA, 2018b). Academies may focus on STEM education, but they are not the only Texas schools that offer this type of education. Some Texas public middle and high schools offer STEM courses as well (Educate Texas, 2018). The focus on STEM education is a step in the right direction, but there is still work to be done to increase student achievement in mathematics. STEM education in Texas is important as the state is expected to have the nation's second-highest percentage of future STEM job opportunities (Educate Texas, 2018). Texas may have put an emphasis on STEM education, but there is a lack of research on how the curricula being used in Texas school align to their academic standards.

CHAPTER THREE

Methodology

This study is a curriculum analysis of STEM curriculum and the Texas state mathematics standards. It examined how well a high school STEM curriculum aligns with the state standards for mathematics. *Project Lead The Way (PLTW)* gave permission for their curriculum to be used in this study (See Appendix A). Because Stohlmann et al. (2011) found that the *PLTW* curriculum *Gateway to Technology* did not align with the middle school Minnesota state standards, this study was designed to determine if there was better alignment with the Texas state mathematics standards or if a similar misalignment was found. Capraro and Nite (2014) found that the *TEKS* for middle school mathematics had many indicators of potential STEM integration, but they did not examine how well STEM curriculum fits into these potential modes of integration. Nathan et al. (2008) found that the *PLTW* courses did not cover as many mathematics standards as traditional academic curricula. They did not however examine any state standards in their study.

For this study, the *Texas Essential Knowledge and Skills (TEKS;* TEA, 2014) were used for comparison. The newest version of the *TEKS* was adopted in 2012 and is separated by subject areas for high school. The *TEKS* are organized by grade level for the earlier grades. The standards for Algebra I, Algebra II, Geometry, and Precalculus were used in this study.

Introduction to Engineering Design, a course from the *PLTW Engineering* curriculum was used in this study to compare to the *TEKS*. *Project Lead The Way* is a national STEM curriculum for all levels of students. The curriculum as a whole "centers on hands-on, real-world activities, projects, and problems that help students understand how the knowledge and skills they develop in the classroom may be applied in everyday life" (*PLTW*, 2019b, para. 2). Engineering topics are connected to the mathematics and science concepts students learn in school. The *PLTW* curriculum aligns to the common core standards for the different subjects. The three foundation courses in *PLTW Engineering* are the most widely taken courses in the engineering curriculum. The foundation course *Introduction to Engineering Design (IED)* was analyzed in this study. The description for *IED* indicates that "Students dig deep into the engineering design process, applying math, science, and engineering standards to hands-on projects like designing a new toy or improving an existing product" (*PLTW*, 2019a, para. 4). In the 2017-2018 school year, there were 172 districts in Texas that utilized the *PLTW* curriculum (Abbitt, 2018). This accounts for approximately 17% of Texas public school districts, as there are 1,031 total districts. This curriculum was chosen because of its popularity and usage in Texas as well as nationally.

This study followed a methodology similar to the study by Stohlmann et al. (2011) that mapped the *PLTW* curriculum to the state mathematics standards. Quantitative methods were used to examine the alignment between *IED* and the *TEKS.* There were 10 units in the *IED* curriculum with 58 total activities and 8 projects. All were analyzed the same and hereafter will be referred to as activities. To answer the research questions, each activity in the *IED* curriculum was analyzed to identify the mathematics topics that were included. Once the mathematics topics were identified, each one was mapped to the *TEKS* to identify which grade level or course included that concept. The standards alignment also showed if the mathematics topics were a primary or secondary focus in the activity and if the activity aimed to develop the mathematical skill or concept, or only apply it in an engineering context. The data were organized in an Excel spreadsheet, and tables were created to display the findings. A doctoral student in the same department as the researcher reviewed a unit with 11 activities in the standards alignment data to ensure accuracy. This unit included the most activities with high school mathematics. The doctoral student examined the spreadsheet for this unit developed by the researcher and checked that each standard marked was accurate for each activity. The concepts developed were also discussed and agreed upon, thus confirming alignment.

The number of standards addressed in each high school course were totaled, as well as the frequency of each standard. The *TEKS* have the Knowledge and Skills (K&S) statement listed as the number and the Student Expectations (SE) lettered. The number of K&S statements and SEs addressed in each high school course were also totaled to see how much of each mathematics course was included in the *IED* curriculum. The total middle school connections were also noted, but because the study focused on high school, these connections were not analyzed in depth but general details of findings are reported.

Once the *TEKS* included in the curriculum were identified, they were analyzed to determine if the high school mathematics topics were the primary or secondary focus in the activity. To be the primary focus, the high school mathematics had to be a main focus of the activity. There may have also been a science or engineering concept in the activity, but the mathematics still played a main role. The topics that were a secondary focus were minor pieces that assisted in accomplishing the main focus of the activity. Along with this, it was noted if the activity focused on developing a mathematical concept, developing a skill or only applying a skill. Skills are the rote procedures that do not require a deep understanding of the mathematics, such as plugging numbers into formulas. Concepts give meaning to the mathematics and allow the skills to be transferrable. For example, the skill of finding the slope of a line is using the rise over run formula. The concept however develops the understanding of the meaning of the slope of a line and what it represents. If the activity explicitly explained the skill and included ways to practice, it was marked as developing the skill. If there was not an explanation or practice and students had to already know when to use the skill, it was marked as applying. Skills that were used in multiple activities were only counted once. The concepts that were developed were used in multiple situations and used skills to support the understanding. The results are provided in Chapter Four, Analysis of Data.

CHAPTER FOUR

Analysis of Data

This study sought to explore how the *Project Lead The Way (PLTW)* course *Introduction to Engineering Design (IED)* aligned to the high school mathematics *TEKS*. This study aimed to answer the following research questions:

1. In what ways does *Project Lead The Way (PLTW)* as a high school STEM curriculum align to state high school mathematics standards in Texas?
2. What percentage of the alignment has high school mathematics as the primary focus versus the secondary focus?

For this study, basic arithmetic skills of addition, subtraction, multiplication, and division were not included in the standards alignment because it was assumed high school students possessed these skills. The mathematical process standards were also not included because they are the same for each grade level. These process standards were addressed throughout the *PLTW* course, but because this study examined each mathematics course separately, these standards were not specific to one course or grade level. For example, one Student Expectation (SE) in the mathematical process standards indicates "the student is expected to apply mathematics to problems arising in everyday life, society, and the workplace" (TEA, 2014). The *PLTW* course included many connections to this standard throughout the curriculum since it applies mathematics concepts to engineering. However, in order to focus on specific mathematical concepts and skills, this study only included the specific mathematics content standards.

High School Mathematics Connections

In *Introduction to Engineering Design (IED)*, 60% of the 10 total units included high school mathematics. However, only 16 activities out of 66 included high school mathematics, or approximately 24%. Table 4.1 shows the total number of connections between the *PLTW* course and the high school *TEKS* for each mathematics course. These connections represent each time a high school mathematics standard was addressed in the *IED* curriculum. These connections could be in the same activity, so the 14 connections for Algebra I does not necessarily mean connections were made in 14 different lessons. For example, the activity *Mathematical Modeling* addressed the concepts of domain and range, linear equations, correlation coefficient, slope and function notation. This counted as five connections to Algebra I *TEKS*. The standards could also be repeated, so the 14 in Algebra I does not necessarily mean 14 different standards.

Table 4.1

Total High School Mathematics Connections

High School Course	Number of Connections
Algebra I	14
Algebra II	4
Geometry	21
Precalculus	2

The topics included in the *IED* curriculum from each high school course are shown in Table 4.2 (See Appendix B for the full description of the included *TEKS*).

Table 4.2

High School Mathematics Topics Addressed in Introduction to Engineering Design Curriculum

Course	Topic
Algebra 1	• Domain and range • Linear functions • Slope • Correlation coefficient • Lines of fit • Laws of exponents • Function notation • Direct Variation
Algebra II	• Rational equations for real-world problems • Analyze data to select appropriate model (linear, quadratic, exponential) and make predictions
Geometry	• Fractional distance between two points • Trigonometric ratios • Effects of changing linear dimensions • Area of polygons and composite figures • Surface area of three-dimensional figures • Volume of three-dimensional figures • Theorems and properties of circles • Transformations
Precalculus	• Vectors

For high school, Algebra I and Geometry had the most connections in the *IED* curriculum. Because some of these connections were to the same standard, it was important to also look at the frequency of each standard's connections.

Frequency of TEKS

The Knowledge and Skills (K&S) statements in the *TEKS* give a broad description for the mathematical concept, while the Student Expectations (SE) specifically describe what the student is expected to do. For example, one of the K&S

statements for Geometry is "(11) Two-dimensional and three-dimensional figures. The student uses the process skills in the application of formulas to determine measures of two- and three-dimensional figures" (TEA, 2014). This K&S statement includes the following four SEs:

> (A) apply the formula for the area of regular polygons to solve problems using appropriate units of measure
>
> (B) determine the area of composite two-dimensional figures comprised of a combination of triangles, parallelograms, trapezoids, kites, regular polygons, or sectors of circles to solve problems using appropriate units of measure
>
> (C) apply the formulas for the total and lateral surface area of three-dimensional figures, including prisms, pyramids, cones, cylinders, spheres, and composite figures, to solve problems using appropriate units of measure
>
> (D) apply the formulas for the volume of three-dimensional figures, including prisms, pyramids, cones, cylinders, spheres, and composite figures, to solve problems using appropriate units of measure

There are between 2 and 14 SEs for each K&S statement in the *TEKS*. The *IED* curriculum was examined for the number of K&S statements and the number of SEs included for each high school mathematics course.

Table 4.3 shows the total number of Knowledge and Skills statements from the *TEKS* addressed in the *IED* curriculum for each high school course along with the total number of statements in the *TEKS* for that course. In order for the K&S statement to be included in the curriculum, at least one of the SEs for that K&S statement must be addressed in the curriculum. For example, there are 11 total K&S statements in the Algebra I *TEKS,* and the *IED* curriculum addressed 5 of them. This means approximately 45% of the total Algebra I K&S statements in the *TEKS* were addressed in the *IED* curriculum.

Table 4.3

Total Knowledge & Skills Statements from TEKS included in Introduction to Engineering Design Curriculum

High School Course	Number of Included K&S Statements	Total K&S Statements in *TEKS*	Percentage
Algebra I	5	11	45%
Algebra II	2	7	29%
Geometry	6	12	50%
Precalculus	1	4	25%

The number of Student Expectations included for each course are included in Table 4.4. Because the total number of connections to each high school course in Table 4.1 included connections to the same SE, this table shows how many SEs were addressed in each course of the *TEKS*. Similar to Table 4.3, this table displays the total number of SEs addressed in the *IED* curriculum and the total number of SEs for that course in the *TEKS.* For example, although there were 14 total connections to Algebra I in the curriculum, only 10 SEs were addressed showing some standards were addressed more than once. In contrast, Algebra II had four connections to *IED* and included four SEs, which means each connection in the curriculum was made to a different standard. Algebra I and Geometry included the most connections to the *IED* curriculum. Because there are 49 total SEs in the *TEKS* for Algebra I, the *IED* curriculum only addressed approximately 20% of the total SEs for this course. Geometry addressed approximately 24% of the total SEs in the Geometry *TEKS*.

Table 4.4

Total Student Expectations from TEKS included in Introduction to Engineering Design Curriculum

High School Course	Number of Included SEs	Total SEs in *TEKS*	Percentage
Algebra I	10	49	20%
Algebra II	4	48	8%
Geometry	10	42	24%
Precalculus	1	50	2%

The frequency of each specific SE included in Algebra I, Algebra II, Geometry, and Precalculus are shown in Table 4.5. Definitions of the included *TEKS* are described in Appendix B. For the *TEKS,* the number represents the Knowledge and Skills Statement and the letter represents the Student Expectation. For A.2A, the "2" corresponds to the K&S statement:

> (2) Linear functions, equations, and inequalities. The student applies the mathematical process standards when using properties of linear functions to write and represent in multiple ways, with and without technology, linear equations, inequalities, and systems of equations. (TEA, 2014)

The "A" corresponds to the SE:

> (A) determine the domain and range of a linear function in mathematical problems; determine reasonable domain and range values for real-world situations, both continuous and discrete; and represent domain and range using inequalities. (TEA, 2014)

In Algebra I, two SEs were included in the curriculum three times each. Both of these topics involved writing linear functions. For Geometry, the most connections were made to the *TEKS* about volume and surface area of three-dimensional figures. Volume was included seven times and surface area was included four times throughout the course.

Table 4.5

Frequency of TEKS

Course	*TEKS*	Number of Times Addressed in *IED* Curriculum
Algebra I	A.2A	1
	A.2C	3
	A.2D	1
	A.3A	1
	A.3B	1
	A.3C	1
	A.4A	1
	A.4C	3
	A.11B	1
	A.12B	1
Algebra II	2A.6H	1
	2A.8A	1
	2A.8B	1
	2A.8C	1
Geometry	G.2A	1
	G.3A	1
	G.9A	1
	G.10B	3
	G.11A	1
	G.11B	1
	G.11C	4
	G.11D	7
	G.12A	1
	G.12B	1
Precalculus	P.4I	2

Middle School Connections

While the study was focused on connections at the high school level, it was noted that overall, there were more connections to middle school level mathematics (grades 6, 7, and 8) *TEKS* than high school level. There were 53 total connections to the middle school mathematics *TEKS*, compared to 41 for high school. The following are the middle school topics that were included in this curriculum:

- Unit conversion
- Area of rectangles, triangles, and circles
- Represent and interpret data
- Mean, median, mode, and range
- Ratios and proportions
- Volume and surface area of rectangular prisms
- Slope and trend lines

Similar to the high school connections, many of the middle school connections addressed the same SEs multiple times. Majority of the connections were unit conversion or data analysis.

Primary Versus Secondary Focus

Looking beyond the total number of topics, the data were analyzed to determine which activities had high school mathematics as the primary focus and which had it as a secondary focus. In order to be the primary focus, the main component of the activity had to include high school mathematics. A topic was considered to be the secondary focus if it was a minor piece of the activity that was included but was not the main component. Based on the 16 activities that included high school mathematics, 56% had high school mathematics as the primary focus and 44% as the secondary focus.

Calculating Properties of Solids provided an example of an activity in the curriculum with a primary focus on high school mathematics. The students had to find volume and surface area of three-dimensional figures, both basic prisms and cylinders and also composite figures, and apply these finding to real-world situations. The students would then plot their findings on a graph, find the line of fit in function notation, and interpret the meaning of the slope and y-intercept of the graph. There were other science concepts included as well which gives students the opportunity to make connections between the disciplines. An example of a lesson with a secondary focus on high school mathematics was *Unit Conversion*. In this lesson, students learned how to convert units in the same measurement system as well as between measurement systems using conversion factors. In the *TEKS,* this is a middle school level topic. However, when converting within the SI system, the curriculum included the laws of exponents to use with the powers of 10. While this high school level concept was included, it was only a minor part of the activity as the goal of this particular lesson was teaching unit conversion, not laws of exponents.

Developing and Applying Concepts and Skills

The analysis of high school mathematics being the primary or secondary focus in the activities led to examining how the specific mathematical skills and concepts were incorporated in the curriculum. The activities were analyzed for whether they were developing the mathematical concepts and skills or only applying them to the engineering or science concepts. Skills are the procedures that support the understanding of the mathematical concept. Concepts give context for the mathematical skills. In order to be considered a developed concept, it had to be addressed multiple times throughout the curriculum in different contexts. Table 4.6 displays the high school mathematics concepts that were developed in the *IED* curriculum.

Table 4.6

High School Mathematics Concepts Developed in Introduction to Engineering Design Curriculum

High School Course	Concept
Algebra 1	• Linear Functions/Lines of fit for data • Slope
Geometry	• Area of polygons and composite figures • Surface Area of Three-Dimensional Figures • Volume of Three-Dimensional Figures

These concepts were supported by the development and application of different mathematical skills. To develop these skills, the curriculum made explicit connections to them. There were opportunities for students to practice these skills and often apply them in later lessons. A few of the minor topics that were secondary components of the activities did not have these explicit explanations. It was assumed students already possessed these skills and knew when to apply them, so the connections of these skills were less explicit in the activities. Table 4.7 displays the number of skills that were developed versus applied in each course. Because skills such as finding volume and surface area using formulas were used multiple times, the skills were developed in one activity, and applied in subsequent activities. Although skills like these were eventually applied, they were included in the developed category in Table 4.7 because they were ultimately developed before applied in the curriculum. The skills included in multiple lessons were only counted once in the table. Some of the standards addressed in the curriculum include the same skill. For example, in Algebra I, A.3A, A.3B, and A.3C all include aspects of finding slope. These were considered to address the same skill.

Table 4.7

Developing Versus Applying Skills

High School Course	Number of Skills Included	
	Developing	Applying
Algebra I	7	1
Algebra II	0	1
Geometry	5	4
Precalculus	1	0

The *Mathematical Modeling* activity provided an example of an activity that developed mathematical skills. The activity included a PowerPoint that explained the concepts of domain and range, lines of fit, correlation coefficient, slope, and function notation. Students had the opportunity to practice these skills in the accompanying activity. There were specific questions that guided students through the different skills, so they would know when to apply them and their purpose. On the other hand, the lesson *Isometric Sketching* only applied the included mathematical skill. When learning how to draw an isometric sketch of a cylinder, there were step-by-step instructions. In order to draw a circle, the students would follow specific steps on where to put points. For one step, the students would have to find 2/3 the distance between two points. This skill matches to G.2A (See Appendix B). There is no explanation on how to do the calculations to find that point; students needed to already know how to calculate that distance and apply that skill.

The findings in this study suggest the *Introduction to Engineering Design* curriculum did include many high school level topics for mathematics. The largest number of connections were to Algebra I and Geometry. There was not a wide variety of *TEKS* that were included however. There was only a small percentage of the total SEs in the *TEKS* included for all four subjects. In the curriculum as a whole, 60% of the units included high school mathematics concepts but only 24% of the total activities in these units included high school mathematics. Overall, there were more connections to middle school level topics than high school level topics. For the activities that did include high school mathematics, a majority incorporated the concepts and skills as the primary focus. Many of the Algebra I skills included were explicitly explained, which considered these skills to be developed in the activities. Geometry had more skills that were applied throughout the curriculum. Because some of the mathematical skills were used multiple times throughout the *IED* course, the skills were usually developed in the first activity, then applied in the subsequent activities.

CHAPTER FIVE

Discussion

Although STEM education has grown in popularity, the concerns regarding the "M" in STEM have increased as well. There are concerns about what mathematics concepts are included in STEM education, the grade level of mathematics included, and the role mathematics plays. Through analyzing a high school STEM curriculum, this study aimed to address these concerns by answering the following research questions:

1. In what ways does *Project Lead The Way (PLTW)* as a high school STEM curriculum align to state high school mathematics standards in Texas?
2. What percentage of the alignment has high school mathematics as the primary focus and what percentage has it as a secondary focus?

High School Mathematics Connections

This study examined a high school *PLTW* curriculum *Introduction to Engineering Design* (*IED)* for the alignment to the Texas state standards for high school mathematics. The results suggested many explicit connections between the STEM curriculum and the *TEKS.* Out of the four high school courses, the *PLTW* course had the most connections to the standards for Algebra I and Geometry. This addressed the concern that STEM education does not include high school level mathematics. The results suggested that the upper level courses of Algebra II and Precalculus did not have as many connections as the lower level courses however. Stohlmann (2018) noted measurement, data analysis, geometry, and linear and quadratic equations as the most common topics included in high school STEM education but suggested a need to expand the mathematical content beyond these concepts. This aligns with the results found in the current study as these were the main topics included in the *IED* curriculum. Linear functions and volume and surface area of three-dimensional figures were the most addressed mathematics topics in this curriculum. Although Algebra I and Geometry had the most connections, less than 25% of the total SEs in each course were included in the *IED* curriculum. These high school mathematics concepts were only included in six out of ten units in the *IED* course. Only 16 out of 66 total activities in the course included connections to the high school mathematics *TEKS.* The other units and activities focused on the design elements of engineering. These results suggested that although high school mathematics is included, there is still room for growth in integrating high school mathematics into STEM education, as majority of the activities did not include connections to the *TEKS* for high school.

Middle School Connections

As mentioned in chapter 4, there were 53 total connections to middle school mathematics and 41 connections for high school. The number of middle school connections is an interesting finding because Stohlmann and colleagues (2011) only found three explicit connections between a middle school *PLTW* curriculum and the Minnesota state standards for middle school. The curriculum in Stohlmann's study was not engineering specific like the curriculum analyzed in this study, which may have accounted for the difference in the results. Also, as shown in the current study, many mathematics connections were below grade level, as this study examined a high school curriculum but found many middle school mathematics connections. The same pattern may have occurred for the middle school curriculum, meaning the mathematics concepts were below middle school level, but the Stohlmann study only focused on sixth, seventh, and eighth grade standards. This suggests a possible misalignment in the mathematics by including lower level concepts, or perhaps these lower level concepts are meant to be applied by students. By including lower level concepts, the curriculum can build upon the application of those skills with on-level skills. An example of this was in the activity *Calculating Properties of Shapes*. The questions were initially focused on finding area of basic shapes such as rectangles, triangles, and circles, which is a middle school level skill according to the *TEKS.* As the lesson continued however, area of regular polygons and more complex composite figures were included, which are high school level concepts. Multiple activities also applied the concept of scale factor and proportions. There may be a similar progression in the middle school curriculum as well.

Primary Versus Secondary Focus

The next research question examined the role high school mathematics played in the activities. This addressed the concern that the role of mathematics is often to serve another subject or task (Picha, 2018). Of the activities in this curriculum that included high school mathematics, 56% had the mathematics as a primary focus of the lesson, while 44% was a secondary focus. Although there was not a wide variety in the mathematics topics that were included, *IED* did put an emphasis on high school mathematics in the activities that included these topics. There were explicit connections that either explained the mathematical skill or asked specific questions to help students know when to apply it. In some activities, science or engineering concepts also had a prominent role, but the mathematics was still a main component as it was being connected to the other disciplines. These aspects of the activities would help develop these mathematical skills and concepts for students. An example of an activity with a primary focus was *Calculating Properties of Shapes.* In this activity, the concept of area of polygons and composite figures was developed. First, there were some straightforward questions about area to practice using the formulas. Then the questions began asking for missing dimensions or more complex composite figures. This whole activity was focused on the concept of area.

There were some activities, however, that focused on science or engineering concepts more than mathematics. Mathematics played the supporting role in these activities, so it was considered the secondary focus. These activities often did not specifically teach the high school mathematics. The *CAD Model Features Part 1* activity was focusing on design element of engineering. Figures were to be sketched and designed using the computer software. In one aspect of the activity, the figure would be rotated about an axis of symmetry. This addressed the topic of transformations of figures in Geometry, but transformations were not the main learning goal of the activity. In order to make these connections, the students would have to already have knowledge about that mathematical concept and understand when to apply it. This led to the analysis of whether the activities were developing a mathematical concept, developing a mathematical skill, or only applying the skill.

Developing and Applying Concepts and Skills

In order to truly understand the mathematics, students need to not only know how to do the skills but need a deep conceptual understanding of the content as well. The relationship between skills and concepts needs to be developed for students to have the ability to utilize higher order thinking and apply their mathematical knowledge in different contexts (Wathall, 2016). Skills are the low-level processes that are important for students to know but do not guarantee a conceptual understanding of the mathematics. Concepts are transferable and give context for the mathematical skills. Skills explain *how,* while the concepts explain *why.*

In this study, the *Introduction to Engineering Design* curriculum was analyzed for the high school mathematical concepts it developed, as well as the skills that were developed and applied. Many of the skills that were developed supported the mathematical concepts. The concepts were used in different situations in the curriculum and gave context to the mathematics topics. For example, lines of fit for data and slope were two concepts developed for Algebra I. These concepts often went together in the activities. In *Motion in One Direction,* slope was used in the context of speed and velocity. The skill of using the formula to find slope was developed, but the activity gave context to the meaning of the slope of a line. This activity was ultimately developing the concept of distance and displacement, but there were multiple questions regarding slope. In the following activity, finding the line of fit for data was introduced. The skills of finding the correlation coefficient, domain and range, and function notation were developed, which supported the different aspects of the line of fit concept. Slope was again included in this activity, but in a different context. Instead of speed and velocity, slope was now being used in the context of rainfall and runoff. The concepts of lines of fit and slope were included in other lessons in different contexts such as maximum displacement with respect to the nominal diameter of a cam. By understanding these concepts, students are able to transfer and apply them in different situations.

The concepts of volume and surface area of three-dimensional figures were developed in the *Introduction to Engineering Design* curriculum by being addressed in multiple activities. After developing the skills of using the formulas to calculate these, activities then included more complex composite figures for students to apply their skills. The concept of surface area was also addressed by questions regarding the amount of paint needed to cover pieces of wood with two coats or the number of quarts of cleaning solution needed to clean the outside of a cylinder. These questions did not explicitly say to use surface area, so students would have to know to apply their knowledge of surface area to those situations. There also came a point in the curriculum when the computer programs would do many of the calculations. At that point, students needed to understand when to apply the concepts of volume and surface area, not just know how to use a formula.

An example of a skill that was applied rather than developed was in an activity that included a question about finding the area of a regular polygon. The area formula given included the trigonometric tangent function, but there was no explicit explanation of trigonometry. Students either had to already have knowledge about this function or merely plug numbers into the formula to find the answer. This example was a minor part of the activity, but while the student would have to use trigonometry to find the area of a regular polygon, they would not necessarily develop an understanding for that skill or concept.

There were also times when the mathematical skills and concepts were being developed and applied, but they were ultimately supporting a science or engineering concept. For example, In the activity *Determining Density,* finding volume of three-dimensional figures had a prominent role, but the ultimate focus of the activity was the concept of density, mass, and weight. So, although the skill of using the volume formulas for three-dimensional figures was included many times, the activity was ultimately serving a science concept. This did allow the mathematical concepts to be applied in real-world situations and connections to be made between STEM disciplines. There needs to be caution when implementing these lessons that the mathematics concepts are not overshadowed.

Future Studies

This study examined how a high school STEM curriculum aligns with the *TEKS* for high school mathematics. Now that the amount and grade level of the mathematics has been identified, there are still areas for research involving how STEM curriculum is implemented in the classroom. Are students learning these mathematics skills with understanding and making the connections in these courses? Does this type of education increase students' mathematical understanding and knowledge? Future studies should investigate when it is best for students to take these STEM courses in their high school mathematics sequence. The *PLTW* course in this study included predominately Algebra I and Geometry for high school mathematics. This leads to the question: Would students benefit the most from taking STEM courses before, during, or after Geometry? Would it help to be introduced to the mathematics concepts during the STEM course, or would students make more connections if they were already familiar with the mathematics content? Also, because this study only looked at one course in the *PLTW* curriculum, other *PLTW* courses and other STEM curricula can be analyzed to identify if the alignment is similar or different to the results found in this study. There are still questions to be answered regarding STEM education and high school mathematics.

Conclusion

From analyzing the *Introduction to Engineering Design* curriculum from *Project Lead The Way,* this study suggested there are explicit connections between a high school STEM curriculum and the Texas state standards for high school mathematics. While there were valuable connections made between disciplines, there is still a need to expand the high school mathematics concepts included in STEM curricula as a majority of the SEs for Algebra I, Algebra II, Geometry, and Precalculus were not addressed in this curriculum. In the units that included high school mathematics, these topics were often the primary focus of the activity but in an engineering context. By being a foundation course for the *PLTW Engineering* curriculum, this course included engineering applications for the mathematics concepts and made connections between the STEM disciplines. It is important for students to have the opportunity to both learn the mathematics concepts, as well as apply them in a real-world context. STEM education has the ability to successfully provide this type of education for students.

APPENDICES

APPENDIX A

Project Lead The Way Authorization

From: solutioncenter@pltw.org
Sent: Tuesday, May 7, 2019 11:43 AM
To: Donham, Melissa
Cc: aking@pltw.org; Wilkerson, Trena L; aangelov@pltw.org
Subject: RE: Curriculum Access Request (24 Please) - PLTW case #CN-05190474360 [ref:_00Do0J6Oj._5001JjE0GD:ref]

PLTW

Hello Melissa,

We have approved your request for temporary access to PLTW curriculum. In order to begin this process, please sign and return the attached PLTW Confidentiality/Nondisclosure Agreement at your earliest convenience.

In addition, you will need to follow the steps below to create a myPLTW account.

1. Visit mypltw.org.
2. Click Create Account.
3. Complete all form fields.
4. Read the terms of service and click the "I have read and agree to the terms of service" check box.
5. Click Create your Account.
6. Verify your email and login to myPLTW

If you have any questions related to this case, please respond to this email or call 877.335.7589. For your reference, your case number is CN-05190474360.

Thank you,
Logan

Solution Center Team
Project Lead The Way, Inc.
877.335.7589 (PLTW)
www.pltw.org

AA **Addie Angelov <aangelov@pltw.org>**
6/17/2019 10:28 AM

To: Donham, Melissa

Yes, you may use our name in your thesis, adsa

APPENDIX B

TEKS in *Introduction to Engineering Design* Curriculum

The following provides the *TEKS* (TEA, 2014) addressed in the *Introduction to Engineering Design* course.

Algebra I TEKS Addressed in IED Curriculum

(2) Linear functions, equations, and inequalities. The student applies the mathematical process standards when using properties of linear functions to write and represent in multiple ways, with and without technology, linear equations, inequalities, and systems of equations. The student is expected to:

> (A) determine the domain and range of a linear function in mathematical problems; determine reasonable domain and range values for real-world situations, both continuous and discrete; and represent domain and range using inequalities
>
> (C) write linear equations in two variables given a table of values, a graph, and a verbal description
>
> (D) write and solve equations involving direct variation

(3) Linear functions, equations, and inequalities. The student applies the mathematical process standards when using graphs of linear functions, key features, and related transformations to represent in multiple ways and solve, with and without technology, equations, inequalities, and systems of equations. The student is expected to:

> (A) determine the slope of a line given a table of values, a graph, two points on the line, and an equation written in various forms, including $y = mx + b$, $Ax + By = C$, and $y - y_1 = m(x - x_1)$
>
> (B) calculate the rate of change of a linear function represented tabularly, graphically, or algebraically in context of mathematical and real-world problems
>
> (C) graph linear functions on the coordinate plane and identify key features, including *x*-intercept, *y*-intercept, zeros, and slope, in mathematical and real-world problems

(4) Linear functions, equations, and inequalities. The student applies the mathematical process standards to formulate statistical relationships and evaluate their reasonableness based on real-world data. The student is expected to:

> (A) calculate, using technology, the correlation coefficient between two quantitative variables and interpret this quantity as a measure of the strength of the linear association
>
> (C) write, with and without technology, linear functions that provide a reasonable fit to data to estimate solutions and make predictions for real-world problems

(11) Number and algebraic methods. The student applies the mathematical process standards and algebraic methods to rewrite algebraic expressions into equivalent forms. The student is expected to:

> (B) simplify numeric and algebraic expressions using the laws of exponents, including integral and rational exponents

(12) Number and algebraic methods. The student applies the mathematical process standards and algebraic methods to write, solve, analyze, and evaluate equations, relations, and functions. The student is expected to:

> (B) evaluate functions, expressed in function notation, given one or more elements in their domains

Algebra II TEKS Addressed in IED Curriculum

(6) Cubic, cube root, absolute value and rational functions, equations, and inequalities. The student applies mathematical processes to understand that cubic, cube root, absolute value and rational functions, equations, and inequalities can be used to model situations, solve problems, and make predictions. The student is expected to:

> (H) formulate rational equations that model real-world situations

(8) Data. The student applies mathematical processes to analyze data, select appropriate models, write corresponding functions, and make predictions. The student is expected to:

> (A) analyze data to select the appropriate model from among linear, quadratic, and exponential models
>
> (B) use regression methods available through technology to write a linear function, a quadratic function, and an exponential function from a given set of data

(C) predict and make decisions and critical judgments from a given set of data using linear, quadratic, and exponential models

Geometry TEKS Addressed in IED Curriculum

(2) Coordinate and transformational geometry. The student uses the process skills to understand the connections between algebra and geometry and uses the one- and two-dimensional coordinate systems to verify geometric conjectures. The student is expected to:

(A) determine the coordinates of a point that is a given fractional distance less than one from one end of a line segment to the other in one- and two-dimensional coordinate systems, including finding the midpoint

(3) Coordinate and transformational geometry. The student uses the process skills to generate and describe rigid transformations (translation, reflection, and rotation) and non-rigid transformations (dilations that preserve similarity and reductions and enlargements that do not preserve similarity). The student is expected to:

(A) describe and perform transformations of figures in a plane using coordinate notation;

(9) Similarity, proof, and trigonometry. The student uses the process skills to understand and apply relationships in right triangles. The student is expected to:

(A) determine the lengths of sides and measures of angles in a right triangle by applying the trigonometric ratios sine, cosine, and tangent to solve problems

(10) Two-dimensional and three-dimensional figures. The student uses the process skills to recognize characteristics and dimensional changes of two- and three-dimensional figures. The student is expected to:

(B) determine and describe how changes in the linear dimensions of a shape affect its perimeter, area, surface area, or volume, including proportional and non-proportional dimensional change.

(11) Two-dimensional and three-dimensional figures. The student uses the process skills in the application of formulas to determine measures of two- and three-dimensional figures. The student is expected to:

(A) apply the formula for the area of regular polygons to solve problems using appropriate units of measure

(B) determine the area of composite two-dimensional figures comprised of a combination of triangles, parallelograms, trapezoids, kites, regular polygons, or sectors of circles to solve problems using appropriate units of measure

(C) apply the formulas for the total and lateral surface area of three-dimensional figures, including prisms, pyramids, cones, cylinders, spheres, and composite figures, to solve problems using appropriate units of measure

(D) apply the formulas for the volume of three-dimensional figures, including prisms, pyramids, cones, cylinders, spheres, and composite figures, to solve problems using appropriate units of measure

(12) Circles. The student uses the process skills to understand geometric relationships and apply theorems and equations about circles. The student is expected to:

(A) apply theorems about circles, including relationships among angles, radii, chords, tangents, and secants, to solve non-contextual problems

(B) apply the proportional relationship between the measure of an arc length of a circle and the circumference of the circle to solve problems;

Precalculus TEKS Addressed in IED Curriculum

(4) Number and measure. The student uses process standards in mathematics to apply appropriate techniques, tools, and formulas to calculate measures in mathematical and real-world problems. The student is expected to:

(I) use vectors to model situations involving magnitude and direction

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