Spring 2024

The influence of teacher experience on Project Lead the Way test scores

Emily Schmitz

SHAWNEE STATE UNIVERSITY

The influence of teacher experience on Project Lead the Way test scores

A Thesis

By

Emily Schmitz

Department of Mathematical Sciences

Submitted in partial fulfillment of the requirements

for the degree of

Master of Science, Mathematics

Date

Accepted by the Graduate Department

06/27/2024

Graduate Director, Date

The thesis entitled **The influence of teacher experience on Project Lead the Way test scores** presented by **Emily Schmitz**, a candidate for the degree of **Master of Science in Mathematics,** has been approved and is worthy of acceptance.

06/27/2024
Date

Graduate Director

6/28/2024
Date

Emily Schmitz
Student

ABSTRACT

Project Lead the Way (PLTW) is an organization that develops engineering curriculum for all grade levels. Research has been conducted on the curriculum and other STEM curriculum to determine student achievement levels and the factors that affect student achievement. These factors include teacher retention, teacher years of experience, student demographics, etc. Investigating how a teacher impacts their students learning can help schools understand the value of a seasoned teacher. With PLTW training having high costs it can make teacher retention a bigger concern. The Highland Prep Academies utilize PLTW curriculum and have about ten trained teachers across the three schools. Data was collected from them during the academic year 2022-23, which included student demographics, PLTW test scores, and teacher semesters of experience. This data was analyzed using multiple linear regression, ANOVA, and two-way ANOVA with and without a covariant in the software R 4.3.0. Through the analysis it was found that two specific PLTW courses had lower scores than the others, Aerospace Engineering and Principles of Engineering. Student test scores were observed to decrease 1% every time a teacher had taught a course. Regarding student demographics, it was found that African American and Native American students scored lower then Caucasian and Asian students. Specifically, male Caucasian students scored higher than the other interactions of ethnicity and gender. It was also determined that students with male teachers scored lower than students with female teachers. Lastly, for the Highland Prep Academies it was determined that Madison Highland Prep's average PLTW test score was a higher than the test scores at Highland Prep West and Highland Prep Surprise. These results imply that changes need

to be made to ensure educational equity of the students and that teachers need continued PLTW curriculum support through the years of teaching.

ACKNOWLEDGMENTS

I would like to acknowledge my thesis advisor, Dr. Douglas Darbro, And the other math professors at Shawnee State University. A big thank you goes to the administration of Highland Prep Academies, specifically Madison Highland Prep. Without the support of Dr. Kerry Clark, Rosanna Rodriguez, Reshma Watson, Steven Mack, and Erin Zhang this research would not have been possible.

A thank you goes out to my mom and twin sister for listening to me talk about the research and their support over the two years. Additionally, thank you goes to Jill, my cat, for keeping me company, trying to help me type, and not overheating my laptop.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

CHAPTER I: Introduction

Introduction:

Project Lead the Way (PLTW) is a non-profit organization that offers curriculum in the K-12 field of education that focuses on hands-on engineering projects. It is commonly used in schools with a STEM (science, technology, engineering, and mathematics) program or STEM schools. The Highland Prep Academies are STEM schools, and nationally STEM certified through Cognia. They utilize several PLTW curriculums, including: Introduction to Engineering Design (IED), Aerospace Engineering (AE), Principles of Engineering (POE), Cybersecurity (CSC), Civil Engineering and Architecture (CEA), Digital Electronics (DE), Biomedical Science (BMS), and AP Computer Science (APCS). Highland Prep Academies consists of three schools: Madison Highland Prep (MHP), Highland Prep Surprise (HPS), and Highland Prep West (HPW).

The Highland Prep Academies are very data driven, analyzing beginning and end of course exams for both English and mathematics every quarter. This will be the first time the PLTW test scores collected at the courses' end will be analyzed for the Highland Prep Academies. The data that will be collected and investigated in addition to the PLTW test scores are entrance math exams, grade level, student ethnicity, student gender, school, course, number of times the teacher has taught the course, teacher gender, and spring/fall semester. From the three schools for this study A total of 1039 data points were collected during the academic year 2022-23. Since the Highland Prep Academies use a block schedule with semester-long courses, the number of times the teacher has taught the course increases in the academic year.

Background:

Project Lead the Way was developed in June 1997 and has undergone numerous research studies to date. Currently, there has been research based on the efficacy of the curriculum, test scores, and participant opinions. There has been no research conducted on the effect of the number of times a teacher has taught a specific PLTW curriculum on student test scores. If teacher experience positively affects student test scores, then teacher retention will be of greater concern for schools. Furthermore, students who perform highly in PLTW courses are eligible for both college credit and scholarships.

In a 2011-2014 survey of forty-five states from the United States the teacher turnover rate was measured and analyzed. It was determined that Arizona had the largest rate at 24% while Utah had the smallest rate of under 10%.[1] In a different study from 2020-2022, it was determined that on average 8% of public-school teachers switched schools while 8% left the teaching profession entirely.[2] With teacher turnover rates being of concern for most schools nationwide, understanding the impact of a teacher's experience with the PLTW curriculum is important to determining the value of a seasoned PLTW teacher.

One of the key factors affecting teacher turnover rate is low salaries that have minimal percent increase each year. In the academic year 2021-22 the national average public school teacher salary increased by two percent from the previous academic year.[3] According to the Social Security Administration the national average wage from 2020 to 2021 increased 8.89%.[4]

---

[1] Marco Learning, "Why Some States Have Higher Teacher Turnover Rates Than Others."

[2] National Center for Education Statistics, "Eight Percent of Public School Teachers Left Teaching in 2021, a Rate Unchanged Since Last Measured in 2012."

[3] Walker, "Teacher Salaries."

[4] Social Security Administration. "Average Wage Index (AWI)."

This disparity between the yearly wage increase has caused current teachers and future teachers to seek other careers.

A teacher must participate in training, in-person or online, with PLTW to teach a course from the Project Lead the Way curriculum. The in-person programs can range from 16 hours over two days or 80 hours over two weeks, while the online training varies from 16 hours over two days to 80 hours over 10 weeks.[5] PLTW offers a total of 29 courses with 17 of their teacher training programs costing $2,400 and the other 12 costing $500 - $1,200.[6] There are further costs associated with a school offering PLTW courses, such as an annual fee and the cost of equipment. However, the cost of training a new teacher makes the turnover rate of a school's PLTW teachers potentially expensive. On average schools spend more than $20,000 on hiring a new teacher.[7] Therefore, the cost to hire a new PLTW teacher can easily reach close to $30,000 due to training in multiple curriculums.

Through Project Lead the Way students have access to 57 different scholarships with five being available nationwide. For college credit there are 73 different opportunities with universities from various states. Students earn these based on their PLTW test scores and course grade. Through scholarships and college credit, students can save money on their postsecondary education. Students who perform poorly in the PLTW course or the end of course assessment are less likely to be eligible for these opportunities.[8]

---

[5] Project Lead the Way, "Professional Development for Teachers."
[6] Project Lead the Way, "Core Training Registration Fees."
[7] Learning Policy Institute, "What's the Cost of Teacher Turnover?."
[8] Project Lead the Way, "See Our Student Opportunities."

Statement of the Problem:

With student test scores and course grades impacting their postsecondary education, it is important to understand what a significant predictor of their PLTW test scores could be. One of the goals of this study is determining the effect a teacher's experience has on student PLTW test scores. If there is a positive correlation between teacher experience and student PLTW test scores, then teacher turnover rate will be of greater concern for schools. Hiring and training a new PLTW teacher requires a lot of time and is very expensive. For schools such as the Highland Prep Academies where there are multiple PLTW teachers, poor retention rates could cause large yearly expenses.

Student scholarship and college credit through PLTW is directly related to their test score and grade. Therefore, if there is a relationship between test scores and teacher experience, then teachers would have a direct impact on their students' future opportunities. These scholarships and college credit enable students to pursue post-secondary education that they otherwise may not have had the means to.

Another goal of this study is to determine if other factors are significant predictors of student PLTW test scores. As the Project Lead the Way curriculum is used in high schools, it is important to encourage diversity in engineering at this age to further diversify the engineering workforce. In 1980, 5% of engineers were women, a statistic that eventually increased to 16.1% in 2022.[9] Student gender will be analyzed to determine if there is a relationship between it and PLTW test scores. Similarly, student ethnicity will be analyzed in relation to PLTW test scores. In a 2019 study, it was determined that 71% of engineers were Caucasian, 5% African American, 9%

[9] Society of Women Engineers, "Employment."

Hispanic, 13% Asian, and 2% other.[10] It is important to understand how different student backgrounds affect student PLTW test scores. Ensuring that all students have equal opportunity for success is a critical role in every school.

Other factors that will be analyzed include teacher gender. As stated previously, most engineers are male, and this holds relatively true for the engineering teachers in this study. In the 2022-23 academic year the Highland Prep Academies had two female engineering teachers out of eight total teachers. There have been studies on the relationship between teacher gender and student test scores, and in this study the relationship will focus on the PLTW test scores. Teachers act as role models for their students, which means female teachers could increase the test scores of their female students.

Typically, Introduction to Engineering (IED) is taught to freshmen, Principles of Engineering (POE) to sophomores, and the other courses to upper classmen (non-freshman students). However, the sequence of engineering courses is not always maintained. As students' progress through high school their math and reading/writing skills increase, which are used throughout the PLTW curriculum. Understanding how grade level affects student PLTW test scores can help with sequencing the courses to improve student success.

Purpose of the Study:

This study will be conducted at the Highland Prep Academies for the academic year 2022-23 as the data has all been collected. Administration of the Highland Prep Academies will provide

---

[10] Pew Research Center, "STEM Jobs See Uneven Progress in Increasing Gender, Racial and Ethnic Diversity."

the following data: student PLTW test scores, course name, student grade level, ethnicity, and gender; teacher of course (designated by a number), teacher gender, number of times teacher has taught course, school, semester (spring or fall), and student math entrance exam. The focus of this study will be determining the relationship between student test scores and the other factors.

Significance of the Study:

Madison Highland Prep was the first of the Highland Prep Academies and was established in August 2014. Highland Prep Surprise followed three years later while Highland Prep West was established in August 2022. Each of the schools test incoming freshmen on mathematics and reading. These results are utilized to organize students into cohorts according to their academic level. As students progress in math and English courses, they complete beginning of course (BOC) and end of course (EOC) exams quarterly. BOC and EOC scores are then analyzed to determine which students need remedial work or supplemental projects and which concepts need additional review.

Project Lead the Way was introduced to the Highland Prep Academies in 2014 when Madison Highland Prep opened. Though the schools are highly data driven, the PLTW test scores have not been analyzed in depth beyond course averages. The raw test score does not include a breakdown of scores based on concepts, but it would enable administration to determine which teachers need additional support. The training for PLTW is intensive, except it typically only occurs prior to a teacher teaching the course. This means there is a possibility for gaps in a teacher's knowledge to become apparent during the semester. Students will struggle to be successful in a course where the teacher is not knowledgeable of the course content.

PLTW curriculum is used nationally with many schools implementing different courses. Studies have been conducted about different factors regarding Project Lead the Way. So far no one has examined the relationship between student test scores and the number of times a teacher has taught the course. With the concern of teacher turnover rates, it's important to determine if there is a correlation. A positive correlation would support further policies and changes in schools to improve these rates.

With the field of engineering containing poor diversity based on ethnicity and gender, the relationship between students' backgrounds and PLTW test scores needs to be examined. Since Project Lead the Way curriculum is engineering focused, student test scores will help indicate if there is a specific ethnicity or gender that is struggling with the courses. From there, remedial and support programs could be set up to ensure all students are successful in the curriculum.

The Women in STEM movement has been ongoing since the early 1900's and has focused on inspiring and empowering young women to pursue careers in STEM. The percent of women in chemistry and biology has increased to 40.4% and 48.6%, respectively.[11] With the number of women in engineering at a low percentage in comparison, it is important to continue encouraging female students to investigate STEM. Female engineering teachers act as role models for their female students, which is a key component of the Women in STEM movement.

---

[11] Zippia, "CHEMIST DEMOGRAPHICS AND STATISTICS IN THE US."; Zippia, "BIOLIGIST DEMOGRAPHICS AND STATISTICS IN THE US."

Research Questions:

The following questions will be investigated in this study:

1. Are the number of times a teacher has taught a course, student grade, gender, ethnicity; course, teacher gender, enrolled school, and semester significant predictors of student PLTW test scores?
2. Is there a significant difference in student PLTW test scores across student ethnicity and gender?
3. Is there a significant difference in student PLTW test scores across teacher gender and student gender?
4. Is there a significant difference in student PLTW test scores across the Highland Prep Academies?

Research Design:

During the 2022-23 academic year, 1066 students took a Project Lead the Way course at the Highland Prep Academies. The end-of-course tests are provided by PLTW and completed digitally through the software Kite Portal. Each students' test score is recorded, but to use the test scores, which range from 100 to 600, they are changed into their corresponding percentiles, because a score in one course is not worth the same in another course. For example, a score of 300 in Aerospace Engineering is in the 16th percentile while in Civil Engineering and Architecture the same score is in the 41st percentile.[12] By changing the raw score values to their corresponding percentiles, as provided by PLTW, the test scores become normalized.

[12] Project Lead the Way, "Understanding End-of-Course Assessment Results."

Student name, course, teacher name, and test score are provided through PLTW. Both student names and teacher names are anonymized by assigning them numbers. Student ethnicity, grade level, and gender were provided by administration, along with student entrance math exam scores. Several other students did not have math entrance exam scores available, but their beginning of course math exam scores from their freshman year were used in substitution as these two exams are similar in setup and content. Due to some entrance math exam scores and BOC scores missing, the following students were dropped: 80, 81, 178, 207, 233, 279, 296, 300, 337, 342, 397, 420, 457, 543, 562, 730, 745, 769, 789, 892, 920, 926, 943, 956, 981, 1032, and 1043.

For Research Question 1 a multi-linear regression (MLR) will be used. This will determine whether semester, student grade, course, or number of times a teacher has taught the course are significant predictors. For Research Question 2 and 3 a two-way analysis of covariance (ANCOVA) will be used. This will determine if there is a significant difference in student PLTW test scores across student ethnicity and gender and if there is a significant difference in student PLTW test scores across student gender and teacher gender. For Research Question 4 an analysis of covariance (ANCOVA) will be used. This will determine if there is a significant difference in student PLTW test scores across the Highland Prep Academies. For the ANCOVA analyses, the student entrance math exam scores will be used as the covariant. The software that will be used for this study are R v. 4.3.0 by the R Foundation and GPOWER 3.1 by Erdfelder, Faul, and Buchner.

Theoretical Framework:

In his Experiential Learning Theory, David Kolb states there is a four-stage cycle to effective learning: concrete experience, reflective observation, abstract conceptualization, and active experimentation. These steps can be simplified to feeling, watching, thinking, and doing.[13] Teachers in the PLTW curriculum gain concrete experience through the preservice training, and in teaching the curriculum. Teachers are then able to reflect on their observations based on how students perform on assessments and complete various activities. Furthermore, teachers can continue to "experiment" with the curriculum by making needed adjustments to lessons to best suit the needs of students. As a result teachers are able to improve the delivery of concepts to students the more years they have taught the curriculum.

In *Evaluation of Mathematical Modeling Activity of 4th Grade Students: A Case of Experiential Learning*, a study by Dilara Yilmaz Can and Gülcenur Kesebir, investigates the use of experiential activities to improve mathematical understanding of 4th grade students. Thirteen students participated in the research and enjoyed the activities. The experiential learning method was shown to be positive on student learning.[14]

Another study utilized informal, near-peer mentoring which is highly interactive following the experiential learning theory. It was observed that near-peer mentorship increased student interest and engagement in STEM. In the study it was determined that students' interest, enjoyment, and self-confidence in mathematics and science were major factors in their

---

13 Kolb, D. A, *Experiential learning : experience as the source of learning and development (Second edition).*

14 Yilmaz Can, Dilara and Kesebir, Gülcenur, "Evaluation of Mathematical Modeling Activity of 4th-Grade Students: A Case of Experiential Learning," *Ankara University Journal of Faculty of Educational Sciences* 56, no. 1 (May 2023): 585-611, https://doi.org/10.30964/auebfd.1037725.

consideration for STEM careers. Experiential learning can boost concept knowledge and a person's confidence in a subject area.[15]

Assumptions, Limitations, and Scope:

Due to some students not having entrance math exam scores their BOC math exam scores from freshman year are used instead. This assumes that the entrance math scores and BOC math exam scores from freshman year are equivalent. Both exams use multiple choice questions with a similar number of questions. The key difference is when the exams are taken by students. The entrance math exam is taken during the student's eighth grade year in the spring while the BOC math exam is taken at the beginning of the student's freshman math class (either spring or fall semester).

Another assumption is that the teachers teach a course the same way. For example, each school has an IED course which uses the same curriculum provided by PLTW. The curriculum includes activities, but how the teacher instructs the class is unique. Each teacher could have their own pacing, grading system, classroom structure, etc. Administration ensures that the teachers cover the required curriculum, so students should be covering the same concepts.

Furthermore, each of the teachers in this study have completed the PLTW training required to teach their courses. This study assumes that the trainings were the same for the

[15] Wilson, A. T., Wang, X., Galarza, M. O., Knight, J., and Patino, E., "Math attitudes and identity of high schoolers impacted through participating in informal, near-peer mentoring," *International Journal of Research in Education and Science (IJRES)* 9, no. 2 (2023): 535-545, https://doi.org/10.46328/ijres.3093.

teachers of the same course. However, the trainings can either be online or in-person and there is no means to know if the training has remained the same over the years.

The Highland Prep Academies have a high percentage of minority (non-white) students. During the academic year 2022 – 2023, Madison Highland Prep had 65.57% minority students, Highland Prep Surprise had 53.5% minority students, and Highland Prep West had 75.54% minority students. The majority of these minority students are Hispanic, and many of them learned English as their second language.[16] All PLTW tests are in English, so the assumption that all students have a comprehensive understanding of written English is made. This simplifies the analysis, allowing the variable to be disregarded.

This study does not take into account students having an Individualized Education Plan (IEP) or a 504 plan. Due to limited facilities and being college preparatory schools, the Highland Prep Academies are unable to offer the academic support needed for students with severe cognitive disabilities. As for the most common accommodations required by IEPs and 504s: modified tests are not available through PLTW, but extended time and alternative testing rooms are available through the school.

All students in this study are enrolled in the Highland Prep Academies. Each of the schools is a STEM college preparatory charter high school and is in Maricopa County of Arizona. This causes a limitation that narrows the scope of the study to similar schools.

Definition of Key Terms:

[16] AZ School Report Cards, "Madison Highland Prep."; AZ School Report Cards, "Highland Prep West."; AZ School Report Cards, "Highland Prep."

- Aerospace Engineering (AE): A course offered through PLTW that focuses on the physics of flight and space with hands-on projects such as building a glider and a model rocket.
- AP Computer Science (APCS): A course offered through PLTW that focuses on coding with Python from data processing, data security, and task automation. As an advanced placement (AP) course, it is endorsed by the College Board and gives students the opportunity to earn college credit.
- Beginning of Course (BOC) exam: An exam completed at the beginning of a course to allow teachers to establish a baseline of students' knowledge on the course's concepts.
- Civil Engineering and Architecture (CEA): A course offered through PLTW that focuses on architecture and site design and development.
- Cybersecurity (CSC): A course offered through PLTW that focuses on concepts and procedures in cybersecurity.
- Digital Electronics (DE): A course offered through PLTW that focuses on circuitry that includes processes of combinational and sequential logic.
- Dual-credit course: A high school level course that allows students the opportunity to earn college credit for the course. This usually requires the high school to have a partnership with a local university.
- End of Course (EOC) exam: An exam completed at the end of a course to allow teachers to determine how much a student's knowledge on the course's concepts has grown.
- 504 Plan: Federally legal document that outlines a student's accommodations based on their disability. Typically used by students who have physical disabilities.

- Highland Prep Academies: A system of charter schools in Arizona that includes MHP, HPS, and HPW that are STEM focused and college preparatory high schools.
- Highland Prep Surprise (HPS): A STEM college preparatory charter high school that is in Surprise, Arizona.
- Highland Prep West (HPW): A STEM college preparatory charter high school that is in Avondale, Arizona.
- Individualized Education Plan (IEP): Federally legal document that outlines a student's accommodations based on their disability that can include speech and/or occupational therapy.
- Introduction to Engineering Design (IED): A course offered through PLTW that focuses on the engineering design process by completing hands-on projects.
- Kite Portal: A software used to complete PLTW end of course exams.
- Madison Highland Prep (MHP): A STEM college preparatory charter high school that is in Phoenix, Arizona.
- Principles of Biomedical Science (BMS): A course offered through PLTW that focuses on skills used in a variety of careers in biomedical sciences.
- Principles of Engineering (POE): A course offered through PLTW that focuses on the engineering design process with projects on mechanical design, infrastructure, and sustainability.
- Project Lead the Way (PLTW): An organization developed in June 1997 that has focused on engineering curriculum with hands-on projects.

- Science, Technology, Engineering, and Mathematics (STEM): An educational program that specializes in preparing students K-12 for college and careers in the fields of science, technology, engineering, and mathematics.
- Women in STEM: An international organization the works on supporting and inspiring young women to pursue degrees and careers in science, technology, engineering, and mathematics.

Summary:

This study will analyze 1036 Project Lead the Way test scores from the Highland Prep Academies. The primary focus will be determining what are the significant predictors of the test scores based on course, student grade, number of times the teacher has taught the course, and the semester. A multi-linear regression analysis will be used for this portion. A two-way analysis of covariance will be used to determine if there is a significant difference in student PLTW test scores across student ethnicity and gender. Similarly, a two-way ANCOVA will be used to determine if there is significant difference in student PLTW test scores across teacher gender and student gender. Lastly, an ANCOVA will be used to determine if there is a significant difference in student PLTW test scores across the Highland Prep Academies.

It is important to understand the value of a teacher through the years with high teacher turnover rates and high cost in PLTW training. Their effect on students can include opportunities for college credit and scholarships. For students of low-income this can encourage them to seek post-secondary education. Furthermore, with a low gender ratio and low minority percentage in engineering, understanding the correlation between student PLTW test scores and student gender/ethnicity can help drive programs to encourage diversity in engineering.

CHAPTER II: Literature Review

Introduction:

Education research is critical to the improvement of students' academic pursuits and the well-being of society. There are five main categories of education research that relate to this study: Project Lead the Way, STEM curriculum, teacher impact, teacher gender, and student gender and ethnicity. In this chapter a literature review of such research is conducted focusing on studies that occurred after 2007.

Research on Project Lead the Way:

Since June 1997, Project Lead the Way (PLTW) has continued to add course offerings and optimize curriculums. Many studies have been conducted on varying aspects of the curriculum, including opinions from parents, teachers, and principals, and test scores. Two of such studies were conducted in Indiana and, though dating back to 2007, give relevant insight for this research.

A study in Indiana was conducted on thirty-seven high school principals, who completed a Likert scale survey on their perceptions of PLTW. The primary research focus was on the principals' perceptions on the effect of PLTW on their schools. Overall, the principals had "very strong positive perception of the effect of PLTW on their schools, their teachers, and their students."[17] The relationship between the principals' demographics and their attitudes toward PLTW was a secondary research question. It was determined that there was no significant

---

[17] Rogers, George E, "The Perceptions of Indiana High School Principals Related to Project Lead The Way."

difference between the principals' perceptions of PLTW based on their demographics. Due to low diversity in participants with a small sample size, the relationship between a principal's characteristics and demographics to their perception of PLTW may not be accurate.

One of the principals' perceptions evaluated was the effect PLTW had on their teachers. An average Likert score of 4.75 was measured for the effect PLTW had on their teachers' motivation and enthusiasm. The success of students in mathematics (M = 4.39) and in science (M = 4.34) were also perceived to be positively affected by PLTW. The relationship between teacher enthusiasm and student success was not evaluated in this study, so the question of how much of student success was due to teacher enthusiasm versus the PLTW curriculum is not understood.[18] This inquiry can be expanded to the investigation of the relationship between a teacher's years of experience with PLTW and a student's success.

Shortly after the previous study, another was conducted on barriers with implementing PLTW as perceived by high school principals. Sixty principals from high schools in Indiana completed a Likert scale survey on varying topics. Responses were analyzed based on principal gender. Overall, female principals agreed more strongly to most statements, including support in implementing the program and equipment being too expensive. Female principals disagreed more strongly with statements such as PLTW would mean removing all other technology education classes and that students in their school didn't have time for PLTW courses due to core

[18] Rogers, George E, "The Perceptions of Indiana High School Principals Related to Project Lead The Way."

classes. All principals agreed that their support is important to teacher success in teaching PLTW courses.[19]

As mentioned in both 2007 studies, principal support is important in teacher success with teaching PLTW courses. Through teacher success with PLTW curriculum, students will be more likely to be successful in the courses too. Since Project Lead the Way is part of the schools' charter it is important that all administrators have positive perceptions of the curriculum.

School staff are only one key influence for students on their education. Parents can impact their children's perception and motivation for learning. At the Highland Prep Academies an annual survey is sent to parents of students who are asked their perception of staff, policies, and curriculum. Similarly, a study was conducted in an Indiana high school on the parents' perception of Project Lead the Way. The participants included 80 parents from a single school in northeastern Indiana. They completed a demographics information survey and a Likert scale survey on their perception of PLTW curriculum. The study determined that parents with a higher gross income or were male had a more positive perception of PLTW. However, this study didn't analyze the parents' perceptions based on ethnicity. This may have been due to 87.5% of parents being white.[20]

Since the Highland Prep Academies are charter schools, parents choose to enroll their students instead of sending them to the public schools. This means parents may feel that the curriculum provided is preferable to that of the other schools. As the previous study stated in

[19] Shields, C. J., "Barriers to the Implementation of Project Lead the Way as Perceived by Indiana High School Principals."

[20] Werner, Gary, Todd R. Kelley, and George E. Rogers, "Perceptions of Indiana Parents Related to Project Lead The Way."

their theoretical framework, parental involvement can have a large impact on a student's education and future. Parents who are more positive about PLTW curriculum can help their students be more successful in the courses.

A method to measure the success of a student is through state test scores. A longitudinal study conducted in Iowa evaluated the state test scores of 26,030 students as eighth graders and later as eleventh graders. A small portion, 5.07%, of these students participated in a PLTW course. The research concluded that PLTW students had a greater increase in their mathematics and science achievement percentiles in 11^{th} grade than non-participants. However, on average PLTW students had higher percentiles in 8^{th} grade than nonparticipants. Demographically, 85% of the PLTW students were male and 91% of them were white.[21]

This study shows that Project Lead the Way curriculum is beneficial to student state test scores for this high school in Iowa. The demographics of the Highland Prep Academies are very different from the Iowa PLTW students. Majority of the students enrolled in HPA are Hispanic and roughly 60% are male.[22] Based on the American College Testing (ACT), the state test in Arizona for eleventh graders, Hispanic students on average score 4.9 to 2.7 points lower than white students.[23] Research into if PLTW has the same state test score benefits for Hispanic students and students of other non-white ethnicities would need to be investigated further.

---

[21] Rethwisch, D., (2014) "A Study of the Impact of Project Lead the Way on Achievement Outcomes in Iowa"

[22] Public School Review, "Madison Highland Prep."

[23] Daniel M. McNeish, Justine Radunzel, and Edgar Sanchez, "A Multidimensional Persepective of College Readiness: Relating Student and School Characteristics to Performance on the ACT," 32.

Further research regarding the positive and negative effects of PLTW is a common thread in all aforementioned studies. A 2019 study evaluated many published articles about PLTW and compiled a pros and cons list for the curriculum. The major cons are the large expense involved with implementing and running PLTW courses, and the time consumption for the students participating in the courses. The major pros are the developing of critical thinking skills and improved academic performance of the students, and for teachers detailed activities and projects are provided in the PLTW curriculum.[24]

A 2011 study analyzed a survey from 174 teachers, of which 78 were PLTW teachers, from across the United States. Based on demographics the gender ratio for nonPLTW teachers (50/50) to PLTW teachers (73/27) of male to female is drastically different. 99% of the nonPLTW teachers and 92% of the PLTW teachers were white. A part of the survey included a Likert 7-point scale on frequency. The results concluded that nonPLTW teachers agreed more strongly that to be a successful engineer, students would need a high understanding of science, math, and technology.[25]

A similar limitation occurs in this study as in previous studies, most of the participants are white and male. This creates a gap in the research on Project Lead the Way. More data and research are needed on participants that are nonwhite and female. This is reiterated in a report from Missouri which looks at demographics of all high schools, including those that offer and don't offer PLTW.

---

[24] Stebbins, Melissa, and Tatiana Goris, "Evaluating STEM Education in the U.S. Secondary Schools: Pros and Cons of the «Project Lead the Way» Platform."

[25] Mitchell J. Nathan, Amy K. Atwood, Amy Prevost, L. Allen Phelps, Natalie A. Tran, "How Professional Development in Project Lead the Way Changes High School STEM Teachers' Beliefs about Engineering Education."

It was determined that 57% of the PLTW schools had more than 1,200 students. 91 out of 524 public schools offered PLTW while one out of thirteen charter schools offered PLTW. The nonPLTW schools had ~80% white students, while the PLTW schools had ~66% white students. However, the students that participated in PLTW at the schools were more likely to be white. All schools were roughly balanced with gender ratio, except that female participation in PLTW engineering was less than 20%. In PLTW's biomedical science course the female participation was ~72%. Schools that offered PLTW had fewer students on a free/reduced lunch plan by 10% compared to nonPLTW schools. In addition, students on a free/reduced lunch plan were less likely to participate in PLTW courses.[26]

Students who participated in PLTW had greater proficiency in 8th grade Measures of Academic Progress (MAP, Missouri state test) math, English, and science achievement by ~10-30%. At the high school level PLTW students scored on average 1.2 points higher on the ACT than nonPLTW students. PLTW students have a 2% higher graduation rate and an 8.5% increase in enrolling in four-year college.[27]

A study at a university in 2019 analyzed engineering students and their retention and graduation rate in comparison to PLTW. The fall 2010 cohort showed no difference between students who had and had not participated in PLTW. For the fall 2015 cohort there were some differences. PLTW students had a higher retention rate than nonPLTW students from first to

---

[26] 10 Camburn, Eric, Karin Chang, Takako Nomi, Michael Podgursky, Darrin DeChane, Anwuli Okwuashi, Mark Ehlert, Jeongmi Moon, and Xinyi Mao. 2023. Review of Final Report of the Impact of Project Lead the Way on Missouri High School Students.

[27] Camburn, Eric, Karin Chang, Takako Nomi, Michael Podgursky, Darrin DeChane, Anwuli Okwuashi, Mark Ehlert, Jeongmi Moon, and Xinyi Mao. 2023. Review of *Final Report of the Impact of Project Lead the Way on Missouri High School Students.*

second year of college. Majority of the enrolled students were white and male. There was no difference found in the retention rate and PLTW participation when controlling for ethnicity. An increase in retention rate was determined for racial minority students who had participated in PLTW than those who had not. No difference could be observed in female students due to all female students having not participated in PLTW.[28]

Research on STEM Curriculum:

Project Lead the Way is a STEM program that can be implemented by any school. Most high schools can be categorized as either a STEM school, a school with no STEM program, a school with a mandatory STEM program, or a school with an optional STEM program. Highland Prep Academies are STEM schools that are STEM certified by Cognia.[29]

A survey from 2019 analyzed engagement and achievement from 2,695 high school students from schools with varying STEM programs. The High School Survey of Student Engagement was used to measure cognitive, emotional, and social engagement of students. Grade point average (GPA) and standardized test scores were used to measure student academic achievement. It was determined that students in STEM programs or STEM schools had a statistically significant increase in achievements compared to non-STEM students. Unexpectedly the increase in achievement not only included mathematics and science, but also social studies, reading, writing, and overall GPA.[30]

---

[28] Juliana Utley, Toni Ivey, John Weaver, "How Professional Development in Project Lead the Way Changes High School STEM Teachers' Beliefs about Engineering Education."

[29] Madison Highland Prep, "Homepage."

[30] Patel, Nimisha H., M. Suzanne Franco, and Larry G. Daniel, "Student Engagement and Achievement: A Comparison of STEM Schools, STEM Programs, and Non-STEM Settings."

A large correlation between engagement and achievement was observed for students in STEM schools. The smallest correlation was found for students in a STEM program. This was surprising as these two instructional programs have the most in common. The correlation between engagement and achievement had similar levels for students in a non-STEM school or students opting to not participate in a STEM program.[31]

Another study evaluated the main considerations for teaching integrated STEM education, such as PLTW. Four teachers at a middle school in a midwestern state participated in the study. Data was collected through field notes, three structured observations, and weekly interviews. Observations included the teachers not always completely confident with the PLTW curriculum and implementation. The teachers weren't sure of the longevity of the curriculum, considering the teaching position as short-term. It stated that "One teacher made several comments throughout the year that she just wanted to teach a mathematics class because she did not go to school to teach STEM.". The researchers developed a "s.t.e.m. model of considerations for teaching integrated STEM education" that include key factors for support, teaching (lesson planning and classroom practices), efficacy, and materials.[32]

Having four participants limited the study to fewer data points. Furthermore, all teachers were from the same middle school in a midwestern state. Though limited by number of participants and location, the teachers had varying backgrounds including two in science, one in mathematics, and one in technology. Another limitation is that the number of years they had

---

[31] Patel, Nimisha H., M. Suzanne Franco, and Larry G. Daniel, "Student Engagement and Achievement: A Comparison of STEM Schools, STEM Programs, and Non-STEM Settings."

[32] Stohlmann, Micah, Tamara J. Moore, and Gillian H. Roehrig, "Considerations for Teaching Integrated STEM Education."

taught PLTW was not mentioned.[33] This is an important factor as confidence in teaching a subject comes with the number of years taught.[34]

Implementing STEM curriculum can create challenges and have complexities that need to be addressed. Three female teachers implementing mathematical decision-making (MDM) participated in a study that was conducted through observations and interviews. When using a prepackaged curriculum, such as MDM, set methods of implementing and presenting activities are included. It was determined that teachers who had negative perceptions of their students' abilities, backgrounds, and engagement tended to use low presentation fidelity. This was due to teachers using more direct instruction, including guided lectures or questioning techniques that were not mentioned in the curriculum. Teachers' belief about teaching affected their implementation fidelity but was primarily related to high presentation fidelity. In addition, a lack of content knowledge was related to low presentation fidelity.[35]

Project Lead the Way is a prepackaged curriculum that provides activities and presentations. A teacher guide goes over how concepts are to be presented and suggests methods for facilitating activities. Though there is no requirement to keep high fidelity with the curriculum from the organization, the cost of using the curriculum encourages proper use of all activities. However, activities can be adjusted when needed, such as due to lack of equipment. For example, in the Principles of Engineering curriculum an activity called "Project 4.2.2

---

[33] Stohlmann, Micah, Tamara J. Moore, and Gillian H. Roehrig, "Considerations for Teaching Integrated STEM Education."

[34] Odette Umugiraneza, Sarah Bansilal, and Delia North, "An Analysis of Teachers' Confidence in Teaching Mathematics and Statistics."

[35] Holstein, Krista A., and Karen Allen Keene, "The Complexities and Challenges Associated With the Implementation of a STEM Curriculum."

Waterwheel Design" has students design and construct a device that uses running water to produce electricity. For the source of water, the teacher guide states, "Use whatever source of moving water is available, whether that is a creek on the school grounds or water from a faucet.".[36] Due to not all classrooms having access to a suitable water source, sink or creek, this activity can be switched to a windmill design. Since this project is part of a unit on renewable energy, this adjustment maintains good fidelity to the original curriculum.

Teachers' perspective on their students not only affects their curriculum fidelity, but also the grade they give to students. A study observed whether biases based on STEM stereotypes were related to teachers' evaluations of student performance in mathematics. Biases can be explicit with the individual being consciously aware of them or implicit which automatically occurs based on observations. One of the most common STEM stereotypes is that white men have greater ability in mathematics and any other math-based studies.[37]

413 teachers reviewed eighteen student responses that were assigned a name distinct to a gender and ethnicity. Though the teachers were primarily white and female, they did vary in age, years of experience, and school region. Based on student gender and ethnicity there was no difference in how teachers graded the responses. It was found that there was a significant difference in grades and a teacher's belief on gender discrimination. Teachers that had strong beliefs (75th percentile) that gender discrimination was no longer a problem gave a higher score to students with a male name. While teachers who believed that gender discrimination was still

[36] Project Lead the Way, "Project 4.2.2 Teacher Resources."

[37] Yasemin Copur-Gencturk, Ian Thacker, and Joseph R. Cimpian, "Teachers' race and gender biases and the moderating effects of their beliefs and dispositions."

an issue (below 50th percentile) had no statistically significant difference in grades based on student gender.[38]

Gender and ethnic biases can affect whether a student would pursue a career in STEM. This stereotype threat is the most cited factor for the reason why female students do not go into STEM. A study in 2024 analyzed the relationship between student gender and their sense of belonging in STEM. 290 students from Durham University, University of Birmingham, and University of Oxford completed a survey. Of these students 48.6% were female and 44.8% were male. 23 students from Durham University participated in one-to-one interviews. It was determined that mostly female students defined STEM belonging as “feeling safe and comfortable in the STEM community and settings”. Furthermore, a majority of female, first-generation, and non-binary students had thought of dropping out of college occasionally or frequently.[39]

With a majority, 79%, of students being white, no definitive results were found for the relationship between ethnicity and STEM belonging. All participants came from chemistry, physics, or mathematical-science departments. Therefore, no data was collected for other fields in STEM like biology, engineering, or computer science.[40] Though high schools do not assign

[38] Yasemin Copur-Gencturk, Ian Thacker, and Joseph R. Cimpian, “Teachers’ race and gender biases and the moderating effects of their beliefs and dispositions.”

[39] Dost, Gulash, “Students’ perspectives on the ‘STEM belonging’ concept at A-level, undergraduate, and postgraduate levels: an examination of gender and ethnicity in student descriptions.”

[40] Dost, Gulash, “Students’ perspectives on the ‘STEM belonging’ concept at A-level, undergraduate, and postgraduate levels: an examination of gender and ethnicity in student descriptions.”

students to different fields of STEM, creating a sense of belonging in STEM at this age impacts their future in the fields.

The study determined key themes for students integrating into the STEM fields based on survey and interview responses. “These themes include (1) feeling safe and comfortable in the STEM community and settings, (2) having a shared passion and an interest in STEM, (3) building, bridging, bonding [...], (4) receiving adequate support from members of the STEM community, (5) building and maintaining individual resilience.” In addition, key themes for students to continue in the STEM fields are “(1) equity, inclusion, and diversity in STEM fields, (2) being valued, appreciated, and respected in STEM environments, (3) individuals’ beliefs in their capacity/ability and inquisitiveness in STEM areas, (4) STEM literacy—advancing knowledge in and of STEM.”[41]

Another study evaluated the themes of conceptualizations of STEM education. Thirteen teachers and administration from a STEM-focused high school, twelve teachers from two traditional middle schools, and nine STEM educators and stakeholders participated by creating concept maps of STEM education and completing a follow-up interview. 85% of participants mentioned connections across disciplinary subjects, 74% mentioned focusing on what “teachers must attend to instructionally when implementing a STEM approach”, and 71% mentioned making connections between classroom content and real-world problems.[42]

[41] Dost, Gulash, “Students’ perspectives on the ‘STEM belonging’ concept at A-level, undergraduate, and postgraduate levels: an examination of gender and ethnicity in student descriptions.”

[42] Tamara D. Holmlund, Kristin Lesseig, and David Slavit. “Making sense of “STEM education” in K-12 contexts.”

A study from 2016 compiled a list of essential elements of a STEM high school. Twenty schools from Ohio, Washington, California, North Carolina, and Tennessee participated through interviews. The eight elements were personalization of learning, problem-based learning, rigorous learning, career, technology, and life skills; school community and belonging, external community, staff foundations, essential factors".[43] These elements are reiterated through other studies, and some can be found in the Highland Prep Academies student handbook. Specifically, problem-based learning, rigorous learning, and career, technology, and life skills.[44]

Research on Teacher Impact:

A study in Jamaica on three school districts investigated the relationship between teacher competencies, student gender, school location, and student standardized academic test results. 623 students from 43 primary schools in grade levels three and four participated in the study. 36% of the third-grade teachers and 43% of the fourth-grade teachers had taught between 1 to 10 years of teaching. Though no relationship was found between teacher competencies and third-grade test scores, two relationships were statistically significant for the fourth-graders. Students were 1.8 times more likely to attain higher proficiency when their teacher had qualifications in education. Furthermore, students were 3.13 times more likely to attain higher

---

[43] Melanie LaForce, Elizabeth Noble, Heather King, Jeanne Century, Courtney Blackwell, Sandra Holt, Ahmed Ibrahim, and Stephanie Loo, "The eight essential elements of inclusive STEM high schools."

[44] Madison Highland Prep, "Student Handbook."

proficiency when their teacher had taught between 1 to 10 years compared to teachers who had taught 31 to 45 years.[45]

In the 2015-16 academic school year, the average years of teaching of an American teacher was 13.7 years. The majority (42.3%) of teachers had taught more than 15 years, while 19.4% taught 10-14 years, 23.2% taught 4-9 years, and 15.0% taught less than 4 years.[46] Therefore, the Jamaican study does not completely extend to American schools. Very few teachers have taught 31-45 years and grouping teachers with experience between 1 and 10 years means that no significance can be determined in the earlier years.

An Australian study focused on the initial years of teacher experience in early childhood education. Classroom observations were conducted with a 7-point scale rating on ten dimensions of teaching. These ten dimensions compose three domains, which the 80 participating teachers scored highest in Emotional Support (M = 5.24) and Classroom Organization (M = 4.90). They scored lowest in Instructional Support (M = 3.60). 25 of the teachers taught between 0-3 years while the rest taught over 3 years. An ANCOVA was used to analyze the relationship between teacher experience and the domains. There was no statistical difference in domain scores across the two groups of teachers. A deeper investigation showed the same results for the individual dimensions.[47]

---

[45] Armstrong, Melva, "The Effects of Teacher Competencies, Gender, and School Location on Primary School Standardised Academic Test Results in Three Districts in Jamaica."

[46] National Center for Education Statistics, "Percentage of public school teachers based on years of teaching experience, average total years of teaching experience, percentage of teachers based on years teaching at current school, and average years teaching at current school, by selected school characteristics: 2015–16."

[47] Graham, Linda J., Sonia L.J. White, Kathy Cologon, and Robert C. Pianta, "Do Teachers' Years of Experience Make a Difference in the Quality of Teaching?"

This study touched on factors beyond knowledge for teacher competencies. Another study investigated the positive and negative effects of teacher attitudes and behaviors on student learning. 164 female and 65 male participants from two Turkish universities completed a survey that broke down positive and negative behaviors. Ninety-nine reported negative classroom management and communication with 45 falling under the category of humiliation or insult. Eighty-three reported discrimination and injustice with 25 of the instances of discrimination based on achievement level. Twenty-three reported professional inadequacy and irresponsibility with 17 being inefficient course management. These negative teacher behaviors can cause students to disengage from lessons, which would inhibit their success.[48]

Seventy-six reported effective communication and ethical attitude with 52 participants feeling valued by their teacher. Seventy-three reported professional competence and commitment with 22 stating their teacher had subject matter expertise and effective teaching. Forty-seven reported individual support and trust with 25 identifying that their teacher gave moral and material support. Teachers with positive attitudes and behaviors can establish good relationships with students and a safe classroom environment. Even teachers who are strict can be appreciated by students for a fair classroom environment and avoiding discrimination.[49]

In the Highland Prep Academies' student handbook, it highlights similar expected behaviors for staff including teachers. Showing respect for students and providing a positive learning environment are a few of the first ones listed. Towards the end of the specified

---

[48] Kahveci, Hakkı, "The Positive and Negative Effects of Teacher Attitudes and Behaviors on Student Progress."

[49] Kahveci, Hakkı, "The Positive and Negative Effects of Teacher Attitudes and Behaviors on Student Progress."

expectations, it states “To uphold and understanding that nobody has the right to interfere with the learning of others regardless of background, race, gender or age and to uphold the understanding that nobody has the right to impose physical or mental harm on another regardless of background, race, gender, or age.”. Therefore, staff have the responsibility to not discriminate, humiliate, or insult any students, staff, parents, etc.[50]

Other aspects of positive teacher behavior are enthusiasm, engagement, creativity, commitment, and flexibility. This encompasses the term passionate teaching. A study from 2023 reviewed the impact of such teachers on student outcomes. Students achieve, learn, and engage more when being taught by a passionate teacher. By creating positive and engaging learning environments in a classroom, these teachers can promote higher academics in their students.[51]

In addition, passionate teachers are more likely to stay at a school when dealing with challenges. The study delves into what schools and districts must do to retain these high-quality teachers. Creating a supportive and rewarding environment is key to growing teacher passion and satisfaction. Providing professional development opportunities allows teachers to grow career skills and increase enthusiasm for their content specialty. Competitive salaries and benefits help teachers feel valued and appreciated. Administration support in managing job demands allows teachers to focus on their passion of teaching. All these factors promote passionate teaching and higher retention rates.[52]

---

[50] Madison Highland Prep, “Student Handbook.”

[51] Levitt, Greg, Steven Grubaugh, Joseph Maderick, and Donald Deever, “The Power of Passionate Teaching and Learning: A Study of Impacts on Social Science Teacher Retention and Student Outcomes.”

[52] Levitt, Greg, Steven Grubaugh, Joseph Maderick, and Donald Deever, “The Power of Passionate Teaching and Learning: A Study of Impacts on Social Science Teacher Retention and Student Outcomes.”

Teacher retention rates affect student achievement, similarly to teacher behavior, attitudes, and enthusiasm. A large study conducted in New York State and New York City reviewed 850,000 fourth and fifth grade students' state test scores. The data consisted of eight academic years, including fall 2001 to spring 2003 and fall 2005 to spring 2011. The math and English language art test scores were linked from student to teacher. Majority (70%) of students were either black or Hispanic and 72% of students were on the free/reduced lunch program. [53]

On average, 4% of teachers transferred to different schools within New York and 86% of teachers stayed at the same school. It was determined that the relationship between student test scores and teacher turnover is statistically significant and negative. This means the students perform poorly when a school experiences many teachers leaving. Math scores, when there is 100% turnover compared to none, are 8.2% to 10.2% standard deviations lower. Similarly, English language art test scores are 4.9% to 6.0% standard deviations lower. The study mentions that schools with large populations of low-performing students are more negatively impacted by teacher turnover.[54]

A teacher's content expertise includes content knowledge and common student misconceptions. Investigating the relationship between student learning and teacher knowledge, a study surveyed 9,556 middle school students and 181 physical science teachers. 62% of the students were white, 10% black, and 14% Hispanic. The majority of the teachers (78%) had degrees in physical science, science education, or another science. The teacher survey contained

[53] Ronfeldt, Matthew, Susanna Loeb, and James Wyckoff, "How Teacher Turnover Harms Student Achievement."

[54] Ronfeldt, Matthew, Susanna Loeb, and James Wyckoff, "How Teacher Turnover Harms Student Achievement."

subject matter knowledge (SMK) that teachers would try to answer correctly and then identify the most common wrong student answer using their knowledge of student misconceptions (SMK).[55]

40.7% of teacher responses were correct in terms of SMK and KOSM. 41.8% of teacher responses were correct with SMK, but not with KOSM. 2.0% of teacher responses were correct with KOSM, but not with SMK. 15.5% of teacher responses were incorrect in terms of SMK and KOSM. For students with high math and reading scores, they benefited from teachers having SMK only and benefited more so when their teacher had both SMK and KOSM. For students with low math and reading scores, they benefited from having teachers with KOSM and SMK. When a teacher only had SMK, the low scoring students performed more poorly in comparison to a teacher with no SMK and no KOSM.[56]

Content knowledge and understanding how to teach that knowledge are key components of being a teacher. A review of studies in 2022 investigated the impact of math teachers' competence, knowledge and pedagogy, on student learning. One study of 373 primary school teachers from Cyprus determined that content knowledge could be a prerequisite to pedagogical knowledge. Another study in the United States of 200 fourth and fifth graders found that advanced content knowledge and pedagogical knowledge were both needed for a teacher to be competent. One study examined thirty-nine novice and expert teachers' classroom management

[55] Sadler, Philip M., Gerhard Sonnert, Harold P. Coyle, Nancy Cook-Smith, and Jaimie L. Miller, "The Influence of Teachers' Knowledge on Student Learning in Middle School Physical Science Classrooms."

[56] Sadler, Philip M., Gerhard Sonnert, Harold P. Coyle, Nancy Cook-Smith, and Jaimie L. Miller, "The Influence of Teachers' Knowledge on Student Learning in Middle School Physical Science Classrooms."

perceptions, interpretations, and decision-making skills. It was determined that expert teachers were more adaptable in their course of action in the classroom. Furthermore, a cross-sectional study in China evaluated preservice, early career, and experienced teachers' noticing skills. A linear growth was observed from preservice to early career to experienced teachers' skill level. Teacher classroom-management skills positively affected student engagement. Overall, it was determined that there was a strong relationship between student outcome and instructional quality.[57]

Teacher Gender Research:

It is commonly known that the majority of teachers are female. A 2020-21 survey in the United States showed that 89% of elementary (kindergarten to sixth grade) school teachers were female. For secondary (seventh thru twelfth grade) school teachers have 64% female.[58] Research has been conducted on the impact of teacher gender on student test scores and ... Concern has been stated in regard to male students not having male teachers as role models. Similarly, concern of female students not having female teacher role models in mathematics, engineering, and physics are mentioned.

A U.S. study investigated the effects of teacher gender on student achievement in elementary schools. The 17 schools that participated were disadvantaged and had teacher shortages. 97% of the 1900 student participants were on free/reduced lunch. Pretests and

[57] Yang, Xinrong, and Gabriele Kaiser, "The Impact of Mathematics Teachers' Professional Competence on Instructional Quality and Students' Mathematics Learning Outcomes."

[58] National Center for Education Statistics, "Characteristics of Public School Teachers."

posttests were completed, and due to missing data the final participants included 1664 students and 95 teachers. Though 75% of the teachers were female the students had a 50/50 gender ratio.[59]

It was noted that in a 2010 negative effect was determined from female teachers on female students' math achievements. In a 2013 study, there was no relationship between teacher gender and student achievement. In the U.S. study it was determined that female teachers have a negative impact on mathematics outcomes of female students. This relationship was not observed for reading test scores. However, if the female teacher has a strong math background, then the negative impact is not observed. A suggestion on the reasoning of this relationship is the math anxiety hypothesis, which states "math anxiety among primary school female teachers in conjunction with female student endorsement of gender stereotypes may be leading to poorer math achievement among female students but not male students.".[60]

Primary school is the first interaction of teachers and students while a four-year university is typically the last. A 2022 study examined the career outcomes of students from the United States Air Force Academy based on professor gender in students' first year math and science classes. Participants graduated between 2004 and 2008, and included 838 female and 3,925 male students. Without taking teacher gender into consideration it was determined that 22% of female graduates worked in a STEM occupation compared to 20% of male students. STEM bachelor's

[59] Antecol, Heather, Ozkan Eren, and Serkan Ozbeklik, "The Effect of Teacher Gender on Student Achievement in Primary School."

[60] Antecol, Heather, Ozkan Eren, and Serkan Ozbeklik, "The Effect of Teacher Gender on Student Achievement in Primary School."

degrees were obtained by 28% of female students and of those with a STEM degree 42% pursued a STEM occupation.[61]

This study determined that teacher gender mostly impacts high-ability students. Female students of female professors have significantly higher academics than female students of male professors. Specifically, female students score on average 14.4% of a standard deviation lower than male students when their professor is male. It was also observed that female students were 37.1% less likely to graduate with a STEM degree than male students when they had a male professor for their freshman year math and science classes. Female students were more likely to switch to STEM occupations in two to six years after graduating if they had female math/science professors freshman year.[62]

In a 2016 study twelve New Zealand elementary schools participated in an investigation of teacher expectations about mathematics based on gender. 73% of the teachers that participated were female. Overall students with male teachers had slightly lower achievement, but it was not statistically significant ($p = 0.14$). However, female students had statistically significant ($p < 0.04$) lower achievement than male students when assigned to a male teacher. Though male students had slightly lower achievement than female students when assigned to a female teacher it was not statistically significant.[63]

---

[61] Mansour, Hani, Daniel I. Rees, Bryson M. Rintala, and Nathan N. Wozny, "The Effects of Professor Gender on the Postgraduation Outcomes of Female Students."

[62] Mansour, Hani, Daniel I. Rees, Bryson M. Rintala, and Nathan N. Wozny, "The Effects of Professor Gender on the Postgraduation Outcomes of Female Students."

[63] St J. Watson, Penelope W., Christine M. Rubie-Davies, Kane Meissei, Elizabeth R. Peterson, Annaline Flint, Lynda Garrett, and Lyn McDonald, "Gendered Teacher Expectations of Mathematics Achievement in New Zealand: Contributing to a Kink at the Base of the STEM Pipeline."

Using a survey, there was no difference in teacher expectations of students' mathematics achievement based on student gender. When expectations of students' mathematics achievement was based on teacher gender, it was found that male teachers had lower expectations. Since these lower expectations by male teachers were observed for all students, then there are other factors affecting female students having significantly lower achievement when assigned to a male teacher. A possibility posed by the study is that a male teacher unintentionally reiterated to female students the stereotype of women having inferior mathematics ability.[64]

Another study in Indiana evaluated how matching teacher and student gender impacted academic achievement. Students in third to eighth grade during the school years 2010-2011 and 2016-2017 participated in the state's standardized test over general mathematics and English language arts. The Indiana Department of Education also includes teacher demographic, which allows connecting student information to their respective teacher. A total of 766,519 students from 1,957 schools participated in the assessment.

Around 87% of the elementary teachers, both math and ELA, were female. In middle school 69.7% of the math teachers and 82.7% of the ELA teachers were female. The study determined a significant trend of an increase in student achievement when assigned to female teachers. This impact was most notable in female middle school students for mathematics. Specifically, for female elementary teachers, the coefficient in mathematics was 0.025 SD for

---

[64] St J. Watson, Penelope W., Christine M. Rubie-Davies, Kane Meissei, Elizabeth R. Peterson, Annaline Flint, Lynda Garrett, and Lyn McDonald, "Gendered Teacher Expectations of Mathematics Achievement in New Zealand: Contributing to a Kink at the Base of the STEM Pipeline."

female students compared to 0.016 SD for male students. For middle school mathematics the female teacher coefficient was 0.033 SD for female students while for male students it was 0.020 SD. These differences in mathematics test scores were statistically significant ($p < 0.001$). For ELA the differences in test scores were not significant across gender.[65]

A study in Spain focused specifically on the effect teacher gender has on student mathematics achievement. Participants included 2,083 high school students and 90 teachers from 90 different schools. Of the ninety teachers, 49.2% were female. It was found that both male and female students had improved test scores when taught by a female teacher. For male students, having a female teacher improved their score by 12 points and was statistically significant ($p < 0.05$). In contrast, test scores for female students with female teachers decreased by 10 points, but were not statistically significant.[66]

Teacher gender affects more than student ELA and mathematics achievements. A study investigated how teacher gender impacts citizenship education, which includes knowledge of rights, responsibilities to society, and roles of a democratic community. The first portion of the study was a Likert scale survey with 223 teacher responses, 30.5% male and 69.5% female. It was observed that teacher gender had statistical significance ($p = 0.01$) on the choice of guest speaker. Male and female teachers were equally likely to have a police officer as a guest speaker. Male teachers were more likely (10% difference) to have a community leader or politician as a

[65] Hwang, NaYoung, and Brian Fitzpatrick, "Student-Teacher Gender Matching and Academic Achievement."

[66] Escardíbul, Josep-Oriol, and Toni Mora, "Teacher Gender and Student Performance in Mathematics. Evidence from Catalonia (Spain)."

guest speaker. Female teachers were more likely (20% difference) to have a representative from a non-governmental agency as a guest speaker.[67]

An open-ended question survey had 206 teacher responses, 74% female and 26% male. Overall, female teachers were more likely to reference social awareness and student voice. While male teachers were more likely to reference citizenship, rights, and responsibility. The study also found some evidence that female teachers were more likely to promote greater student participation in class. Furthermore, female teachers believed that student councils were more effective than male teachers. It was determined that there was little difference in the teachers' method of teaching and perspective about civil education.[68]

Student Gender and Ethnicity Research:

Education begins in early childhood with parents and guardians introducing numbers, the alphabet, etc. This can impact a child's future in how they perceive different subjects such as mathematics and reading. A study in 2024 interviewed ten Latina mothers about their beliefs and attitudes towards mathematics. This study is important as 57% of Hispanic students who take the SAT score less than 490 in the math section.[69] In previous studies, it has been observed that Latine

[67] O'Brien, Gearóid, "Teacher Gender in Citizenship Education: Does It Make a Difference?"

[68] O'Brien, Gearóid, "Teacher Gender in Citizenship Education: Does It Make a Difference?"

[69] Ember Smith and Richard V. Reeves, "SAT math scores mirror and maintain racial inequity".

parents tend to have limited formal math education, which causes difficulties with introducing the concepts to their children.[70]

All ten participants spoke Spanish and only a few spoke English. It was quickly evident during the interviews that literacy, reading and writing English, were emphasized more in the households. The primary reason for this was to help their children adjust to American culture and achieve the American dream. All participants mentioned negative experiences with learning mathematics, which led to their lack of confidence and mathematics anxiety. This led to the participants believing there was an inherent reason why they could not understand math. Both the mathematics anxiety and misconception of the math "gene" impacted the participants ability to help their children learn early mathematical concepts.[71]

At the beginning of 2020 COVID-19 caused the lockdown of most countries. The impacts on students' education due to online learning is still being studied. A 2021 study investigated how online learning during the lockdown affected the gender gap at the college level in engineering education. The study took place at Universidad Politécnica de Madrid with the computer engineering department and included students and professors, of which 27% were female. One of the largest factors that affected female students was difficulties in managing domestic and academic tasks. This caused challenges in attending and participating in class. It was observed that the female students' performed worse academically than their male counterparts during the lockdown. This was further observed in other studies, focusing on varying academic subjects.

[70] Beltrán-Grimm, Susana, "Latina Mothers' Cultural Experiences, Beliefs, and Attitudes May Influence Children's Math Learning."

[71] Beltrán-Grimm, Susana, "Latina Mothers' Cultural Experiences, Beliefs, and Attitudes May Influence Children's Math Learning."

Furthermore, the gender gap in computer engineering increased as the dropout rate of female students increased statistically significant ($p < 0.05$) while there was no significant change in the dropout rate of male students.[72]

For some academic subjects the racial gap is more pressing than the gender gap. The medical field is white and Asian dominant, while African Americans, Latinos, and others are underrepresented. A 2023 study surveyed 192 medical students on their number of Medical College Admission Test (MCAT) attempts. 63% of the students were white, 15% Asian, 9% African American, 10% Hispanic, and 5% multiple races. The underrepresented students had more MCAT attempts than their white and Asian classmates. Additional investigation showed no statistically significant ($p < 0.05$) difference in students' use of MCAT preparation resources, attendance to a university with MCAT preparation support, cost for test, and final test scores.[73]

Another university study investigated how student gender and ethnicity affected the likelihood of earning a STEM degree. A total of 15,600 students from a research-focused institution in the southeastern United States participated. This included 7423 male students and 8177 female students. 1309 of the students were white, 1032 African American, 488 Hispanic, 366 Asian, and 105 Native Americans. International students and students who did not indicate their race were not included. This study categorized ethnic groups together in order to increase statistical power for the analysis. Hispanic, African American, and Native American students are

[72] Bordel, Borja, Ramon Alcarria, Tomás Robles, and Diego Martin, "The Gender Gap in Engineering Education During The COVID-19 Lockdown: A Study Case."

[73] Gely, Yumiko I, Ikenna H Ifearulundu, Melissa Rangel, Johanna S Balas, Yuanqing Liu, Gwyneth Sullivan, Edie Chan, Jose Velasco, and Rosalinda Alvarado, "Effects of Race and Test Preparation Resources on Standardized Test Scores, a Pilot Study."

grouped as “persons excluded due to their ethnicity or race” (PEER), while white and Asian students are in the non-PEER group.[74]

Asian students were more likely to graduate with a STEM degree than white students. However, white and Asian students are 30% more likely to receive a STEM degree than Hispanic, African American, and Native American students. Minority students were more likely than non-minority students to leave college with no degree instead of switching majors. In addition, male students were 30% more likely to earn a STEM degree than female students. Although female students are less likely to earn a STEM degree, they are more likely to earn a college degree than male students.[75]

The 2020 study in Jamaica, that included three school districts, investigated how student gender impacted standardized test scores. 623 third and fourth grade students participated in the study. For the third graders, female students were 1.92 times more likely to score mastery on the standardized test than male students. Similarly, fourth grade female students were 2.5 times more likely to score mastery on the standardized test than male students.[76]

Dual-credit courses in high school can help students obtain college degrees. Therefore, open enrollment of such courses is an important part of educational equity. A study in eastern North Carolina investigated the demographics of enrollment in Advanced Placement (AP) courses

[74] Robin A. Costello, Shima Salehi, Cissy J. Ballen, and Eric Burkholder, “Pathways of opportunity in STEM: comparative investigation of degree attainment across different demographic groups at a large research institution.”

[75] Robin A. Costello, Shima Salehi, Cissy J. Ballen, and Eric Burkholder, “Pathways of opportunity in STEM: comparative investigation of degree attainment across different demographic groups at a large research institution.”

[76] Armstrong, Melva, “The Effects of Teacher Competencies, Gender, and School Location on Primary School Standardised Academic Test Results in Three Districts in Jamaica.”

at five high schools. This included a total of 5,470 students, of which 21.92% were African American male, 23.77% were African American female, 24.84% were white male, and 24.15% were white female. White female students had the highest enrollment (43.4 - 59.0%) in all five subject areas (math, physical science, English, social science, and foreign language). White male students had the second highest enrollment (29.6 - 42.3%) in all five subject areas with foreign language being the smallest. African American female students had low enrollment (7.6 - 12.3%) in all five subject areas. African American male students had the lowest enrollment (3.8 - 6.3%) in all five subject areas. [77]

AP courses not only give college credit, but also prepare students for taking college entrance exams like the SAT. The five high schools have an average verbal SAT score of 498 and an average math SAT score of 504. African American male students average 390.4 and 407.2, while white male students average 530.4 and 557.2. African American female students average 425.2 and 429.6, while white female students average 502 and 502.4. This discrepancy is carried into college.[78]

Summary:

A gap in the published research allows this study to be impactful. Project Lead the Way research needs to be investigated for students of all demographics and types of schools. By analyzing test scores of individual PLTW courses Project Lead the Way, teachers, and

[77] Corra, Mamadi, J. Scott Carter, and Shannon K. Carter, "The Interactive Impact of Race and Gender on High School Advanced Course Enrollment."

[78] Corra, Mamadi, J. Scott Carter, and Shannon K. Carter, "The Interactive Impact of Race and Gender on High School Advanced Course Enrollment."

administration can provide required support. Curriculum such as PLTW allows schools an additional tool to implement STEM education. The knowledge of how STEM curriculum can be beneficial to students is a driving force behind schools such as the Highland Prep Academies.

Since fields of STEM have been traditionally male dominated, research on the correlation of teacher gender and student achievement can help schools know how to support change in these STEM gender stereotypes. In addition, understanding the impact of student gender and ethnicity on academic success can help schools know how to improve educational equity. Ensuring that all students have access to quality education is key to cultivating a brighter future.

CHAPTER III: METHODOLOGY

Introduction

The focus of this study is determining the significant predictors of student Project Lead the Way test scores at the Highland Prep Academies. Information on the setting and participants involved in the study is in Subsection 1, as well as limitations and the primary research question's power. Instrumentation details on the PLTW test, and the data's reliability and validity are described in Subsection 2. The procedure of how data was collected and information about the Institutional Review Board (IRB) application is given in Subsection 3. Lastly, Subsection 4 covers how each research question will be analyzed and citations on the variables used in previous studies.

Subsection 1: Setting and Participants

The Highland Prep Academies are STEM charter high schools located in Arizona, United States. Specifically, Madison Highland Prep (MHP) is in Phoenix, Highland Prep (HPS) is in Surprise, and Highland Prep West (HPW) is in Avondale. These are schools with open, limited enrollment that focus on preparing students for college. Majority of students are Hispanic at MHP (52.63%) and HPW (58.15%), while majority of students are white at HPS (46.5%). The second majority of students are white at MHP (34.3%) and HPW (24.46%), while the second majority of students are Hispanic at HPS (37.16%).

During the academic year 2022-2023, HPW only had ninth grade as the school had opened in the fall of 2022. HPS and MHP had ninth through twelfth grade students in attendance. Only MHP had Title I status due to the high percentage of students from low-income families. In total

1066 students participated in the study, though 27 students were removed due to missing data. Of the remaining 1039 students, 464 are from MHP, 438 are from HPS, and 137 are from HPW. 607 of the students are male and 432 are female. 576 of the students are Caucasian, 406 are Hispanic, 29 are African American, 10 are Native American, and 18 are Asian. 388 of the students are in ninth grade, 323 are in tenth grade, 201 are in eleventh grade, and 127 are in twelfth grade.

Students were enrolled into one of the following classes, Introduction to Engineering Design (IED), Aerospace Engineering (AE), Principles of Engineering (POE), Cybersecurity (CSC), Civil Engineering and Architecture (CEA), Digital Electronics (DE), Biomedical Science (BMS), and AP Computer Science (APCS). Of the 1039 student participants, 157 students took AE, 352 took IED, 123 took POE, 141 took CSC, 56 took DE, 108 took BMS, 102 took CEA, and 27 took APCS.

Eight teachers participated in the study by teaching the different classes. To anonymize teacher names, they are identified by letters. At MHP Teacher A taught AE, POE, and CSC at MHP, Teacher B taught BMS, and Teacher C taught IED, CEA, and APCS. AT HPW Teacher D taught IED. AT HPS Teacher E taught AE and IED, Teacher F taught CSC, DE, and CEA, Teacher G taught POE, and Teacher H taught BMS. Two of the teachers (A and B) are female while the others are male.

The results of this investigation are beneficial to the administration of Highland Prep Academies or other similar high schools that utilize Project Lead the Way curriculum. Threats to this generalization are that other schools may not have the same ratio of ethnic groups or percent of students in the free/reduced lunch program. It would be best to generalize specifically to other STEM schools but could be possibly applied to non-STEM schools. The issue with applying to non-STEM schools would be that non-STEM schools tend to not be as focused on project-based learning, which is the fundamental of PLTW.

For the main research question the desired sample size is 92. This value was determined using G*Power 3.1.9.7 with an effect size $f^2 = 0.15$, alpha level = 0.05, power = 0.80, and number of tested predictors = 5. Due to 1039 student participants, sample size is not a concern. When running a post hoc with effect size $f^2 = 0.15$, alpha level = 0.05, total sample size = 1039, and number of tested predictors = 5 a power value of 1.00 is calculated. The effect size value was selected since it is the default value in G*Power 3.1.9.7 for the statistical test of linear multiple regression.

Subsection 2: Instrumentation

Project Lead the Way tests are provided digitally by PLTW though the software Kite Portal and are given to students at the end of each course. This is a standardized test proctored similarly regardless of the school following guidelines given by PLTW. Each test is completed over two days with each day having 20 – 25 questions, which are a mix of short answer and multiple–choice questions. During the test, students can use an equation sheet, provided by PLTW, and a calculator.

If a student has an IEP or 504 that specifies a testing accommodation of extended time, alternative testing room, or questions to be read aloud, these are met through the special education department. Accommodations such as fewer questions or fewer answers in multiple-choice are unavailable since teachers are unable to edit the tests. This causes validity concerns for special education students that their PLTW scores may not accurately reflect their conceptual understanding of the curriculum.

In terms of reliability, there may be difficulty in duplicating results in other schools due to the class schedule of the Highland Prep Academies. Most traditional public schools have six to seven classes a day that are each slightly shorter than an hour. A PLTW class at such a school would be a yearlong course and PLTW's curriculum pacing guide is formulated for this. At HPA, students have four classes a day, each 90 minutes long, and most are a semester except AP classes. The curriculum's pacing is accelerated at HPA due to the difference in class schedule.

Subsection 3: Procedure

Since Highland Prep Academies has semester long courses, final exams are administered at the end of each semester. Project Lead the Way final exams are administered digitally through the Kite Portal over a two-day period. A score is then reported to the students' teachers along with a ranking on their proficiency. PLTW exams are the norm at HPA as all students must complete three PLTW courses to graduate. The scores used for this study are from 2022-23 and required no direct interaction with students as the data had been previously collected.

From the PLTW exams anonymized student scores, course, and teacher were reported. The administration of HPA provided anonymized student ethnicity, gender, grade, and entrance math exams, teacher gender, number of times the teacher had taught the course, enrolled school, and semester. All data was deidentified, ensuring participant anonymity. The identification of participants will not be available during or after the study.

The Shawnee State University's Institutional Review Board (IRB) approved an exempt review application for this study on November 7, 2023. A copy of the IRB approval form can be found in the Appendices.

Subsection 4: Data Processing and Analysis

The primary research question, "Are the number of times a teacher has taught a course, student grade, gender, ethnicity; course, teacher, teacher gender, enrolled school, and semester significant predictors of student PLTW test scores?", will use multiple linear regression (MLR) test. This test will be run with and without the covariant of entrance math exam scores. The MLR will create a model that estimates the relationship between the student PLTW test scores and the other listed variables. The variables student gender and ethnicity have been used in a study about medical certification exams.[79] Teacher gender was used in a 2021 study to evaluate the relationship in student achievement to teacher-student gender matching.[80] Though not specific to the Highland Prep Academies, other studies have investigated how different schools impact student achievement.[81] The number of times a teacher has taught a course is related to the number of years teaching which is a variable used in a study about teacher impact on emotional support, classroom organization, and instructional support.[82] A study on scientific reasoning ability investigated how student grade level relates to it.[83] Teacher and semester have been used previously but are not common. The variable teacher is included to give insight on if a specific teacher is more proficient at teaching a course. The variable semester is due to the block schedule followed by HPA such that classes only last semester.

---

[79] Haq I, Higham J, Morris R, and Dacre J, "Effect of Ethnicity and Gender on Performance in Undergraduate Medical Examinations."
[80] Hwang, NaYoung, and Brian Fitzpatrick, "Student-Teacher Gender Matching and Academic Achievement."
[81] Patel, Nimisha H., M. Suzanne Franco, and Larry G. Daniel, "Student Engagement and Achievement: A Comparison of STEM Schools, STEM Programs, and Non-STEM Settings."
[82] Graham, Linda J., Sonia L.J. White, Kathy Cologon, and Robert C. Pianta, "Do Teachers' Years of Experience Make a Difference in the Quality of Teaching?"
[83] Luo, Ma, Daner Sun, Liying Zhu, and Yuqin Yang, "Evaluating Scientific Reasoning Ability: Student Performance and the Interaction Effects between Grade Level, Gender, and Academic Achievement Level."

The secondary research question, "Is there a significant difference in student PLTW test scores across student ethnicity and gender?", will use two-way analysis of variance (ANOVA). This test will be run with and without the covariant of entrance math exam scores. An ANOVA is a statistical test that analyzes the difference between the means of more than two groups. Specifically, a two-way ANOVA uses two independent variables, and for this research question those variables are student ethnicity and gender. The dependent variable is the student PLTW test scores. For this question, the PLTW test scores will be analyzed as a whole and not by course. An analysis like this was completed in a 2005 study that evaluated the mean difference in undergraduate medical examinations across student gender and ethnicity. Two-way ANOVA was used to determine that white female students performed best on all tests.[84]

The third research question, "Is there a significant difference in student PLTW test scores across teacher gender and student gender?", will use two-way analysis of variance (ANOVA). This test will be run with and without the covariant of entrance math exam scores. As stated previously a two-way ANOVA use two independent variables, student gender and teacher gender, to analyze the difference between the mean of the dependent variable, student PLTW test scores. Similarly, for this question, the PLTW test scores will be analyzed as a whole and not by course. Student-teacher gender matchings effect on academic achievement has been previously investigated in a 2021 study. Two-way ANOVA was used to determine if there was a significant difference in mean student achievement across student and teacher gender.[85]

---

[84] Haq I, Higham J, Morris R, and Dacre J, "Effect of Ethnicity and Gender on Performance in Undergraduate Medical Examinations."

[85] Hwang, NaYoung, and Brian Fitzpatrick, "Student-Teacher Gender Matching and Academic Achievement."

The fourth research question, "Is there a significant difference in student PLTW test scores across the Highland Prep Academies?", will use multivariate analysis of variance (MANOVA). This test will be run with and without the covariant of entrance math exam scores. A MANOVA is used to analyze the differences between two or more groups when there are multiple dependent variables. The three groups are the Highland Prep Academies, MHP, HPS, and HPW. The dependent variables are the student PLTW test scores for each of the PLTW classes, AE, IED, POE, CSC, DE, BMS, CEA, APCS. A study in 2019 used the same technique with four groups (traditional school, STEM program non-participating, STEM program participating, and STEM school) and analyzing if there was a significant difference across the dependent variables, which varied from student scores in subject areas, student engagement, and student GPA.[86] By using MANOVA to analyze the student PLTW test scores across the Highland Prep Academies, any significant differences in student test scores will be identified for the courses across the schools.

Summary

Most of the participants are Hispanic and majority of participants attend Madison Highland Prep or Highland Prep Surprise. There are fewer participants from Highland Prep West since when data was collected the school only had ninth graders. Using G*Power 3.1.9.7, it was determined that with a participant pool size of 1036, there was no concern about there being too few participants. Since test scores are collected through PLTW's Kite Portal there are concerns for validity of special education students' test scores. A concern for reliability is due to

[86] Patel, Nimisha H., M. Suzanne Franco, and Larry G. Daniel, "Student Engagement and Achievement: A Comparison of STEM Schools, STEM Programs, and Non-STEM Settings."

the block schedule used by the Highland Prep Academies that includes classes only lasting one semester. A requirement of the HPA is all students must take at least three PLTW courses. Therefore, students are not exposed to any additional stressors by participating in the study. All information was provided directly by the HPA administration and was anonymized for the safety of participants. Shawnee State University's IRB approved an exempt review application for this study on November 7, 2023.

The primary research question focuses on determining significant predictors of student PLTW test scores. This will be done through multiple linear regression. The second and third research questions will use two-way analysis of variance. Question two investigates the mean difference in scores across student gender and ethnicity while question three investigates the mean difference in scores across student gender and teacher gender. The last research question analyzes the mean difference in course scores across the three schools in the HPA by using multivariate analysis of variance. Each research question will be analyzed with and without the covariant of student entrance math exam scores.

CHAPTER IV: RESULTS

Introduction:

The results of this study will be presented in this chapter. The primary goal of this study was to determine if there are significant predictors of students Project Lead the Way test scores at the Highland Prep Academies. The research questions investigated were:

1. Are the number of times a teacher has taught a course, student grade, gender, ethnicity; course, teacher gender, enrolled school, and semester significant predictors of student PLTW test scores?

2. Is there a significant difference in student PLTW test scores across student ethnicity and gender?

3. Is there a significant difference in student PLTW test scores across teacher gender and student gender?

4. Is there a significant difference in student PLTW test scores across the Highland Prep Academies (MHP, HPS, HPW)?

The following sections will go over data cleaning, description of the participants, and then addressing each of the research questions with and without the covariant entrance math exam scores. Significance levels were set at 0.05. The following references were selected for qualitative variables: C for Ethnicity, APCS for Course, MHP for school, and A for teacher.

Data Cleaning:

Initially, there were 1066 students that completed a PLTW course at one of the Highland Prep Academies. Some students did not have a recorded entrance math exam scores available. However, since this exam is very similar in concepts and set up to freshman students beginning of course exam in their mathematics course, the entrance math exam score could be replaced with their BOC score. A total of 27 students were dropped due to no recorded entrance math exam score or BOC score. The following students were dropped from the study: 80, 81, 178, 207, 233, 279, 296, 300, 337, 342, 397, 420, 457, 543, 562, 730, 745, 769, 789, 892, 920, 926, 943, 956, 981, 1032, and 1043.

Description of Participants:

The Highland Prep Academies consists of three schools: Madison Highland Prep (MHP), Highland Prep Surprise (HPS), and Highland Prep West (HPW). MHP and HPS have 9th through 12th grade students, while HPW only has 9th graders. This is due to the school having just opened for the 2022-23 academic year. Table 1 describes the number of students and their PLTW percentiles across multiple variables.

Table 1. Number of students and mean (standard deviation) of PLTW percentiles

Course	Number Students	Percentile	Gender	Number Students	Percentile
AE	157	35.567 (24.509)	F	432	37.787 (20.752)
APCS	27	57.852 (16.002)	M	607	40.361 (22.956)
BMS	108	50.907 (26.268)	Ethnicity		
CEA	102	41.304 (23.724)	A	18	43.667 (22.829)
CSC	114	38.719 (28.269)	B	29	24.793 (16.653)
DE	56	45.554 (20.047)	C	576	43.101 (22.565)
IED	352	38.759 (13.159)	H	406	34.879 (20.372)
POE	123	27.301 (21.407)	NAm	10	33.100 (25.921)
School			Grade		
MHP	464	37.646 (22.739)	9	388	40.000 (15.717)

HPS	438	38.372 (11.307)	10	323	38.025 (24.182)
HPW	137	41.114 (23.716)	11	201	36.139 (22.940)
			12	127	45.331 (29.562)

In the Highland Prep Academies there are eight teachers that teach PLTW courses. Table 2 details the information about the teachers, including mean PLTW percentiles.

Table 2. Teacher information

Teacher	Gender	School	Courses Taught	Semesters Taught	Student Percentile
A	F	MHP	AE, CSC, POE	3 and 4	35.307 (25.356)
B	F	MHP	BMS	0 and 1	55.679 (25.843)
C	M	MHP	IED, CEA, APCS	3 and 4	41.661 (16.931)
D	M	HPW	IED	0 and 1	38.372 (11.307)
E	M	HPS	AE, IED	4 and 5	36.094 (18.374)
F	M	HPS	CSC, DE, CEA	2 and 3	41.807 (25.113)
G	M	HPS	POE	4 and 5	25.457 (22.034)
H	M	HPS	BMS	0	38.500 (23.497)

Research Question 1 without Covariant:

Initially, the multiple linear regression equation was incomplete due to independent variables having perfectly collinear. Teacher was one such variable and the ones that had coefficients calculated were not statistically significant. Semester had collinearity with SemestersTaught. Dropping both variables allows a complete multiple linear regression equation. Further investigation on non-statistically significant variables, Grade ($p = 0.545$) and TeacherGender ($p = 0.197$), produced the largest adjusted R-squared value, resulting in the equation described in Table 3.

Table 3. Coefficients of RQ1 w/o Covariant

Coefficients	Estimate	Std. Error	t value	p value	2.5% CI	97.5% CI
(intercept)	62.6460	4.1230	15.194	< 0.001	54.5555	70.7365
Course AE	-16.9565	4.4028	-3.851	< 0.001	-25.5960	-8.3170
Course BMS	-3.7512	4.4502	-0.843	0.3995	-12.4838	4.9814
Course CEA	-13.1984	4.5778	-2.883	< 0.01	-22.1814	-4.2155

Course CSC	-15.0938	4.4747	-3.373	< 0.001	-23.8745	-6.3131
Course DE	-8.8445	5.0209	-1.762	0.0784	-18.6969	1.0079
Course IED	-14.6312	4.2898	-3.411	< 0.001	-23.0490	-6.2134
Course POE	-25.8984	4.4525	-5.817	< 0.001	-34.6356	-17.1613
School HPS	-3.2794	1.5271	-2.148	< 0.05	-6.2760	-0.2829
School HPW	-6.9902	2.6666	-2.621	< 0.01	-12.2229	-1.7575
SemestersTaught	-1.3222	0.3556	-3.718	< 0.001	-2.0201	-0.6244
StudentGender M	2.7951	1.3024	2.146	< 0.05	0.2393	5.3508
Ethnicity A	-0.8936	4.9126	-0.182	0.8557	-10.5335	8.7463
Ethnicity B	-15.5474	3.9307	-3.955	< 0.001	-23.2605	-7.8343
Ethnicity H	-8.2562	1.3395	-6.163	< 0.001	-10.8847	-5.6276
Ethnicity Nam	-9.9913	6.5652	-1.522	0.1284	-22.8742	2.8915

This model of calculating percentiles using the above variables is statistically reliable, $F(15, 1023) = 12.49$, $p < 0.001$, and explained 14.24% of the variance in percentile based on the regression of the other variables.

Focusing on percentiles based on course when controlling for other variables, all but two courses were not statistically significant. The reference factor for Course was chosen to be APCS as this is the highest academic level engineering course since it is an Advanced Placement course. POE students had a statistically significant, $p < 0.001$, lower percentile by about 26 points than APCS students. This was the largest difference in percentile with APCS, while CEA students had the smallest in percentile. CEA students had a statistically significant, $p < 0.001$, lower percentile by about 13 points than APCS students. AE, CSC, and IED students all had statistically significant lower percentiles than APCS students by 13 to 26 points (specific values and p-values are listed in Table 3). DE, $p = 0.0784$, and BMS, $p = 0.3995$, were not statistically significant.

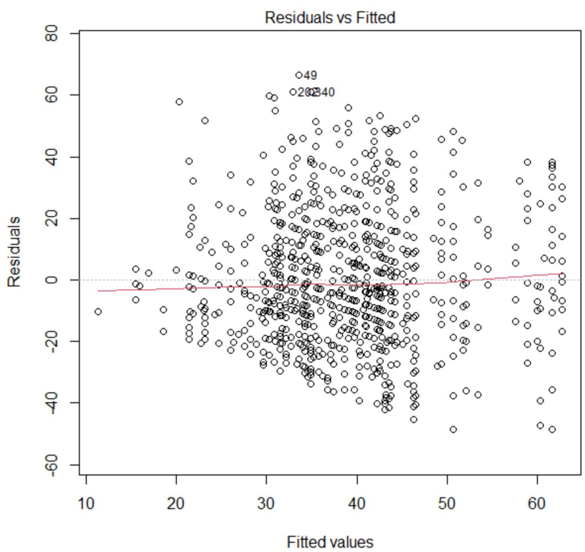
The reference factor for School is MHP since it is the founding school of the Highland Prep Academies. Controlling for other variables, HPS students had a statistically significant, $p < 0.05$, lower percentile by about 3 points than MHP students. HPW students had a statistically significant, $p < 0.01$, lower percentile by 7 points than MHP students.

Though MHP was founded a few years before HPS, HPS has an average number of semesters taught by teachers of 4.1 while MHP has an average of 3.6 semesters taught. In contrast, the average number of semesters taught by teachers is 0.4 at HPW. The number of semesters taught is statistically significant, $p < 0.001$, and indicates that for every semester a teacher has taught a course their students percentiles decrease by about 1 point.

41.6% of students at HPA are female. When controlling for other variables, this model determined that male students have a statistically significant, $p < 0.05$, greater percentile by about 3 points than female students.

For Ethnicity, Caucasian is the reference factor since 55.4% of all HPA students are Caucasian. Controlling for other variables, African American students had a statistically significant, $p < 0.001$, lower percentile by about 16 points than Caucasian students. Hispanic students had a statistically significant, $p < 0.001$, lower percentile by about 8 points than Caucasian students. Native American, $p = 0.128$, and Asian, $p = 0.856$, students were not statistically significant.

Assumptions for MLR include y-values (errors) are independent and y-values can be expressed as a linear function of the x-values. The Residuals vs. Fitted graph (*Figure 1*) below indicates that a linear relationship between Percentile and the other variables may not be the best fit. The Standardized Residuals vs. Theoretical Quantiles graph (Figure 2) suggests some concern for normality assumption. Using the Shapiro Wilks test it is determined that the data does not come from a normally distributed population, $W = 0.98336$ and $p < 0.001$.



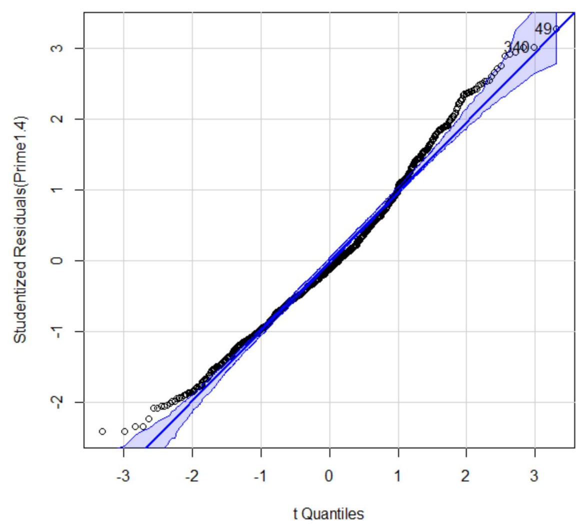


Figure 1. Graph of Residuals vs. Fitted for MLR Percentile ~ Course + School +SemestersTaught + StudentGender + StudentEthnicity

Figure 2. Graph of Standardized Residuals vs. Theoretical Quantiles for MLR Percentile ~ Course + School +SemestersTaught + StudentGender + StudentEthnicity

This model produces 50 outliers based on standard residuals being greater than 2 or less than -2. Using Cooks distance greater than 1, no outliers are determined. There are a total of 180 students that are leverages with a large difference between their percentile and the average percentile. Furthermore, this model has 691 influential points where deleting the student's data would significantly change the slope of the linear regression.

Using G*Power 3.1.9.7 with an effect size of 0.15 and an alpha error of 0.05, a total sample size of 85 participants is required to have a power of 0.80. The study has 1039 participants so having enough participants is not a concern. However, the post-hoc power with 1039 participants is 1.00.

Research Question 1 with Covariant:

Using a similar multiple linear regression equation to the previous section, a covariant is added as a baseline for students' academic levels. Entrance mathematics exams occur before students start 9th grade and allow the HPAs to adjust a student's course schedule to fit their academic levels. By adding a covariant, 27.46% of the variance in percentile based on the regression of the other variables. Therefore adding the covariant enables percentile to be more accurately predicted by the variables than without it. This model of calculating percentiles is statistically reliable, $F(16, 1022) = 25.56$, $p < 0.001$.

Table 4 Coefficients of RQ1 w/ Covariant

Coefficients	Estimate	Std. Error	t value	p value	2.5% CI	97.5% CI
(intercept)	32.2778	4.3928	7.348	< 0.001	23.6579	40.8977
Course AE	-9.2500	4.0881	-2.263	< 0.05	-17.2720	-1.2281
Course BMS	-0.6699	4.0990	-0.163	0.870	-8.7132	7.3724
Course CEA	-5.2018	4.2504	-1.224	0.221	-13.5424	3.1387
Course CSC	-6.5767	4.1620	-1.580	0.114	-14.7438	1.5904
Course DE	-2.6542	4.6397	-0.572	0.567	-11.7586	6.4502
Course IED	-6.5689	3.9889	-1.647	0.100	-14.3963	1.2585
Course POE	-17.9579	4.1358	-4.342	< 0.001	-26.0735	-9.8424
School HPS	-4.7103	1.4083	-3.345	< 0.001	-7.4738	-1.9469
School HPW	-6.8869	2.4524	-2.808	< 0.01	-11.6993	-2.0745
SemestersTaught	-1.0647	0.3276	-3.250	< 0.01	-1.7075	-0.4218
StudentGender M	2.3279	1.1983	1.943	0.052	-0.0235	4.6793
Ethnicity A	-2.8741	4.5203	-0.636	0.525	-11.7442	5.9961
Ethnicity B	-13.6675	3.6176	-3.778	< 0.001	-20.7662	-6.5688
Ethnicity H	-6.3608	1.2397	-5.131	< 0.001	-8.7935	-3.9282
Ethnicity Nam	-10.8863	6.0383	-1.803	0.072	-22.7351	0.9625
EntMathScore	0.4748	0.0347	13.693	< 0.001	0.4067	0.5428

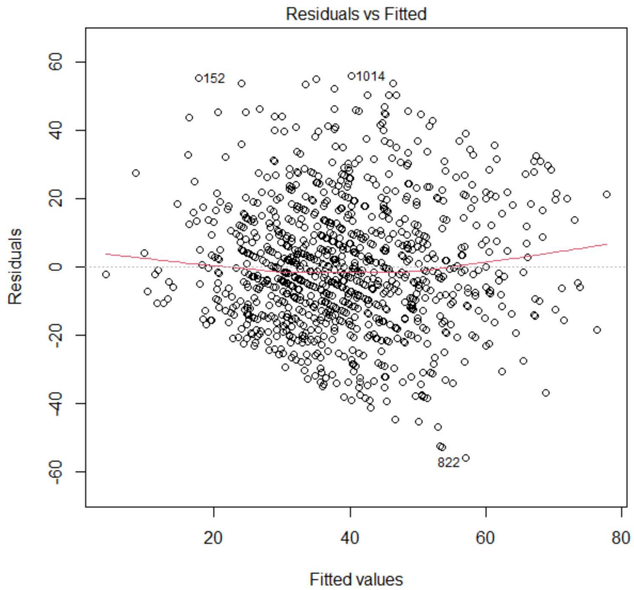
When controlling for all variables except for course, there are only two courses with statistical significance for student percentiles. POE students have a statistically significant, $p < 0.001$, lower percentile by 18 points than APCS students. AE students have a statistically significant, $p < 0.05$, lower percentile by about 9 points than APCS students. The other courses were not statistically significant and the corresponding p-values are listed in Table 4.

Both HPS and HPW are still statistically significant, $p < 0.001$ and $p < 0.01$ respectively, when controlling for other variables. HPS students score about 5 points lower than MHP students while HPW students score about 7 points lower than MHP students. Similarly, the number of semesters a teacher has taught a course is statistically significant, $p < 0.01$. For every semester a teacher has taught a course their students percentiles decrease by about 1 point. However, student gender is not a statistically significant, $p = 0.052$, variable when including the covariant in the model.

When controlling for other variables except for student ethnicity, it is found that two ethnic groups are statistically significant. Native American and Asian students are not a statistically significant, $p = 0.072$ and $p = 0.525$ respectively, predictor of percentile compared to Caucasian students. African American students score about 14 points less than Caucasian students and are statistically significant, $p < 0.001$. Likewise, Hispanic students are statistically significant, $p < 0.001$, and score about 6 points less than Caucasian students.

The covariant of entrance mathematics exam score is a statistically significant, $p < 0.001$, predictor of student PLTW percentiles. For every point on the entrance exam a student's percentile increases by half a point.

Assumptions for MLR include y-values (errors) are independent and y-values can be expressed as a linear function of the x-values. The Residuals vs. Fitted graph (Figure 3) below indicates that a linear relationship between Percentile and the other variables may not be the best fit. The Standardized Residuals vs. Theoretical Quantiles graph (Figure 4) suggests some concern for normality assumption. Using the Shapiro Wilks test it is determined that the data does not come from a normally distributed population, W = 0.98995 and $p < 0.001$.



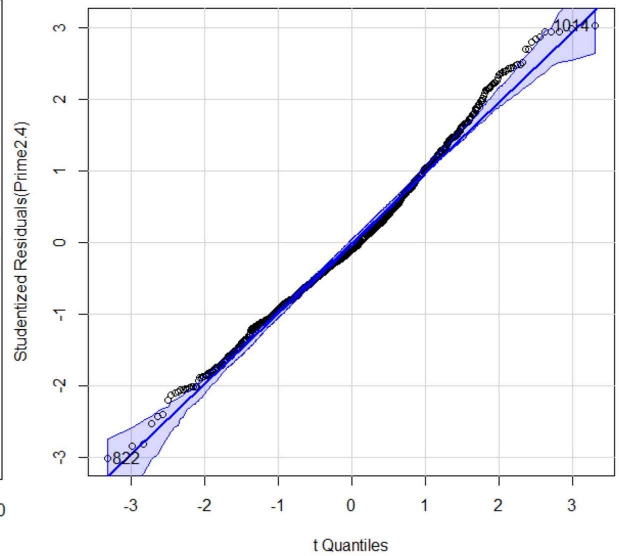


Figure 3. Graph of Residuals vs. Fitted for MLR Percentile ~ Course + School +SemestersTaught + StudentGender + StudentEthnicity + EntMathScore

Figure 4. Graph of Standardized Residuals vs. Theoretical Quantiles for MLR Percentile ~ Course + School +SemestersTaught + StudentGender + StudentEthnicity + EntMathScore

This model produces 58 outliers based on standard residuals being greater than 2 or less than -2. Using Cooks distance greater than 1, no outliers are determined. There are a total of 144 students that are leverages with a large difference between their percentile and the average percentile. Furthermore, this model has 664 influential points where deleting the student's data would significantly change the slope of the linear regression.

Using G*Power 3.1.9.7 with an effect size of 0.15 and an alpha error of 0.05, a total sample size of 92 participants is required to have a power of 0.80. The study has 1039 participants so having enough participants is not a concern. However, the post-hoc power with 1039 participants is 1.00.

Research Question 2 without Covariant:

The focus of the secondary research question is determining if there is a significant difference in student PLTW percentiles across student ethnicity and gender. Mean percentiles across student ethnicity and gender are listed in Table 5. Male, African American students had the lowest mean percentile while male, Native American students had the highest mean percentile. It's important to note there are less than 20 Native American, African American, and Asian students for each gender. This may cause misrepresentation of mean percentiles across student ethnicity and gender. Furthermore, since the groups are not evenly sized, this causes an unbalanced design.

Table 5. Student mean percentiles across student ethnicity and gender

Ethnicity	Gender	Number of Students	Mean Percentile
C	F	225	41.427 (21.259)
A	F	6	41.667 (27.156)
B	F	10	34.900 (22.358)
H	F	184	33.995 (19.231)
NAm	F	7	21.286 (11.528)
C	M	351	44.174 (23.330)
A	M	12	44.667 (21.609)
B	M	19	19.474 (9.737)
H	M	222	35.613 (21.288)
NAm	M	3	60.667 (31.565)

Table 6 details the results of the two-way ANOVA, investigating variables Ethnicity, StudentGender, and their interaction. There is a statistically significant mean difference in percentile across student ethnicity, F(4, 1029) = 12.151, p < 0.001. Though there is no statistically significant mean difference across student gender, F(1, 1029) = 2.447, p = 0.118, there is a statistically significant mean difference across the interaction of student ethnicity and gender, F(4, 1029) = 2.703, p < 0.05. Therefore focus will be directed towards this interaction.

*Table 6. ANOVA values for Percentile ~ Ethnicity * StudentGender*

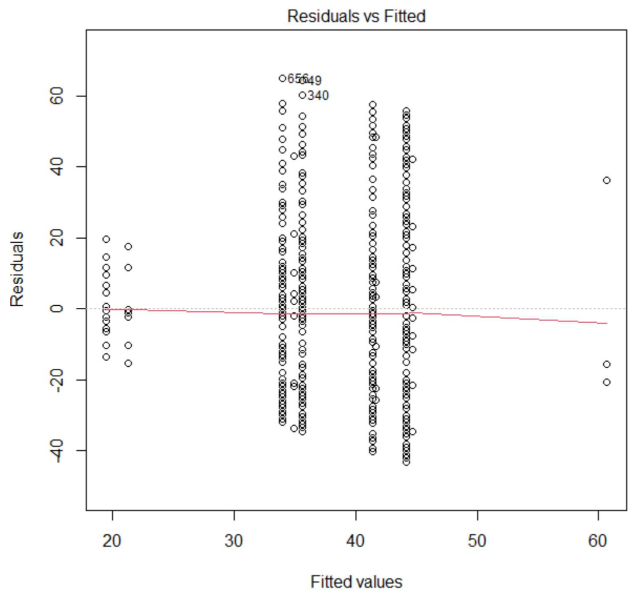
	Sum Sq	df	F-value	p-value
Ethnicity	22548	4	12.151	< 0.001
StudentGender	1135	1	2.447	0.118
Ethnicity:StudentGender	5015	4	2.703	< 0.05
Residuals	477377	1029		

An in-depth analysis of the mean differences for the interaction of student ethnicity and gender was completed using Tukey Honest Significant Differences. Results of this test are given in Table 7. Most differences are not statistically significant and have p-values listed in Table 7, while six interactions are statistically significant. Hispanic female students score on average about 7% less than Caucasian female students, p < 0.05. African American male students score on average 22% less than Caucasian female students, p < 0.001, and score on average about 25% less than Caucasian male students, p <0.001. In addition, African American male students score on average 25% less than Asian male students, p < 0.05. Caucasian male students score on average 10% higher than Hispanic female students, p < 0.001, and score on average about 9% higher than Hispanic male students, p <,0.001.

*Table 7. Tukey multiple comparisons of means for the two-way ANOVA of Percentile ~ Ethnicity * StudentGender based on the interaction of Ethnicity and StudentGender*

Group 1	**Group2**	**Difference**	**2.5% CI**	**97.5% CI**	**p-value**
A:F	C:F	0.240	-28.010	28.490	1.000
B:F	C:F	-6.527	-28.597	15.544	0.995

H:F	C:F	-7.432	-14.220	-0.644	< 0.05
NAm:F	C:F	-20.141	-46.352	6.070	0.305
C:M	C:F	2.747	-3.085	8.579	0.895
A:M	C:F	3.240	-16.993	23.473	1.000
B:M	C:F	-21.953	-38.269	-5.637	< 0.001
H:M	C:F	-5.814	-12.274	0.646	0.120
NAm:M	C:F	19.240	-20.451	58.931	0.877
B:F	A:F	-6.767	-42.033	28.500	1.000
H:F	A:F	-7.672	-36.003	20.659	0.998
NAm:F	A:F	-20.381	-58.375	17.614	0.795
C:M	A:F	2.507	-25.611	30.625	1.000
A:M	A:F	3.000	-31.146	37.146	1.000
B:M	A:F	-22.193	-54.174	9.788	0.457
H:M	A:F	-6.054	-34.309	22.201	1.000
NAm:M	A:F	19.000	-29.290	67.290	0.964
H:F	B:F	-0.905	-23.081	21.270	1.000
NAm:F	B:F	-13.614	-47.269	20.041	0.957
C:M	B:F	9.274	-12.628	31.175	0.943
A:M	B:F	9.767	-19.475	39.008	0.988
B:M	B:F	-15.426	-42.107	11.254	0.714
H:M	B:F	0.713	-21.365	22.790	1.000
NAm:M	B:F	25.767	-19.189	70.723	0.724
NAm:F	H:F	-12.709	-39.008	13.590	0.879
C:M	H:F	10.179	3.964	16.395	< 0.001
A:M	H:F	10.672	-9.675	31.019	0.816
B:M	H:F	-14.521	-30.977	1.936	0.138
H:M	H:F	1.618	-5.190	8.427	0.999
NAm:M	H:F	26.672	-13.077	66.421	0.508
C:M	NAm:F	22.888	-3.180	48.956	0.143
A:M	NAm:F	23.381	-9.099	55.861	0.401
B:M	NAm:F	-1.812	-32.007	28.383	1.000
H:M	NAm:F	14.327	-11.889	40.543	0.777
NAm:M	NAm:F	39.381	-7.746	86.507	0.196
A:M	C:M	0.493	-19.556	20.541	1.000
B:M	C:M	-24.700	-40.786	-8.614	< 0.001
H:M	C:M	-8.561	-14.417	-2.705	< 0.001
NAm:M	C:M	16.493	-23.104	56.090	0.949
B:M	A:M	-25.193	-50.375	-0.011	< 0.05
H:M	A:M	-9.054	-29.294	11.186	0.922
NAm:M	A:M	16.000	-28.083	60.083	0.979
H:M	B:M	16.139	-0.185	32.463	0.056
NAm:M	B:M	41.193	-1.235	83.621	0.066
NAm:M	H:M	25.054	-14.640	64.748	0.598



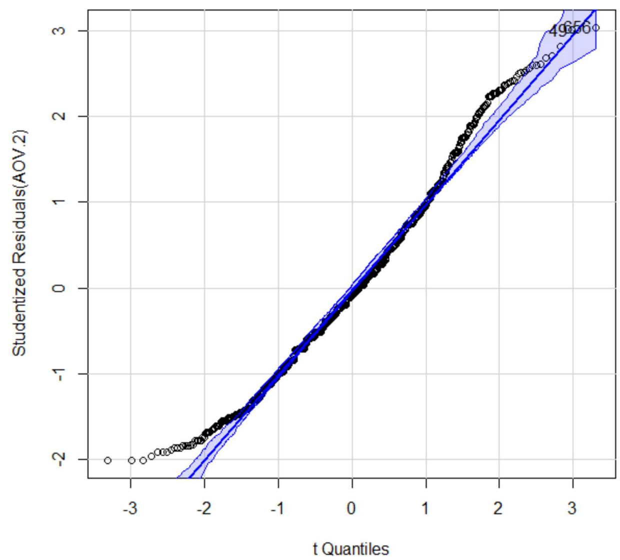


*Figure 5. Graph of Residuals vs Fitted values for two-way ANOVA Percentile ~ Ethnicity * StudentGender*

*Figure 6. Graph of Standardized Residuals vs. Theoretical Quantiles of two-way ANOVA Percentile ~ Ethnicity * StudentGender*

The first assumption checked is homogeneity of variance through a graph of residuals vs. fitted values, depicted in Figure 5. Based on the graph there is concern for the homogeneity of the data. Using the Levene Test, $F(9, 1029) = 2.8147$, $p < 0.01$, it is clear that the assumption of homogeneity of variance is false. A deeper dive into the variances of the interactions results in the data under *Table 8*. The variances for female Native American and male African American students are smaller compared to the others. Variances for male Native American and female Asian students are much larger compared to the other variances. The second assumption is normality, which is depicted in a graph of standardized residuals vs theoretical quantiles (Figure 6). This graph presents concerns for the normality assumption and using the Shapiro-Wilk test, $W = 0.982$, $p < 0.001$, it is confirmed that the data does not come from a normally distributed population.

Table 8. Variances across StudentGender and Ethnicity

Gender	Ethnicity	Variance
F	C	451.933
M	C	544.281
F	A	737.467
M	A	466.970
F	B	499.878
M	B	94.819
F	H	369.820
M	H	453.161
F	NAm	132.905
M	NAm	996.333

Using G*Power 3.1.9.7 with an effect size of 0.102 and an alpha error of 0.05, a total sample size of 1152 participants is required to have a power of 0.80. The study has 1039 participants so there are not enough participants to meet a power of 0.80. The post-hoc power with 1039 participants is 0.752.

Research Question 2 with Covariant:

Following the same model as the previous section, a covariant of entrance math exam score is added. *Table 9* details the mean entrance math exam scores across student gender and ethnicity. Female Asian students had the highest mean at 55.917 while male African American students had the lowest mean at 41.758.

Table 9. Mean Entrance Math Scores across student gender and ethnicity

Ethnicity	Gender	Number of Students	Mean Entrance Math Score
C	F	225	47.488 (17.766)
A	F	6	55.917 (17.472)
B	F	10	50.140 (14.662)
H	F	184	44.959 (17.604)
NAm	F	7	49.929 (20.858)
C	M	351	49.757 (17.130)
A	M	12	53.992 (19.024)

B	M	19	41.758 (12.544)
H	M	222	44.155 (17.762)
NAm	M	3	51.500 (3.593)

Table 10 details the results of the ANCOVA for percentile across student gender and ethnicity with entrance math exam scores as the covariant. Student gender is not statistically significant, $F(40, 907) = 0.115$, $p = 0.735$, and student ethnicity is statistically significant, $F(5435, 907) = 3.900$, $p < 0.01$. The main focus will be the interaction between student ethnicity and gender since it is statistically significant, $F(4, 907) = 3.008$, $p < 0.05$.

*Table 10. ANCOVA values for Percentile ~ Ethnicity * StudentGender + EntMathScore*

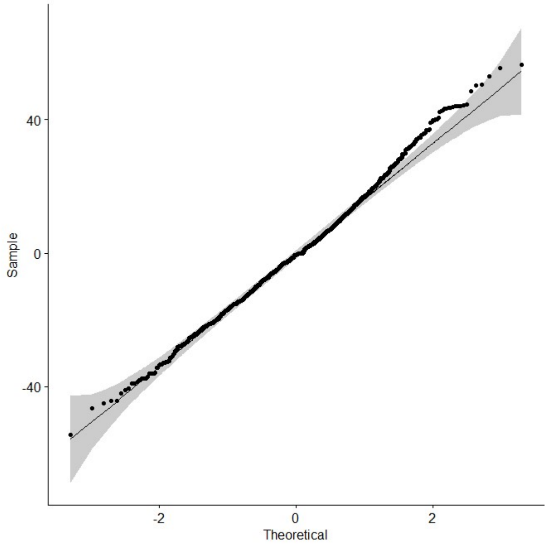
	Sum Sq	df	F-value	p-value
(Intercept)	9941	1	28.535	< 0.001
StudentGender	40	1	0.115	0.735
Ethnicity	5435	4	3.900	< 0.01
EntMathScore	161382	122	3.797	< 0.001
StudentGender:Ethnicity	4191	4	3.008	< 0.05
Residuals	315995	907		

Nine mean differences across student gender and ethnicity are statistically significant. The mean differences and p-values for all groups are listed in *Table 11*. There is a significant mean difference between male African American students and female Caucasian students, $p < 0.001$, with male African American students scoring 19 percent lower on PLTW exams. The mean difference between female Hispanic students and female Caucasian students is statistically significant, $p < 0.001$, with female Hispanic students scoring 8 percent lower. The mean difference between male Hispanic students and female Caucasian students is statistically significant, $p < 0.05$, with male Hispanic students scoring 6 percent lower. The mean difference between male African American students and male Caucasian students is statistically significant, $p < 0.001$, with male African American students scoring 21 percent lower. The mean difference between female Hispanic students and male Caucasian students is statistically significant, $p < 0.001$, with female Hispanic students scoring 10 percent lower. The mean difference between male Hispanic students and male Caucasian students is statistically significant, $p < 0.001$, with male Hispanic students scoring 8 percent lower. The mean difference between female Native American students and male Caucasian students is statistically significant, $p < 0.05$, with female Native American students scoring 23 percent lower. The mean difference between male African American students and male Asian students is statistically significant, $p < 0.05$, with male African American students scoring 24 percent lower. The mean difference between male African American students and male Native American students is statistically significant, $p < 0.05$, with male African American students scoring 39 percent lower.

*Table 11. Tukey multiple comparisons of means for the two-way ANCOVA of Percentile ~ Ethnicity * StudentGender + EntMathScore based on the interaction of Ethnicity and StudentGender*

Group 1 - Group 2	Difference	2.5% CI	97.5% CI	p-value
M:C-F:C	1.815	-3.241	6.870	0.981
F:A-F:C	-5.043	-29.531	19.445	1.000
M:A-F:C	5.029	-12.510	22.568	0.996
F:B-F:C	-13.182	-32.314	5.950	0.468
M:B-F:C	-19.317	-33.460	-5.174	< 0.001
F:H-F:C	-8.195	-14.079	-2.311	< 0.001
M:H-F:C	-6.221	-11.821	-0.620	< 0.05
F:NAm-F:C	-21.105	-43.826	1.615	0.095
M:NAm-F:C	19.596	-14.810	54.002	0.731
F:A-M:C	-6.858	-31.232	17.516	0.997
M:A-M:C	3.215	-14.165	20.594	1.000
F:B-M:C	-14.997	-33.983	3.988	0.267
M:B-M:C	-21.132	-35.076	-7.188	< 0.001
F:H-M:C	-10.010	-15.398	-4.622	< 0.001
M:H-M:C	-8.035	-13.112	-2.959	< 0.001

F:NAm-M:C	-22.920	-45.517	-0.323	< 0.05
M:NAm-M:C	17.781	-16.543	52.106	0.827
M:A-F:A	10.072	-19.527	39.672	0.987
F:B-F:A	-8.139	-38.710	22.431	0.998
M:B-F:A	-14.274	-41.997	13.449	0.832
F:H-F:A	-3.152	-27.711	21.407	1.000
M:H-F:A	-1.177	-25.670	23.315	1.000
F:NAm-F:A	-16.062	-48.998	16.873	0.873
M:NAm-F:A	24.639	-17.221	66.500	0.692
F:B-M:A	-18.212	-43.559	7.136	0.404
M:B-M:A	-24.346	-46.175	-2.518	< 0.05
F:H-M:A	-13.225	-30.862	4.413	0.340
M:H-M:A	-11.250	-28.795	6.295	0.575
F:NAm-M:A	-26.135	-54.289	2.020	0.095
M:NAm-M:A	14.567	-23.646	52.780	0.971
M:B-F:B	-6.135	-29.263	16.993	0.998
F:H-F:B	4.987	-14.235	24.210	0.998
M:H-F:B	6.962	-12.176	26.099	0.979
F:NAm-F:B	-7.923	-37.097	21.251	0.997
M:NAm-F:B	32.779	-6.191	71.748	0.189
F:H-M:B	11.122	-3.143	25.387	0.285
M:H-M:B	13.097	-1.054	27.247	0.097
F:NAm-M:B	-1.788	-27.963	24.386	1.000
M:NAm-M:B	38.913	2.135	75.692	< 0.05
M:H-F:H	1.975	-3.927	7.877	0.988
F:NAm-F:H	-12.910	-35.707	9.887	0.738
M:NAm-F:H	27.792	-6.665	62.248	0.239
F:NAm-M:H	-14.885	-37.610	7.841	0.544
M:NAm-M:H	25.817	-8.592	60.226	0.339
M:NAm-F:NAm	40.701	-0.150	81.553	0.052



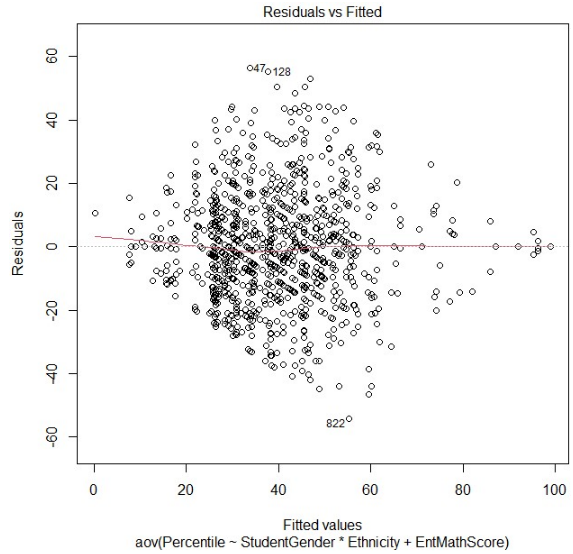


*Figure 7. Graph of Standardized Residuals vs. Theoretical Quantiles of two-way ANCOVA Percentile ~ Ethnicity * StudentGender + EntMathScore*

*Figure 8. Graph of Residuals vs Fitted values for two-way ANCOVA Percentile ~ Ethnicity * StudentGender + EntMathScore*

Graphing standardized residuals vs. theoretical quantiles, *Figure 7*, it is apparent that there is some concern for the normality assumption. The Shapiro-Wilk test, W = 0.994, $p < 0.001$, makes it clear that the data does not come from a normally distributed population. Based on *Figure 8*, a graph of residuals vs fitted values, it is discerned that the equal variances assumption cannot be held true. This is further proven by looking at *Table 8*.

Using G*Power 3.1.9.7 with an effect size of 0.102 and an alpha error of 0.05, a total sample size of 1152 participants is required to have a power of 0.80. The study has 1039 participants so there are not enough participants to meet a power of 0.80. The post-hoc power with 1039 participants is 0.752.

Research Question 3 without Covariant:

The third research question focuses on determining if there is a significant mean difference in student PLTW percentiles across student and teacher genders. Mean percentiles across student and teacher genders are presented in Table 12. The lowest mean percentile is from female students with male teachers, while the highest mean percentile is male students with female teachers. The number of students with female teachers is low in comparison to the number of students with male teachers due to there only being two female PLTW teachers at the Highland Prep Academies.

Table 12. Number of students and mean (standard deviation) percentiles across student and teacher genders

Teacher Gender	Student Gender	Number of Students	Mean Percentile
F	F	124	39.387 (25.347)
M	F	308	37.143 (18.593)
F	M	166	41.831 (28.209)
M	M	441	39.807 (20.646)

Using a two-way ANOVA it is determined that neither the interaction nor individual variables are statistically significant. Specific p-values are listed in Table 13. Therefore, no further investigation into the mean differences across the variables will be completed.

Table 13. Two-way ANOVA of StudentGender and TeacherGender

	Sum Sq	df	F-value	p-value
(Intercept)	192367	1	395.038	< 0.001
StudentGender	424	1	0.871	0.351
TeacherGender	445	1	0.914	0.339
StudentGender:TeacherGender	2	1	0.005	0.943
Residuals	504001	1035		

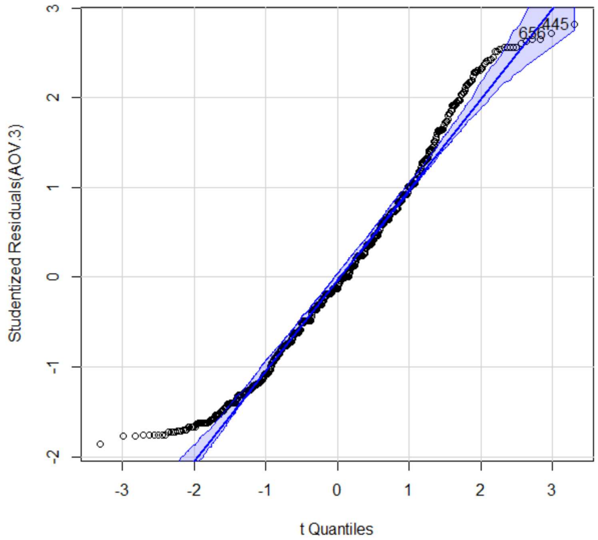


*Figure 9. Graph of Standardized Residuals vs. Theoretical Quantiles of two-way ANOVA Percentile ~ TeacherGender * StudentGender*

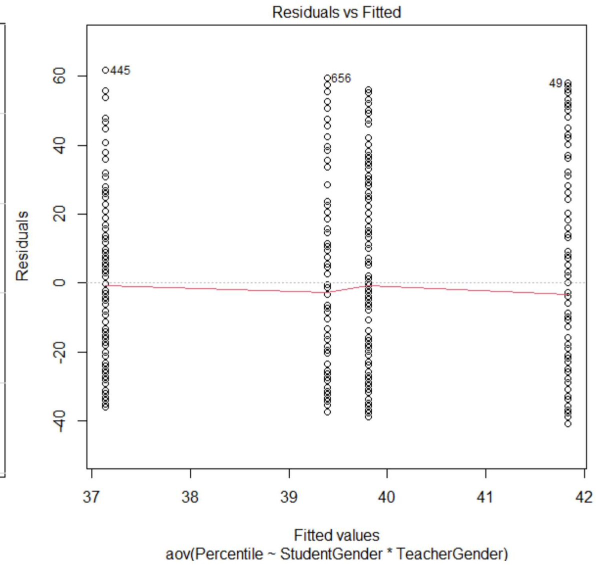


Figure 10. Graph of Residuals vs Fitted values for two-way ANOVA Percentile ~ TeacherGender StudentGender*

The graph of standardized residuals vs. theoretical quantiles (*Figure 9*) raises concerns for the normality assumption. Using the Shapiro-Wilk's test, W = 0.982, $p < 0.001$, it is determined that the data does not come from a normally distributed population. *Figure 10* depicts residuals vs. fitted values for the model and does not appear too concerning in regard to the equal variances' assumption. A Levene's test, F(3) = 22.915, $p < 0.001$, however makes it clear that the assumption is rejected. Furthermore, *Table 14* lists the variances across student and teacher genders showing a large range in values from 345.699 to 795.741.

Table 14. Variances across student and teacher genders

Teacher Gender	Student Gender	Variance
F	F	642.482
M	F	345.699
F	M	795.741
M	M	426.247

Using G*Power 3.1.9.7 with an effect size of 0.0022 and an alpha error of 0.05, a total sample size of 1,621,668 participants is required to have a power of 0.80 for the interaction of StudentGender and TeacherGender. The study has 1039 participants so there are not enough participants to meet a power of 0.80. The post-hoc power with 1039 participants is 0.051.

Research Question 3 with Covariant:

The mean entrance math exam scores across student and teacher genders is listed in *Table 15*. The range in means is very small, 46.572 – 47.725. Adding the variable of entrance math exam scores to the previous model as a covariant results in an ANCOVA where no statistically significant mean difference of PLTW percentiles across the interaction variable occurs, $F(1,913) = 1.199$, $p = 0.274$. In addition, there is no statistically significant mean difference of PLTW percentiles across student gender either, $F(1, 913) = 0.221$, $p = 0.639$. A statistically significant mean difference of PLTW percentiles across teacher gender does exist, $F(1, 913) = 4.773$, $p < 0.05$. More details on the ANCOVA results are listed in *Table 16*.

Table 15. Mean Entrance Math Score across student gender and teacher gender

Teacher Gender	Student Gender	Number of Students	Mean Entrance Math Score
F	F	124	46.768 (18.236)
M	F	308	46.572 (17.496)
F	M	166	47.085 (18.102)
M	M	441	47.725 (17.228)

*Table 16. ANCOVA values for Percentile ~ TeacherGender * StudentGender + EntMathScore*

	Sum Sq	df	F-value	p-value
(Intercept)	9388	1	26.299	< 0.001
StudentGender	79	1	0.221	0.639
TeacherGender	1704	1	4.773	< 0.05

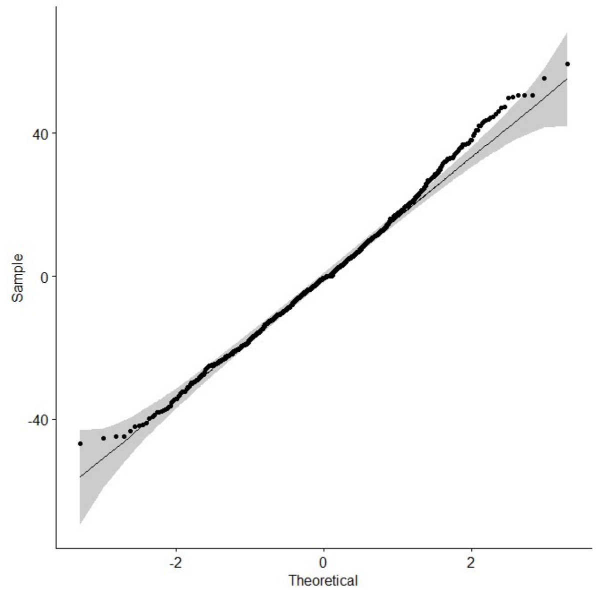
EntMathScore	178096	122	4.090	< 0.001
StudentGender:TeacherGender	428	1	1.199	0.274
Residuals	325905	913		

Focusing on the mean difference of PLTW percentiles across teacher gender, a Tukey HSD results are listed in *Table 17*. Though the mean difference across teacher gender is statistically significant, the difference from students with male teachers to students with female teachers is not statistically significant, p = 0.106.

*Table 17. Tukey multiple comparisons of means for the two-way ANCOVA of Percentile ~ TeacherGender * StudentGender + EntMathScore based on the variable TeacherGender*

Group 1 - Group 2	Difference	2.5% CI	97.5% CI	p-value
M-F	-2.117	-4.681	0.448	0.106

Figure 11 is a graph of standardized residuals vs. theoretical quantiles and shows some concern for the normality assumption. The Shapiro-Wilks test, W = 0.995, p < 0.001, indicates that the data does not come from a normally distributed population. The graph of residuals vs fitted values, *Figure 12*, shows concern for the equal variance assumption. From the previous section and *Table 14* it is clear that the equal variance assumption cannot be made for the ANCOVA model.



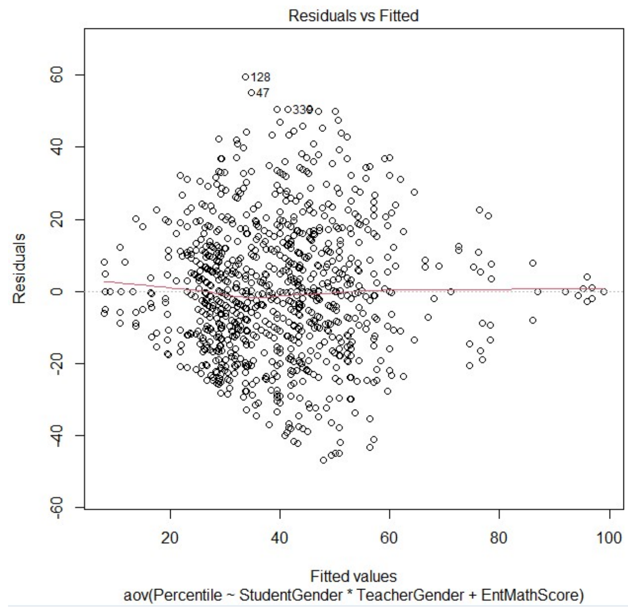


*Figure 11. Graph of Standardized Residuals vs. Theoretical Quantiles of two-way ANCOVA Percentile ~ TeacherGender * StudentGender + EntMathScore*

*Figure 12. Graph of Residuals vs Fitted values for two-way ANCOVA Percentile ~ TeacherGender * StudentGender + EntMathScore*

Focusing on TeacherGender and using G*Power 3.1.9.7 with an effect size of 0.068 and an alpha error of 0.05, a total sample size of 1700 participants is required to have a power of 0.80. The study has 1039 participants so there are not enough participants to meet a power of 0.80. The post-hoc power with 1039 participants is 0.591.

Research Question 4 without Covariant:

The Highland Prep Academies consist of three schools: Madison Highland Prep, Highland Prep Surprise, and Highland Prep West. MHP had 464 students complete PLTW courses in 2022-23 with a mean percentile of 41.1, which is the highest average of the three schools. HPS has the lowest mean percentile of 37.6 with 438 students completing PLTW courses in the same year. Values for the schools are listed in *Table 18*.

Table 18. Mean Percentiles across Highland Prep Academies

School	Number of Students	Mean Percentile
HPS	438	37.646 (22.739)
HPW	137	38.372 (11.307)
MHP	464	41.114 (23.716)

The results of the ANOVA investigating the percentile mean difference across the schools is detailed in *Table 19*. The mean difference across the schools is not statistically significant, $F(2, 1036) = 2.923$, $p = 0.054$.

Table 19. ANOVA values for Percentile ~ School

	Sum Sq	df	F-value	p-value
(Intercept)	784336	1	1612.985	< 0.001
School	2843	2	2.923	0.054
Residuals	503769	1036		

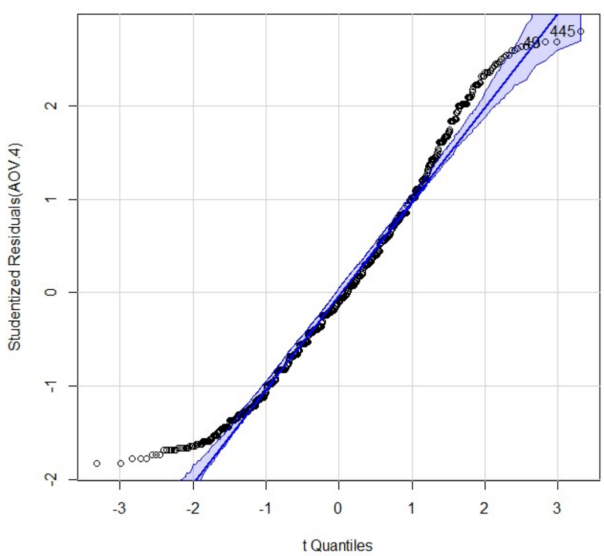


Figure 13. Graph of Standardized Residuals vs. Theoretical Quantiles of ANOVA Percentile ~ School

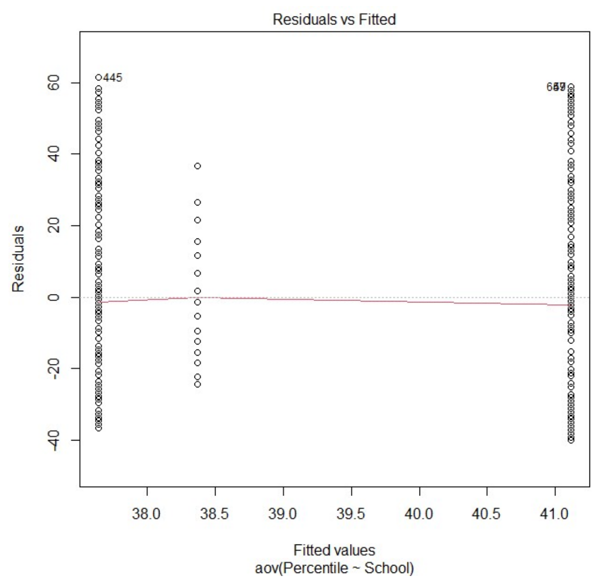


Figure 14. Graph of Residuals vs Fitted values for ANOVA Percentile ~ School

The graph of standardized residuals vs. theoretical quantiles,

Figure 13, indicates major concerns regarding the normality assumption. The Shapiro-Wilk test proves that the data cannot be assumed to come from a normally distributed population, $W = 0.979$, $p < 0.001$. Concern for the equal variance assumption is apparent in *Figure 14*. The Levene's Test for Homogeneity of Variance indicates that variances cannot be assumed to be equal, $F(2, 1036) = 36.077$, $p < 0.001$. *Table 20* lists the percentile variances for each school. MHP and HPS have similar variances, while HPW does not.

Table 20. Percentile variances at each school

School	Variance
MHP	562.464
HPS	517.076
HPW	127.838

Using G*Power 3.1.9.7 with an effect size of 0.075 and an alpha error of 0.05, a total sample size of 1716 participants is required to have a power of 0.80. The study has 1039 participants so there are not enough participants to meet a power of 0.80 for the School variable. The post-hoc power with 1039 participants is 0.571.

Research Question 4 with Covariant:

Following the previous section, the covariant of entrance math exam score is added to the ANOVA. *Table 21* details the mean and standard deviation of entrance math score for each of the schools. Highland Prep Surprise had the highest mean of 48.276 for the entrance math score, while Highland Prep West had the lowest mean of 45.580.

Table 21. Mean Entrance Math Score across Highland Prep Academies

School	Number of Students	Mean Entrance Math Score
HPS	438	48.276 (16.919)
HPW	137	45.580 (17.261)
MHP	464	46.588 (18.188)

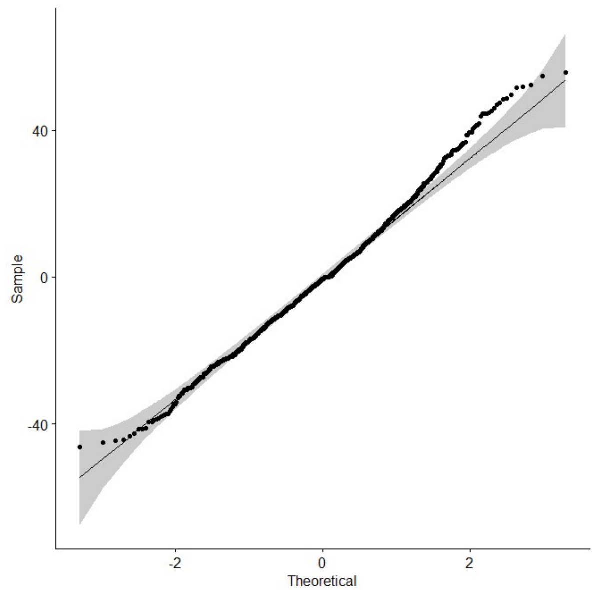
By adding the covariant of entrance math exam score, the mean difference in PLTW percentiles across the schools is statistically significant, $F(2, 914) = 6.771$, $p < 0.01$. Other values from the ANCOVA are listed in *Table 22*. Using a Tukey multiple comparisons of means for the ANCOVA, a significant mean difference is observed between Highland Prep Surprise and Madison Highland Prep, $p < 0.05$. HPS students score 3.5% less than MHP on PLTW. The other comparisons did not have statistically significant mean differences; values detailed in *Table 23*.

Table 22. ANCOVA values for Percentile ~ School + EntMathScore

	Sum Sq	df	F-value	p-value
(Intercept)	8965	1	25.344	< 0.001
School	4791	2	6.771	< 0.01
EntMathScore	180452	122	4.181	< 0.001
Residuals	323317	914		

Table 23. Tukey multiple comparisons of means for the ANCOVA of Percentile ~ School + EntMathScore

Group 1 - Group 2	Difference	2.5% CI	97.5% CI	p-value
HPS-MHP	-3.468	-6.410	-0.527	< 0.05
HPW-MHP	-2.742	-7.035	1.551	0.292
HPW-HPS	0.726	-3.596	5.048	0.918



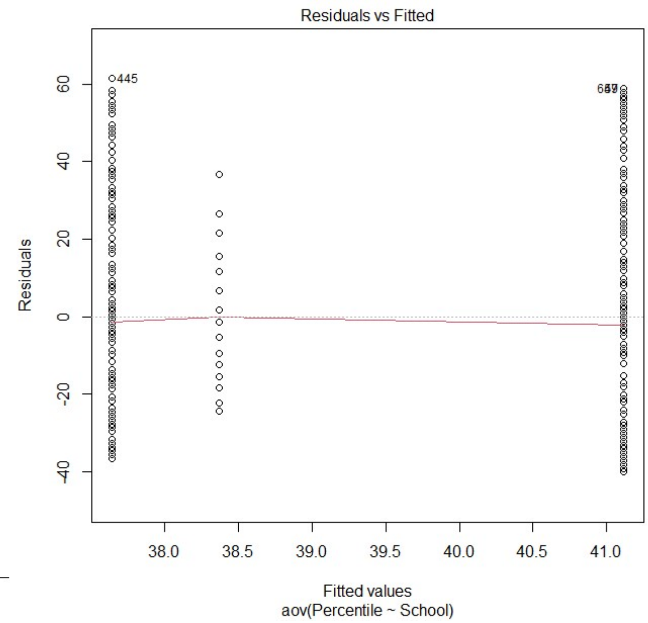


Figure 15. Graph of Standardized Residuals vs. Theoretical Quantiles of ANCOVA Percentile ~ School + EntMathScore

Figure 16. Graph of Residuals vs Fitted values for ANCOVA Percentile ~ School + EntMathScore

The graph of standardized residuals vs. theoretical quantiles,

Figure 15, indicates there is concern for the normality assumption. The Shapiro-Wilk normality test results, W = 0.994, p < 0.001, confirms that the data comes from a population that is not normally distributed. The graph of residuals vs. fitted values, *Figure 16*, shows concern for the equal variance assumption. From the previous section's Levene Test and *Table 20*, it is clear that equal variance cannot be assumed.

Using G*Power 3.1.9.7 with an effect size of 0.114 and an alpha error of 0.05, a total sample size of 1152 participants is required to have a power of 0.80. The study has 1039 participants so there are enough participants to meet a power of 0.80. The post-hoc power with 1039 participants is 0.956.

Summary:

Below are the research questions with a summary of results for the models with and without covariant:

1. Are the number of times a teacher has taught a course, student grade, gender, ethnicity; course, teacher, teacher gender, enrolled school, and semester significant predictors of student PLTW test scores?
    - Without Covariant: Course AE, CEA, CSC, IED, and POE; School HPS and HPW, SemestersTaught, StudentGender M, and Ethnicity B and H were all significant predictors of students' PLTW percentile. This model explained 14.24% of the variance in PLTW percentiles.
    - With Covariant: Course AE and POE; School HPS and HPW, SemestersTaught, Ethnicity B and H, and EntMathScore were all significant predictors of students' PLTW percentile. This model explained 27.46% of the variance in PLTW percentiles.
2. Is there a significant difference in student PLTW test scores across student ethnicity and gender?
    - Without Covariant: The interaction variable between student ethnicity and gender is statistically significant, $p < 0.05$. Specifically, the mean difference between six interactions were statistically significant. The largest mean difference was between male African American students and male Caucasian students with male African American students scoring 25% less than male Caucasian students.

- With Covariant: The interaction variable between student ethnicity and gender is statistically significant, $p < 0.05$. Specifically, the mean difference between nine interactions were statistically significant. The largest mean difference was between male Native American students and male African American students with male African American students scoring 39% less than male Native American students.

3. Is there a significant difference in student PLTW test scores across teacher gender and student gender?
   - Without Covariant: The interaction variable between student gender and teacher gender was not statistically significant. Focus was shifted to the individual variables, except those were not statistically significant either. Therefore, there was no statistically significant mean difference in student PLTW percentiles across student and teacher genders.
   - With Covariant: The interaction variable between student gender and teacher gender was not statistically significant. Focus was shifted to the individual variables, and TeacherGender is statistically significant, $p < 0.05$. Using Tukey comparison it was determined the students with male teachers score 2% less than students with female teachers.
4. Is there a significant difference in student PLTW test scores across the Highland Prep Academies?

- Without Covariant: The mean difference across the schools was not statistically significant, $p = 0.054$.
- With Covariant: The mean difference across the schools was statistically significant, $p < 0.01$. A Tukey comparison determined that the mean difference between HPS and MHP was statistically significant, $p < 0.05$. Specifically, HPS students score 3.5% lower than MHP students. The other mean difference between the three schools (HPS, HPW, and MHP) were not statistically significant.

For all models in this study the normality assumption could not be made. Therefore, it could not be assumed that the data came from a normally distributed population. In addition, the equal variance assumption was proven false for all models.

CHAPTER V: SUMMARY

Introduction:

Summary of findings, conclusion, and recommendations for future research will be covered in this chapter. The summary of findings will go through the results from the analysis of data, while the conclusion will connect the results to the literature and theoretical framework. Lastly, recommendations will be made on future research, including actions that should be taken and who should be conducting the research.

Summary of Findings:

The primary research question was "Are the number of times a teacher has taught a course, student grade, gender, ethnicity; course, teacher, teacher gender, enrolled school, and semester significant predictors of student PLTW test scores?". Due to multicollinearity semester, student grade, teacher, and teacher gender were dropped from the analysis. Both models, with and without the covariant, did not meet the normality or equal variance assumptions.

A multiple linear regression analysis without a covariant was used and the independent variables explained 14.24% of the variance in student PLTW percentiles. The significant predictors included Course AE, CEA, CSC, IED, and POE; School HPS and HPW, SemestersTaught, StudentGender M, and Ethnicity B and H. AE, CEA, CSC, IED, and POE students had statistically significant lower PLTW percentiles than AP Computer Science students. Students enrolled at Highland Prep West and Surprise had lower PLTW percentiles than students enrolled at Madison Highland Prep. For each semester a teacher taught a course, their students PLTW score percentile decreased by 1%. Male students scored higher than female students, while African American and

Hispanic students scored lower than Caucasian students. The post-hoc power of this model was 1.00.

A multiple linear regression analysis with a covariant of student entrance math exam scores was used and the independent variables explained 27.46% of the variance in student PLTW percentiles. The significant predictors included Course AE, IED, and POE; School HPS and HPW, SemestersTaught, Ethnicity B and H, and EntMathScore. Aerospace Engineering and Principles of Engineering students had statistically significant lower PLTW percentiles than AP Computer Science students. Similarly, to the model with no covariant, it was found that HPW and HPS had lower percentiles than MHP, African American and Hispanic students had lower percentiles than Caucasian students, and that for each semester a teacher taught a course their students percentiles decreased by about 1%. The covariant was statistically significant as well, indicating that for each percent students got correct on the entrance math exam score their PLTW percentile increased by 0.5%. The post-hoc power of this model was 1.00.

The secondary research question was "Is there a significant difference in student PLTW test scores across student ethnicity and gender?". A two-way analysis of variance was used to answer this question. Both models, with and without the covariant, did not meet the normality or equal variance assumptions.

The two-way ANOVA determined that the interaction of student ethnicity and gender was statistically significant. Six group mean differences were statistically significant: H:F – C:F, B:M – C:F, C:M – H:F, B:M – C:M, H:M – C:M, and B:M – A:M. Overall, Caucasian students scored higher than Hispanic and African American students. In addition, male Asian students scored higher than African American students. The post-hoc power of this model was 0.752.

The two-way ANCOVA determined that the interaction of student ethnicity and gender was statistically significant with the covariant of student entrance math exam scores. Nine group mean differences were statistically significant: M:B – F:C, F:H – F:C, M:H – F:C, M:B – M:C, F:H – M:C, M:H – M:C, F:NAm – M:C, M:B – M:A, and M:NAm – M:B. Regardless of gender, Caucasian students scored higher than Hispanic, Native American, and African American students. In addition, male Asian and male Native American students scored higher than male African American students. The post-hoc power of this model was 0.752.

The third research question was "Is there a significant difference in student PLTW test scores across teacher gender and student gender?". A two-way analysis of variance was used to answer this question. Both models, with and without the covariant, did not meet the normality or equal variance assumptions.

The two-way ANOVA determined that the interaction of student gender and teacher gender and the individual variables were not statistically significant. The post-hoc power of this model was 0.051. The two-way ANCOVA determined that the interaction of student gender and teacher gender were not statistically significant with the covariant of student entrance math exam scores. However, the teacher gender was statistically significant. Students with male teachers had lower scores than students with female teachers. The post-hoc power of this model was 0.591.

The fourth research question was "Is there a significant difference in student PLTW test scores across the Highland Prep Academies?". An analysis of variance was used to answer this question. Both models, with and without the covariant, did not meet the normality or equal variance assumptions. The ANOVA determined that there was no statistically significant mean difference across the schools. When a covariant of student entrance math exam scores was added, there was a statistically significant mean difference across the schools. Specifically, Highland Prep Surprise's average scores were less than Madison Highland Prep's. The ANOVA had a post-hoc power of 0.571 and the ANCOVA had a post-hoc power of 0.956.

Conclusion:

Educational equity is the concept that all students have the right to quality education. This does not mean using the same curriculum, activities, lessons, etc. for all students, but meeting students at their educational level. Identifying the additional needs of groups of students starts with research. Many previous studies focused on Project Lead the Way were from schools with majority (70% - 90%) Caucasian students. At the Highland Prep Academies, the majority of students are Hispanic with a small percentage of Asian, Native American, and African American students. It was found that Hispanic, Native American, African American, and female students had statistically significant lower PLTW scores than male Caucasian students. Similar results were found in other studies that investigated mathematics, ACT, etc.

Two of the PLTW courses were found to have statistically significant lower scores than AP Computer Science. Principles of Engineering is a course that goes over a wide range of concepts from computer programming, simple machines, thermal mechanics, circuitry, and more. At the beginning of the 2023-24 school year, PLTW released a new version of POE that is more project focused. Some of the same concepts from the original curriculum are used, but many of the activities are new. Therefore, the results for POE from this study do not correlate to this new version of the curriculum.

The other course with statistically significant lower scores than AP Computer Science is Aerospace Engineering. Airplanes, gliders, rocketry, and rovers are all included in this course's activities. Though not a mathematics heavy course, the math that is involved uses quite tedious calculations such as for lift, drag, potential energy of a satellite, air pressure, etc. This maybe what is causing lower scores, but further investigation is required.

In previous studies it was found that student scores did not significantly change the more years of experience a teacher had. Unless a teacher had been teaching for forty to fifty years, then student test scores decreased. At HPA it was found that student PLTW test scores decreased statistically significant each time a teacher taught a course. Further investigations would be needed to determine more information.

The relationship between student and teacher gender and student PLTW test scores was somewhat inconclusive. The ANOVA determined no statistically significant mean difference, while the ANCOVA found statistically significant mean difference based only on teacher gender. Previous studies found that students performed better academically with female teachers, and specifically that female students did better with female teachers in mathematic classes. The results maybe influenced by the limited number of teacher participants and 20% of them were female.

Lasty, it was found that when not taking student entrance math exam scores into account as the covariant there was no statistically significant mean difference in student PLTW scores across the Highland Prep Academies. When the covariant was added there was a statistically significant mean difference in the student PLTW scores from Highland Prep Surprise and Madison Highland Prep. Specifically, HPS students score lower than MHP students on PLTW tests. This was surprising since HPS students on average score higher on the entrance math exam than MHP students.

There are several limitations to take into consideration for this study. Most schools do not use a semester long block schedule with four classes a day. The Highland Prep Academies also use additional academic support such as mandatory tutoring and homework support that may not be available in most schools. Though HPA has a high percentage of Hispanic students, the percent of Asian, African American, and Native American students is small. All HPA schools are located in urban Maricopa County of Arizona. Lastly, the students that participated had different online learning circumstances for COVID-19 quarantine in 2020 – 21.

Recommendations:

Continued research will need to be conducted about Project Lead the Way test scores. There is still a gap in available research about the relationship between test scores and students of African American and Native American ethnicity. Ideally, Project Lead the Way would publish a detailed analysis of scores based on student ethnicity and gender similar to how American College Testing (ACT) and College Board do.

Project Lead the Way needs to continue research on their curriculums and the impact of it on a school's community. In addition, it is important that outside organizations conduct their own research. Schools have firsthand experience on the impacts of PLTW curriculum and by publishing research can assist in refining how the curriculum is utilized. Data driven schools, like the Highland Prep Academies, have the resources and skills to pave the way for future research of PLTW curriculum.

In the future, restructuring the analysis of Highland Prep Academies' PLTW test scores to use a repeated measures ANOVA may yield more informative results. With this sort of analysis students' can be tracked as they take different PLTW courses, since HPA requires students to complete three PLTW courses to graduate. In addition, using the breakdown of the PLTW scores for each course might yield insight into which concepts need more support.

REFERENCES

Marco Learning. "Why Some States Have Higher Teacher Turnover Rates Than Others." Copyrighted 2024. https://marcolearning.com/teacher-turnover-rate-by-state/#:~:text=According%20to%20data%20from%20the,%2C%20just%20below%20with%2023%25.

Antecol, Heather, Ozkan Eren, and Serkan Ozbeklik. "The Effect of Teacher Gender on Student Achievement in Primary School." *Journal of Labor Economics 33*, no. 1 (January 2015): 63–89. doi:10.1086/677391.

Armstrong, Melva. "The Effects of Teacher Competencies, Gender, and School Location on Primary School Standardised Academic Test Results in Three Districts in Jamaica." Journal of Arts Science & Technology 13, no. 1 (March 2020): 190–206. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=b7h&AN=142759239&site=eds-live&scope=site.

Armstrong, Melva. "The Effects of Teacher Competencies, Gender, and School Location on Primary School Standardised Academic Test Results in Three Districts in Jamaica." Journal of Arts Science & Technology 13, no. 1 (March 2020): 190–206. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=b7h&AN=142759239&site=eds-live&scope=site.

AZ School Report Cards. "Highland Prep West." Copyrighted 2022 – 2023. https://azreportcards.azed.gov/schools/detail/1001524.

AZ School Report Cards. "Highland Prep." Copyrighted 2022 – 2023. https://azreportcards.azed.gov/schools/detail/703390.

AZ School Report Cards. "Madison Highland Prep." Copyrighted 2022 – 2023. https://azreportcards.azed.gov/schools/detail/92605.

Beltrán-Grimm, Susana. "Latina Mothers' Cultural Experiences, Beliefs, and Attitudes May Influence Children's Math Learning." Early Childhood Education Journal 52, no. 1 (January 2024): 43–53. doi:10.1007/s10643-022-01406-2.

Bordel, Borja, Ramon Alcarria, Tomás Robles, and Diego Martin. "The Gender Gap in Engineering Education During The COVID-19 Lockdown: A Study Case." International Journal of Engineering Pedagogy 11, no. 6 (November 2021): 117–31. doi:10.3991/ijep.v11i6.24945.

Camburn, Eric, Karin Chang, Takako Nomi, Michael Podgursky, Darrin DeChane, Anwuli Okwuashi, Mark Ehlert, Jeongmi Moon, and Xinyi Mao. 2023. Review of *Final Report of the Impact of Project Lead the Way on Missouri High School Students*. University of Missouri - Kansas City. https://info.umkc.edu/uerc/wp-content/uploads/2023/04/Final-MO-PLTW-Report-FINAL.pdf.

Corra, Mamadi, J. Scott Carter, and Shannon K. Carter. “The Interactive Impact of Race and Gender on High School Advanced Course Enrollment.” Journal of Negro Education 80, no. 1 (Winter 2011): 33–46. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=eft&AN=62607837&site=eds-live&scope=site.

Daniel M. McNeish, Justine Radunzel, and Edgar Sanchez. “A Multidimensional Persepective of College Readiness: Relating Student and School Characteristics to Performance on the ACT.” *ACT Research Report Series* 2015*,* no. 6 (2015). https://www.act.org/content/dam/act/unsecured/documents/ACT_RR2015-6.pdf

Dost, Gulash. “Students’ perspectives on the ‘STEM belonging’ concept at A-level, undergraduate, and postgraduate levels: an examination of gender and ethnicity in student descriptions.” *International Journal of STEM Education 11*, no. 12 (2024): https://doi.org/10.1186/s40594-024-00472-9.

Ember Smith and Richard V. Reeves. “SAT math scores mirror and maintain racial inequity”. *Brookings*. December 1, 2020. https://www.brookings.edu/articles/sat-math-scores-mirror-and-maintain-racial-inequity/#:~:text=Despite%20a%20wide%20range%20of,gap%20narrowed%20to%2093%20points.

Escardíbul, Josep-Oriol, and Toni Mora. “Teacher Gender and Student Performance in Mathematics. Evidence from Catalonia (Spain).” *Journal of Education and Training Studies 1*, no. 1 (April 1, 2013): 39–46. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=eric&AN=EJ1054826&site=eds-live&scope=site.

Gely, Yumiko I, Ikenna H Ifearulundu, Melissa Rangel, Johanna S Balas, Yuanqing Liu, Gwyneth Sullivan, Edie Chan, Jose Velasco, and Rosalinda Alvarado. “Effects of Race and Test Preparation Resources on Standardized Test Scores, a Pilot Study.” American Journal of Surgery 225, no. 3 (March 2023): 573–76. doi:10.1016/j.amjsurg.2022.10.047.

Graham, Linda J., Sonia L.J. White, Kathy Cologon, and Robert C. Pianta. “Do Teachers’ Years of Experience Make a Difference in the Quality of Teaching?” Teaching and Teacher Education 96 (November 1, 2020). doi:10.1016/j.tate.2020.103190.

Haq I, Higham J, Morris R, and Dacre J. “Effect of Ethnicity and Gender on Performance in Undergraduate Medical Examinations.” Medical Education 39, no. 11 (November 2005): 1126–28. doi:10.1111/j.1365-2929.2005.02319.x.

Holstein, Krista A., and Karen Allen Keene. “The Complexities and Challenges Associated With the Implementation of a STEM Curriculum.” *Teacher Education & Practice 26*, no. 4 (Fall 2013): 616–36. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=eue&AN=95456131&site=eds-live&scope=site.

Hwang, NaYoung, and Brian Fitzpatrick. “Student-Teacher Gender Matching and Academic Achievement.” *AERA Open 7*, no. 1 (January 1, 2021). doi:10.1177/23328584211040058.

Juliana Utley, Toni Ivey, John Weaver. "How Professional Development in Project Lead the Way Changes High School STEM Teachers' Beliefs about Engineering Education." Journal of Pre-College Engineering Education Research 2019(9), no. 2 (2019): Article 3. doi: https://doi.org/10.7771/2157-9288.1209

Kahveci, Hakkı. "The Positive and Negative Effects of Teacher Attitudes and Behaviors on Student Progress." Journal of Pedagogical Research (JPR) 7, no. 1 (March 2023): 290–306. doi:10.33902/JPR.202319128.

Kolb, D. A. *Experiential learning : experience as the source of learning and development (Second edition).* Pearson Education LTD, 2015.

Learning Policy Institute. "What's the Cost of Teacher Turnover?." Published September 13, 2017. https://learningpolicyinstitute.org/product/the-cost-of-teacher-turnover.

Levitt, Greg, Steven Grubaugh, Joseph Maderick, and Donald Deever. "The Power of Passionate Teaching and Learning: A Study of Impacts on Social Science Teacher Retention and Student Outcomes." Technium Social Sciences Journal 41 (January 1, 2023): 82–85. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=edshol&AN=edshol.hein.journals.techssj41.8&site=eds-live&scope=site.

Luo, Ma, Daner Sun, Liying Zhu, and Yuqin Yang. "Evaluating Scientific Reasoning Ability: Student Performance and the Interaction Effects between Grade Level, Gender, and Academic Achievement Level." Thinking Skills and Creativity 41 (September 1, 2021). doi:10.1016/j.tsc.2021.100899.

Madison Highland Prep. "Homepage." Copyrighted 2024. https://madisonhighlandprep.com.

Madison Highland Prep. "Student Handbook." Edition 2023-24. https://madisonhighlandprep.com/wp-content/uploads/2024/01/student-handbook-mhp.pdf.

Mansour, Hani, Daniel I. Rees, Bryson M. Rintala, and Nathan N. Wozny. "The Effects of Professor Gender on the Postgraduation Outcomes of Female Students." *ILR Review 75*, no. 3 (May 2022): 693–715. doi:10.1177/0019793921994832.

Melanie LaForce, Elizabeth Noble, Heather King, Jeanne Century, Courtney Blackwell, Sandra Holt, Ahmed Ibrahim, and Stephanie Loo. "The eight essential elements of inclusive STEM high schools." *International Journal of STEM Education 3*, no. 21 (2016): https://doi.org/10.1186/s40594-016-0054-z.

Mitchell J. Nathan, Amy K. Atwood, Amy Prevost, L. Allen Phelps, Natalie A. Tran. "How Professional Development in Project Lead the Way Changes High School STEM Teachers' Beliefs about Engineering Education." *Journal of Pre-College Engineering Education Research 2011(1)*, no. 1 (2011): Article 3. doi: https://doi.org/10.7771/2157-9288.1027

National Center for Education Statistics. "Characteristics of Public School Teachers." Updated May 2023. https://nces.ed.gov/programs/coe/indicator/clr/public-school-teachers

National Center for Education Statistics. "Eight Percent of Public School Teachers Left Teaching in 2021, a Rate Unchanged Since Last Measured in 2012." Published December 13, 2023. https://nces.ed.gov/whatsnew/press_releases/12_13_2023.asp#:~:text=Overall%2C%2084%20percent%20of%20public,profession%20(%E2%80%9Cleavers%E2%80%9D.

National Center for Education Statistics. "Percentage of public school teachers based on years of teaching experience, average total years of teaching experience, percentage of teachers based on years teaching at current school, and average years teaching at current school, by selected school characteristics: 2015–16." Accessed March 3, 2024. https://nces.ed.gov/surveys/ntps/tables/ntps1516_18051504_t1n.asp.

O'Brien, Gearóid. "Teacher Gender in Citizenship Education: Does It Make a Difference?" *Citizenship, Social and Economics Education 22*, no. 1 (April 1, 2023): 3–17. doi:10.1177/14788047231153822.

Odette Umugiraneza, Sarah Bansilal, and Delia North. "An Analysis of Teachers' Confidence in Teaching Mathematics and Statistics." *Statistics Education Research Journal 3,* no. 21 (November 2022). https://doi.org/10.52041/serj.v21i3.422.

Patel, Nimisha H., M. Suzanne Franco, and Larry G. Daniel. "Student Engagement and Achievement: A Comparison of STEM Schools, STEM Programs, and Non-STEM Settings." *Research in the Schools 26*, no. 1 (Spring 2019): 1–11. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=eue&AN=139170318&site=eds-live&scope=site.

Pew Research Center. "STEM Jobs See Uneven Progress in Increasing Gender, Racial and Ethnic Diversity." Published April 1, 3032. https://www.pewresearch.org/science/wp-content/uploads/sites/16/2021/03/PS_2021.04.01_diversity-in-STEM_REPORT.pdf.

Project Lead the Way. "Core Training Registration Fees." Copyrighted 2024. https://knowledge.pltw.org/s/article/Does-this-cost-more.

Project Lead the Way. "End-of-Course Assessment Scale Score Reports FAQ." Copyrighted 2020. https://ed.sc.gov/instruction/career-and-technical-education/professional-development/end-of-course-assessment/.

Project Lead the Way. "PLTW Score Interpretation Guide." Copyrighted 2019. https://ed.sc.gov/instruction/career-and-technical-education/professional-development/pltw-score-interpretation/.

Project Lead the Way. "Professional Development for Teachers." Copyrighted 2024. https://www.pltw.org/professional-development/training-schedules?program=*&course=*&type=%22Online%22.

Project Lead the Way. "Project 4.2.2 Teacher Resources." Copyrighted 2024. https://pltw.read.inkling.com/a/b/fd4b4de6f1214b17bd563d01de52a6ef/p/cedd2f741af547ffa56905d20a386b07.

Project Lead the Way. "See Our Student Opportunities." Copyrighted 2024. https://www.pltw.org/experience-pltw/student-opportunities?.

Project Lead the Way. “Understanding End-of-Course Assessment Results.” Copyrighted 2024. https://s3.amazonaws.com/assets.pltw.org/pdf/Understanding_EoC_Assessment_Scores_2022_23.pdf.

Public School Review. “Madison Highland Prep.” Copyrighted 2023-2024. https://www.publicschoolreview.com/madison-highland-prep-profile.

Rethwisch, D., (2014) “A Study of the Impact of Project Lead the Way on Achievement Outcomes in Iowa”, 2014 ASEE North Midwest Section Conference 2014(1), 1-18. doi: https://doi.org/10.17077/aseenmw2014.1033
Rethwisch, D., (2014) “A Study of the Impact of Project Lead the Way on Achievement Outcomes in Iowa”, 2014 ASEE North Midwest Section Conference 2014(1), 1-18. doi: https://doi.org/10.17077/aseenmw2014.1033
Robin A. Costello, Shima Salehi, Cissy J. Ballen, and Eric Burkholder. “Pathways of opportunity in STEM: comparative investigation of degree attainment across different demographic groups at a large research institution.” *International Journal of STEM Education 10,* no. 46 (2023): https://doi.org/10.1186/s40594-023-00436-5.

Rogers, George E. “The Perceptions of Indiana High School Principals Related to Project Lead The Way.” *Journal of Industrial Teacher Education* 44, no. 1 (March 15, 2007): 49–65. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=eric&AN=EJ830475&site=eds-live&scope=site.

Rogers, George E. “The Perceptions of Indiana High School Principals Related to Project Lead The Way.” Journal of Industrial Teacher Education 44, no. 1 (March 15, 2007): 49–65. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=eric&AN=EJ830475&site=eds-live&scope=site.

Ronfeldt, Matthew, Susanna Loeb, and James Wyckoff. “How Teacher Turnover Harms Student Achievement.” American Educational Research Journal 50, no. 1 (February 1, 2013): 4–36. doi:10.2307/23319706.

Sadler, Philip M., Gerhard Sonnert, Harold P. Coyle, Nancy Cook-Smith, and Jaimie L. Miller. “The Influence of Teachers’ Knowledge on Student Learning in Middle School Physical Science Classrooms.” American Educational Research Journal 50, no. 5 (October 1, 2013): 1020–49. doi:10.2307/23526122.

Shields, C. J. “Barriers to the Implementation of Project Lead the Way as Perceived by Indiana High School Principals.” *Journal of Industrial Teacher Education* 44, no. 3 (September 15, 2007): 43–70. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=eric&AN=EJ830484&site=eds-live&scope=site.

Shields, C. J. “Barriers to the Implementation of Project Lead the Way as Perceived by Indiana High School Principals.” Journal of Industrial Teacher Education 44, no. 3 (September 15, 2007): 43–70. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=eric&AN=EJ830484&site=eds-live&scope=site.

Social Security Administration. “Average Wage Index (AWI).” Accessed January 17, 2024. https://www.ssa.gov/oact/cola/awidevelop.html.

Society of Women Engineers. “Employment.” Copyrighted 2023. https://swe.org/research/2023/employment/.

St J. Watson, Penelope W., Christine M. Rubie-Davies, Kane Meissei, Elizabeth R. Peterson, Annaline Flint, Lynda Garrett, and Lyn McDonald. “Gendered Teacher Expectations of Mathematics Achievement in New Zealand: Contributing to a Kink at the Base of the STEM Pipeline.” *International Journal of Gender, Science & Technology 8*, no. 1 (January 2016): 82–102. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=qth&AN=114526600&site=eds-live&scope=site.

Stebbins, Melissa, and Tatiana Goris. “Evaluating STEM Education in the U.S. Secondary Schools: Pros and Cons of the «Project Lead the Way» Platform.” *International Journal of Engineering Pedagogy 9*, no. 1 (January 2019): 50–56. doi:10.3991/ijep.v9i1.9277.

Stebbins, Melissa, and Tatiana Goris. “Evaluating STEM Education in the U.S. Secondary Schools: Pros and Cons of the «Project Lead the Way» Platform.” International Journal of Engineering Pedagogy 9, no. 1 (January 2019): 50–56. doi:10.3991/ijep.v9i1.9277.

Stohlmann, Micah, Tamara J. Moore, and Gillian H. Roehrig. “Considerations for Teaching Integrated STEM Education.” *Journal of Pre-College Engineering Education Research 2*, no. 1 (April 2012): 28–34. doi:10.5703/1288284314653.

Tamara D. Holmlund, Kristin Lesseig, and David Slavit. “Making sense of “STEM education” in K-12 contexts.” *International Journal of STEM Education 3,* no. 32 (2018): https://doi.org/10.1186/s40594-018-0127-2.

Walker, Tim. “Teacher Salaries Not Keeping Up With Inflation, NEA Report Finds.” *neaToday*, April 24, 2023. https://www.nea.org/nea-today/all-news-articles/teacher-salaries-not-keeping-inflation-nea-report-finds#:~:text=Key%20Takeaways,2.6%20percent%20in%202022%2D23.

Werner, Gary, Todd R. Kelley, and George E. Rogers. “Perceptions of Indiana Parents Related to Project Lead The Way.” *Journal of STEM Teacher Education* 48, no. 2 (January 1, 2011): 137–54. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=eric&AN=EJ952049&site=eds-live&scope=site.

Werner, Gary, Todd R. Kelley, and George E. Rogers. “Perceptions of Indiana Parents Related to Project Lead The Way.” Journal of STEM Teacher Education 48, no. 2 (January 1, 2011): 137–54. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=eric&AN=EJ952049&site=eds-live&scope=site.

Wilson, A. T., Wang, X., Galarza, M. O., Knight, J., and Patino, E.. “Math attitudes and identity of high schoolers impacted through participating in informal, near-peer mentoring.” *International Journal of Research in Education and Science (IJRES)* 9, no. 2 (2023): 535-545. https://doi.org/10.46328/ijres.3093.

Yang, Xinrong, and Gabriele Kaiser. “The Impact of Mathematics Teachers’ Professional Competence on Instructional Quality and Students’ Mathematics Learning Outcomes.” Current Opinion in Behavioral Sciences 48 (December 2022). doi:10.1016/j.cobeha.2022.101225.

Yasemin Copur-Gencturk, Ian Thacker, and Joseph R. Cimpian. “Teachers’ race and gender biases and the moderating effects of their beliefs and dispositions.” *International Journal of STEM Education 10*, no. 31 (2023): https://doi.org/10.1186/s40594-023-00420-z.

Yilmaz Can, Dilara and Kesebir, Gülcenur. “Evaluation of Mathematical Modeling Activity of 4th-Grade Students: A Case of Experiential Learning.” *Ankara University Journal of Faculty of Educational Sciences* 56, no. 1 (May 2023): 585-611. https://doi.org/10.30964/auebfd.1037725.

Zippia. “BIOLOGIST DEMOGRAPHICS AND STATISTICS IN THE US.” Copyrighted 2024. https://www.zippia.com/biologist-jobs/demographics/.

Zippia. “CHEMIST DEMOGRAPHICS AND STATISTICS IN THE US.” Copyrighted 2024. https://www.zippia.com/chemist-jobs/demographics/.

ABSTRACT

Project Lead the Way (PLTW) is an organization that develops engineering curriculum for all grade levels. Research has been conducted on the curriculum and other STEM curriculum to determine student achievement levels and the factors that affect student achievement. These factors include teacher retention, teacher years of experience, student demographics, etc. Investigating how a teacher impacts their students learning can help schools understand the value of a seasoned teacher. With PLTW training having high costs it can make teacher retention a bigger concern. The Highland Prep Academies utilize PLTW curriculum and have about ten trained teachers across the three schools. Data was collected from them during the academic year 2022-23, which included student demographics, PLTW test scores, and teacher semesters of experience. This data was analyzed using multiple linear regression, ANOVA, and two-way ANOVA with and without a covariant in the software R 4.3.0. Through the analysis it was found that two specific PLTW courses had lower scores than the others, Aerospace Engineering and Principles of Engineering. Student test scores were observed to decrease 1% every time a teacher had taught a course. Regarding student demographics, it was found that African American and Native American students scored lower then Caucasian and Asian students. Specifically, male Caucasian students scored higher than the other interactions of ethnicity and gender. It was also determined that students with male teachers scored lower than students with female teachers. Lastly, for the Highland Prep Academies it was determined that Madison Highland Prep's average PLTW test score was a higher than the test scores at Highland Prep West and Highland Prep Surprise. These results imply that changes need

to be made to ensure educational equity of the students and that teachers need continued PLTW curriculum support through the years of teaching.

ACKNOWLEDGMENTS

I would like to acknowledge my thesis advisor, Dr. Douglas Darbro, And the other math professors at Shawnee State University. A big thank you goes to the administration of Highland Prep Academies, specifically Madison Highland Prep. Without the support of Dr. Kerry Clark, Rosanna Rodriguez, Reshma Watson, Steven Mack, and Erin Zhang this research would not have been possible.

A thank you goes out to my mom and twin sister for listening to me talk about the research and their support over the two years. Additionally, thank you goes to Jill, my cat, for keeping me company, trying to help me type, and not overheating my laptop.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

Table Page

LIST OF FIGURES

CHAPTER I: Introduction

Introduction:

Project Lead the Way (PLTW) is a non-profit organization that offers curriculum in the K-12 field of education that focuses on hands-on engineering projects. It is commonly used in schools with a STEM (science, technology, engineering, and mathematics) program or STEM schools. The Highland Prep Academies are STEM schools, and nationally STEM certified through Cognia. They utilize several PLTW curriculums, including: Introduction to Engineering Design (IED), Aerospace Engineering (AE), Principles of Engineering (POE), Cybersecurity (CSC), Civil Engineering and Architecture (CEA), Digital Electronics (DE), Biomedical Science (BMS), and AP Computer Science (APCS). Highland Prep Academies consists of three schools: Madison Highland Prep (MHP), Highland Prep Surprise (HPS), and Highland Prep West (HPW).

The Highland Prep Academies are very data driven, analyzing beginning and end of course exams for both English and mathematics every quarter. This will be the first time the PLTW test scores collected at the courses' end will be analyzed for the Highland Prep Academies. The data that will be collected and investigated in addition to the PLTW test scores are entrance math exams, grade level, student ethnicity, student gender, school, course, number of times the teacher has taught the course, teacher gender, and spring/fall semester. From the three schools for this study A total of 1039 data points were collected during the academic year 2022-23. Since the Highland Prep Academies use a block schedule with semester-long courses, the number of times the teacher has taught the course increases in the academic year.

Background:

Project Lead the Way was developed in June 1997 and has undergone numerous research studies to date. Currently, there has been research based on the efficacy of the curriculum, test scores, and participant opinions. There has been no research conducted on the effect of the number of times a teacher has taught a specific PLTW curriculum on student test scores. If teacher experience positively affects student test scores, then teacher retention will be of greater concern for schools. Furthermore, students who perform highly in PLTW courses are eligible for both college credit and scholarships.

In a 2011-2014 survey of forty-five states from the United States the teacher turnover rate was measured and analyzed. It was determined that Arizona had the largest rate at 24% while Utah had the smallest rate of under 10%.[1] In a different study from 2020-2022, it was determined that on average 8% of public-school teachers switched schools while 8% left the teaching profession entirely.[2] With teacher turnover rates being of concern for most schools nationwide, understanding the impact of a teacher's experience with the PLTW curriculum is important to determining the value of a seasoned PLTW teacher.

One of the key factors affecting teacher turnover rate is low salaries that have minimal percent increase each year. In the academic year 2021-22 the national average public school teacher salary increased by two percent from the previous academic year.[3] According to the Social Security Administration the national average wage from 2020 to 2021 increased 8.89%.[4]

---

[1] Marco Learning, "Why Some States Have Higher Teacher Turnover Rates Than Others."

[2] National Center for Education Statistics, "Eight Percent of Public School Teachers Left Teaching in 2021, a Rate Unchanged Since Last Measured in 2012."

[3] Walker, "Teacher Salaries."

[4] Social Security Administration. "Average Wage Index (AWI)."

This disparity between the yearly wage increase has caused current teachers and future teachers to seek other careers.

A teacher must participate in training, in-person or online, with PLTW to teach a course from the Project Lead the Way curriculum. The in-person programs can range from 16 hours over two days or 80 hours over two weeks, while the online training varies from 16 hours over two days to 80 hours over 10 weeks.[5] PLTW offers a total of 29 courses with 17 of their teacher training programs costing $2,400 and the other 12 costing $500 - $1,200.[6] There are further costs associated with a school offering PLTW courses, such as an annual fee and the cost of equipment. However, the cost of training a new teacher makes the turnover rate of a school's PLTW teachers potentially expensive. On average schools spend more than $20,000 on hiring a new teacher.[7] Therefore, the cost to hire a new PLTW teacher can easily reach close to $30,000 due to training in multiple curriculums.

Through Project Lead the Way students have access to 57 different scholarships with five being available nationwide. For college credit there are 73 different opportunities with universities from various states. Students earn these based on their PLTW test scores and course grade. Through scholarships and college credit, students can save money on their postsecondary education. Students who perform poorly in the PLTW course or the end of course assessment are less likely to be eligible for these opportunities.[8]

---

[5] Project Lead the Way, "Professional Development for Teachers."
[6] Project Lead the Way, "Core Training Registration Fees."
[7] Learning Policy Institute, "What's the Cost of Teacher Turnover?."
[8] Project Lead the Way, "See Our Student Opportunities."

Statement of the Problem:

With student test scores and course grades impacting their postsecondary education, it is important to understand what a significant predictor of their PLTW test scores could be. One of the goals of this study is determining the effect a teacher's experience has on student PLTW test scores. If there is a positive correlation between teacher experience and student PLTW test scores, then teacher turnover rate will be of greater concern for schools. Hiring and training a new PLTW teacher requires a lot of time and is very expensive. For schools such as the Highland Prep Academies where there are multiple PLTW teachers, poor retention rates could cause large yearly expenses.

Student scholarship and college credit through PLTW is directly related to their test score and grade. Therefore, if there is a relationship between test scores and teacher experience, then teachers would have a direct impact on their students' future opportunities. These scholarships and college credit enable students to pursue post-secondary education that they otherwise may not have had the means to.

Another goal of this study is to determine if other factors are significant predictors of student PLTW test scores. As the Project Lead the Way curriculum is used in high schools, it is important to encourage diversity in engineering at this age to further diversify the engineering workforce. In 1980, 5% of engineers were women, a statistic that eventually increased to 16.1% in 2022.[9] Student gender will be analyzed to determine if there is a relationship between it and PLTW test scores. Similarly, student ethnicity will be analyzed in relation to PLTW test scores. In a 2019 study, it was determined that 71% of engineers were Caucasian, 5% African American, 9%

[9] Society of Women Engineers, "Employment."

Hispanic, 13% Asian, and 2% other.[10] It is important to understand how different student backgrounds affect student PLTW test scores. Ensuring that all students have equal opportunity for success is a critical role in every school.

Other factors that will be analyzed include teacher gender. As stated previously, most engineers are male, and this holds relatively true for the engineering teachers in this study. In the 2022-23 academic year the Highland Prep Academies had two female engineering teachers out of eight total teachers. There have been studies on the relationship between teacher gender and student test scores, and in this study the relationship will focus on the PLTW test scores. Teachers act as role models for their students, which means female teachers could increase the test scores of their female students.

Typically, Introduction to Engineering (IED) is taught to freshmen, Principles of Engineering (POE) to sophomores, and the other courses to upper classmen (non-freshman students). However, the sequence of engineering courses is not always maintained. As students' progress through high school their math and reading/writing skills increase, which are used throughout the PLTW curriculum. Understanding how grade level affects student PLTW test scores can help with sequencing the courses to improve student success.

Purpose of the Study:

This study will be conducted at the Highland Prep Academies for the academic year 2022-23 as the data has all been collected. Administration of the Highland Prep Academies will provide

---

[10] Pew Research Center, "STEM Jobs See Uneven Progress in Increasing Gender, Racial and Ethnic Diversity."

the following data: student PLTW test scores, course name, student grade level, ethnicity, and gender; teacher of course (designated by a number), teacher gender, number of times teacher has taught course, school, semester (spring or fall), and student math entrance exam. The focus of this study will be determining the relationship between student test scores and the other factors.

Significance of the Study:

Madison Highland Prep was the first of the Highland Prep Academies and was established in August 2014. Highland Prep Surprise followed three years later while Highland Prep West was established in August 2022. Each of the schools test incoming freshmen on mathematics and reading. These results are utilized to organize students into cohorts according to their academic level. As students progress in math and English courses, they complete beginning of course (BOC) and end of course (EOC) exams quarterly. BOC and EOC scores are then analyzed to determine which students need remedial work or supplemental projects and which concepts need additional review.

Project Lead the Way was introduced to the Highland Prep Academies in 2014 when Madison Highland Prep opened. Though the schools are highly data driven, the PLTW test scores have not been analyzed in depth beyond course averages. The raw test score does not include a breakdown of scores based on concepts, but it would enable administration to determine which teachers need additional support. The training for PLTW is intensive, except it typically only occurs prior to a teacher teaching the course. This means there is a possibility for gaps in a teacher's knowledge to become apparent during the semester. Students will struggle to be successful in a course where the teacher is not knowledgeable of the course content.

PLTW curriculum is used nationally with many schools implementing different courses. Studies have been conducted about different factors regarding Project Lead the Way. So far no one has examined the relationship between student test scores and the number of times a teacher has taught the course. With the concern of teacher turnover rates, it's important to determine if there is a correlation. A positive correlation would support further policies and changes in schools to improve these rates.

With the field of engineering containing poor diversity based on ethnicity and gender, the relationship between students' backgrounds and PLTW test scores needs to be examined. Since Project Lead the Way curriculum is engineering focused, student test scores will help indicate if there is a specific ethnicity or gender that is struggling with the courses. From there, remedial and support programs could be set up to ensure all students are successful in the curriculum.

The Women in STEM movement has been ongoing since the early 1900's and has focused on inspiring and empowering young women to pursue careers in STEM. The percent of women in chemistry and biology has increased to 40.4% and 48.6%, respectively.[11] With the number of women in engineering at a low percentage in comparison, it is important to continue encouraging female students to investigate STEM. Female engineering teachers act as role models for their female students, which is a key component of the Women in STEM movement.

---

[11] Zippia, "CHEMIST DEMOGRAPHICS AND STATISTICS IN THE US."; Zippia, "BIOLIGIST DEMOGRAPHICS AND STATISTICS IN THE US."

Research Questions:

The following questions will be investigated in this study:

1. Are the number of times a teacher has taught a course, student grade, gender, ethnicity; course, teacher gender, enrolled school, and semester significant predictors of student PLTW test scores?
2. Is there a significant difference in student PLTW test scores across student ethnicity and gender?
3. Is there a significant difference in student PLTW test scores across teacher gender and student gender?
4. Is there a significant difference in student PLTW test scores across the Highland Prep Academies?

Research Design:

During the 2022-23 academic year, 1066 students took a Project Lead the Way course at the Highland Prep Academies. The end-of-course tests are provided by PLTW and completed digitally through the software Kite Portal. Each students' test score is recorded, but to use the test scores, which range from 100 to 600, they are changed into their corresponding percentiles, because a score in one course is not worth the same in another course. For example, a score of 300 in Aerospace Engineering is in the 16th percentile while in Civil Engineering and Architecture the same score is in the 41st percentile.[12] By changing the raw score values to their corresponding percentiles, as provided by PLTW, the test scores become normalized.

[12] Project Lead the Way, "Understanding End-of-Course Assessment Results."

Student name, course, teacher name, and test score are provided through PLTW. Both student names and teacher names are anonymized by assigning them numbers. Student ethnicity, grade level, and gender were provided by administration, along with student entrance math exam scores. Several other students did not have math entrance exam scores available, but their beginning of course math exam scores from their freshman year were used in substitution as these two exams are similar in setup and content. Due to some entrance math exam scores and BOC scores missing, the following students were dropped: 80, 81, 178, 207, 233, 279, 296, 300, 337, 342, 397, 420, 457, 543, 562, 730, 745, 769, 789, 892, 920, 926, 943, 956, 981, 1032, and 1043.

For Research Question 1 a multi-linear regression (MLR) will be used. This will determine whether semester, student grade, course, or number of times a teacher has taught the course are significant predictors. For Research Question 2 and 3 a two-way analysis of covariance (ANCOVA) will be used. This will determine if there is a significant difference in student PLTW test scores across student ethnicity and gender and if there is a significant difference in student PLTW test scores across student gender and teacher gender. For Research Question 4 an analysis of covariance (ANCOVA) will be used. This will determine if there is a significant difference in student PLTW test scores across the Highland Prep Academies. For the ANCOVA analyses, the student entrance math exam scores will be used as the covariant. The software that will be used for this study are R v. 4.3.0 by the R Foundation and GPOWER 3.1 by Erdfelder, Faul, and Buchner.

Theoretical Framework:

In his Experiential Learning Theory, David Kolb states there is a four-stage cycle to effective learning: concrete experience, reflective observation, abstract conceptualization, and active experimentation. These steps can be simplified to feeling, watching, thinking, and doing.[13] Teachers in the PLTW curriculum gain concrete experience through the preservice training, and in teaching the curriculum. Teachers are then able to reflect on their observations based on how students perform on assessments and complete various activities. Furthermore, teachers can continue to "experiment" with the curriculum by making needed adjustments to lessons to best suit the needs of students. As a result teachers are able to improve the delivery of concepts to students the more years they have taught the curriculum.

In *Evaluation of Mathematical Modeling Activity of 4th Grade Students: A Case of Experiential Learning*, a study by Dilara Yilmaz Can and Gülcenur Kesebir, investigates the use of experiential activities to improve mathematical understanding of 4th grade students. Thirteen students participated in the research and enjoyed the activities. The experiential learning method was shown to be positive on student learning.[14]

Another study utilized informal, near-peer mentoring which is highly interactive following the experiential learning theory. It was observed that near-peer mentorship increased student interest and engagement in STEM. In the study it was determined that students' interest, enjoyment, and self-confidence in mathematics and science were major factors in their

---

[13] Kolb, D. A, *Experiential learning : experience as the source of learning and development (Second edition).*

[14] Yilmaz Can, Dilara and Kesebir, Gülcenur, "Evaluation of Mathematical Modeling Activity of 4th-Grade Students: A Case of Experiential Learning," *Ankara University Journal of Faculty of Educational Sciences* 56, no. 1 (May 2023): 585-611, https://doi.org/10.30964/auebfd.1037725.

consideration for STEM careers. Experiential learning can boost concept knowledge and a person's confidence in a subject area.[15]

Assumptions, Limitations, and Scope:

Due to some students not having entrance math exam scores their BOC math exam scores from freshman year are used instead. This assumes that the entrance math scores and BOC math exam scores from freshman year are equivalent. Both exams use multiple choice questions with a similar number of questions. The key difference is when the exams are taken by students. The entrance math exam is taken during the student's eighth grade year in the spring while the BOC math exam is taken at the beginning of the student's freshman math class (either spring or fall semester).

Another assumption is that the teachers teach a course the same way. For example, each school has an IED course which uses the same curriculum provided by PLTW. The curriculum includes activities, but how the teacher instructs the class is unique. Each teacher could have their own pacing, grading system, classroom structure, etc. Administration ensures that the teachers cover the required curriculum, so students should be covering the same concepts.

Furthermore, each of the teachers in this study have completed the PLTW training required to teach their courses. This study assumes that the trainings were the same for the

[15] Wilson, A. T., Wang, X., Galarza, M. O., Knight, J., and Patino, E., "Math attitudes and identity of high schoolers impacted through participating in informal, near-peer mentoring," *International Journal of Research in Education and Science (IJRES)* 9, no. 2 (2023): 535-545, https://doi.org/10.46328/ijres.3093.

teachers of the same course. However, the trainings can either be online or in-person and there is no means to know if the training has remained the same over the years.

The Highland Prep Academies have a high percentage of minority (non-white) students. During the academic year 2022 – 2023, Madison Highland Prep had 65.57% minority students, Highland Prep Surprise had 53.5% minority students, and Highland Prep West had 75.54% minority students. The majority of these minority students are Hispanic, and many of them learned English as their second language.[16] All PLTW tests are in English, so the assumption that all students have a comprehensive understanding of written English is made. This simplifies the analysis, allowing the variable to be disregarded.

This study does not take into account students having an Individualized Education Plan (IEP) or a 504 plan. Due to limited facilities and being college preparatory schools, the Highland Prep Academies are unable to offer the academic support needed for students with severe cognitive disabilities. As for the most common accommodations required by IEPs and 504s: modified tests are not available through PLTW, but extended time and alternative testing rooms are available through the school.

All students in this study are enrolled in the Highland Prep Academies. Each of the schools is a STEM college preparatory charter high school and is in Maricopa County of Arizona. This causes a limitation that narrows the scope of the study to similar schools.

Definition of Key Terms:

[16] AZ School Report Cards, "Madison Highland Prep."; AZ School Report Cards, "Highland Prep West."; AZ School Report Cards, "Highland Prep."

- Aerospace Engineering (AE): A course offered through PLTW that focuses on the physics of flight and space with hands-on projects such as building a glider and a model rocket.
- AP Computer Science (APCS): A course offered through PLTW that focuses on coding with Python from data processing, data security, and task automation. As an advanced placement (AP) course, it is endorsed by the College Board and gives students the opportunity to earn college credit.
- Beginning of Course (BOC) exam: An exam completed at the beginning of a course to allow teachers to establish a baseline of students' knowledge on the course's concepts.
- Civil Engineering and Architecture (CEA): A course offered through PLTW that focuses on architecture and site design and development.
- Cybersecurity (CSC): A course offered through PLTW that focuses on concepts and procedures in cybersecurity.
- Digital Electronics (DE): A course offered through PLTW that focuses on circuitry that includes processes of combinational and sequential logic.
- Dual-credit course: A high school level course that allows students the opportunity to earn college credit for the course. This usually requires the high school to have a partnership with a local university.
- End of Course (EOC) exam: An exam completed at the end of a course to allow teachers to determine how much a student's knowledge on the course's concepts has grown.
- 504 Plan: Federally legal document that outlines a student's accommodations based on their disability. Typically used by students who have physical disabilities.

- Highland Prep Academies: A system of charter schools in Arizona that includes MHP, HPS, and HPW that are STEM focused and college preparatory high schools.
- Highland Prep Surprise (HPS): A STEM college preparatory charter high school that is in Surprise, Arizona.
- Highland Prep West (HPW): A STEM college preparatory charter high school that is in Avondale, Arizona.
- Individualized Education Plan (IEP): Federally legal document that outlines a student's accommodations based on their disability that can include speech and/or occupational therapy.
- Introduction to Engineering Design (IED): A course offered through PLTW that focuses on the engineering design process by completing hands-on projects.
- Kite Portal: A software used to complete PLTW end of course exams.
- Madison Highland Prep (MHP): A STEM college preparatory charter high school that is in Phoenix, Arizona.
- Principles of Biomedical Science (BMS): A course offered through PLTW that focuses on skills used in a variety of careers in biomedical sciences.
- Principles of Engineering (POE): A course offered through PLTW that focuses on the engineering design process with projects on mechanical design, infrastructure, and sustainability.
- Project Lead the Way (PLTW): An organization developed in June 1997 that has focused on engineering curriculum with hands-on projects.

- Science, Technology, Engineering, and Mathematics (STEM): An educational program that specializes in preparing students K-12 for college and careers in the fields of science, technology, engineering, and mathematics.
- Women in STEM: An international organization the works on supporting and inspiring young women to pursue degrees and careers in science, technology, engineering, and mathematics.

Summary:

This study will analyze 1036 Project Lead the Way test scores from the Highland Prep Academies. The primary focus will be determining what are the significant predictors of the test scores based on course, student grade, number of times the teacher has taught the course, and the semester. A multi-linear regression analysis will be used for this portion. A two-way analysis of covariance will be used to determine if there is a significant difference in student PLTW test scores across student ethnicity and gender. Similarly, a two-way ANCOVA will be used to determine if there is significant difference in student PLTW test scores across teacher gender and student gender. Lastly, an ANCOVA will be used to determine if there is a significant difference in student PLTW test scores across the Highland Prep Academies.

It is important to understand the value of a teacher through the years with high teacher turnover rates and high cost in PLTW training. Their effect on students can include opportunities for college credit and scholarships. For students of low-income this can encourage them to seek post-secondary education. Furthermore, with a low gender ratio and low minority percentage in engineering, understanding the correlation between student PLTW test scores and student gender/ethnicity can help drive programs to encourage diversity in engineering.

CHAPTER II: Literature Review

Introduction:

Education research is critical to the improvement of students' academic pursuits and the well-being of society. There are five main categories of education research that relate to this study: Project Lead the Way, STEM curriculum, teacher impact, teacher gender, and student gender and ethnicity. In this chapter a literature review of such research is conducted focusing on studies that occurred after 2007.

Research on Project Lead the Way:

Since June 1997, Project Lead the Way (PLTW) has continued to add course offerings and optimize curriculums. Many studies have been conducted on varying aspects of the curriculum, including opinions from parents, teachers, and principals, and test scores. Two of such studies were conducted in Indiana and, though dating back to 2007, give relevant insight for this research.

A study in Indiana was conducted on thirty-seven high school principals, who completed a Likert scale survey on their perceptions of PLTW. The primary research focus was on the principals' perceptions on the effect of PLTW on their schools. Overall, the principals had "very strong positive perception of the effect of PLTW on their schools, their teachers, and their students."[17] The relationship between the principals' demographics and their attitudes toward PLTW was a secondary research question. It was determined that there was no significant

[17] Rogers, George E, "The Perceptions of Indiana High School Principals Related to Project Lead The Way."

difference between the principals' perceptions of PLTW based on their demographics. Due to low diversity in participants with a small sample size, the relationship between a principal's characteristics and demographics to their perception of PLTW may not be accurate.

One of the principals' perceptions evaluated was the effect PLTW had on their teachers. An average Likert score of 4.75 was measured for the effect PLTW had on their teachers' motivation and enthusiasm. The success of students in mathematics (M = 4.39) and in science (M = 4.34) were also perceived to be positively affected by PLTW. The relationship between teacher enthusiasm and student success was not evaluated in this study, so the question of how much of student success was due to teacher enthusiasm versus the PLTW curriculum is not understood.[18] This inquiry can be expanded to the investigation of the relationship between a teacher's years of experience with PLTW and a student's success.

Shortly after the previous study, another was conducted on barriers with implementing PLTW as perceived by high school principals. Sixty principals from high schools in Indiana completed a Likert scale survey on varying topics. Responses were analyzed based on principal gender. Overall, female principals agreed more strongly to most statements, including support in implementing the program and equipment being too expensive. Female principals disagreed more strongly with statements such as PLTW would mean removing all other technology education classes and that students in their school didn't have time for PLTW courses due to core

[18] Rogers, George E, "The Perceptions of Indiana High School Principals Related to Project Lead The Way."

classes. All principals agreed that their support is important to teacher success in teaching PLTW courses.[19]

As mentioned in both 2007 studies, principal support is important in teacher success with teaching PLTW courses. Through teacher success with PLTW curriculum, students will be more likely to be successful in the courses too. Since Project Lead the Way is part of the schools' charter it is important that all administrators have positive perceptions of the curriculum.

School staff are only one key influence for students on their education. Parents can impact their children's perception and motivation for learning. At the Highland Prep Academies an annual survey is sent to parents of students who are asked their perception of staff, policies, and curriculum. Similarly, a study was conducted in an Indiana high school on the parents' perception of Project Lead the Way. The participants included 80 parents from a single school in northeastern Indiana. They completed a demographics information survey and a Likert scale survey on their perception of PLTW curriculum. The study determined that parents with a higher gross income or were male had a more positive perception of PLTW. However, this study didn't analyze the parents' perceptions based on ethnicity. This may have been due to 87.5% of parents being white.[20]

Since the Highland Prep Academies are charter schools, parents choose to enroll their students instead of sending them to the public schools. This means parents may feel that the curriculum provided is preferable to that of the other schools. As the previous study stated in

---

[19] Shields, C. J., "Barriers to the Implementation of Project Lead the Way as Perceived by Indiana High School Principals."

[20] Werner, Gary, Todd R. Kelley, and George E. Rogers, "Perceptions of Indiana Parents Related to Project Lead The Way."

their theoretical framework, parental involvement can have a large impact on a student's education and future. Parents who are more positive about PLTW curriculum can help their students be more successful in the courses.

A method to measure the success of a student is through state test scores. A longitudinal study conducted in Iowa evaluated the state test scores of 26,030 students as eighth graders and later as eleventh graders. A small portion, 5.07%, of these students participated in a PLTW course. The research concluded that PLTW students had a greater increase in their mathematics and science achievement percentiles in 11th grade than non-participants. However, on average PLTW students had higher percentiles in 8th grade than nonparticipants. Demographically, 85% of the PLTW students were male and 91% of them were white.[21]

This study shows that Project Lead the Way curriculum is beneficial to student state test scores for this high school in Iowa. The demographics of the Highland Prep Academies are very different from the Iowa PLTW students. Majority of the students enrolled in HPA are Hispanic and roughly 60% are male.[22] Based on the American College Testing (ACT), the state test in Arizona for eleventh graders, Hispanic students on average score 4.9 to 2.7 points lower than white students.[23] Research into if PLTW has the same state test score benefits for Hispanic students and students of other non-white ethnicities would need to be investigated further.

---

[21] Rethwisch, D., (2014) "A Study of the Impact of Project Lead the Way on Achievement Outcomes in Iowa"

[22] Public School Review, "Madison Highland Prep."

[23] Daniel M. McNeish, Justine Radunzel, and Edgar Sanchez, "A Multidimensional Persepective of College Readiness: Relating Student and School Characteristics to Performance on the ACT," 32.

Further research regarding the positive and negative effects of PLTW is a common thread in all aforementioned studies. A 2019 study evaluated many published articles about PLTW and compiled a pros and cons list for the curriculum. The major cons are the large expense involved with implementing and running PLTW courses, and the time consumption for the students participating in the courses. The major pros are the developing of critical thinking skills and improved academic performance of the students, and for teachers detailed activities and projects are provided in the PLTW curriculum.[24]

A 2011 study analyzed a survey from 174 teachers, of which 78 were PLTW teachers, from across the United States. Based on demographics the gender ratio for nonPLTW teachers (50/50) to PLTW teachers (73/27) of male to female is drastically different. 99% of the nonPLTW teachers and 92% of the PLTW teachers were white. A part of the survey included a Likert 7-point scale on frequency. The results concluded that nonPLTW teachers agreed more strongly that to be a successful engineer, students would need a high understanding of science, math, and technology.[25]

A similar limitation occurs in this study as in previous studies, most of the participants are white and male. This creates a gap in the research on Project Lead the Way. More data and research are needed on participants that are nonwhite and female. This is reiterated in a report from Missouri which looks at demographics of all high schools, including those that offer and don't offer PLTW.

---

[24] Stebbins, Melissa, and Tatiana Goris, "Evaluating STEM Education in the U.S. Secondary Schools: Pros and Cons of the «Project Lead the Way» Platform."

[25] Mitchell J. Nathan, Amy K. Atwood, Amy Prevost, L. Allen Phelps, Natalie A. Tran, "How Professional Development in Project Lead the Way Changes High School STEM Teachers' Beliefs about Engineering Education."

It was determined that 57% of the PLTW schools had more than 1,200 students. 91 out of 524 public schools offered PLTW while one out of thirteen charter schools offered PLTW. The nonPLTW schools had ~80% white students, while the PLTW schools had ~66% white students. However, the students that participated in PLTW at the schools were more likely to be white. All schools were roughly balanced with gender ratio, except that female participation in PLTW engineering was less than 20%. In PLTW's biomedical science course the female participation was ~72%. Schools that offered PLTW had fewer students on a free/reduced lunch plan by 10% compared to nonPLTW schools. In addition, students on a free/reduced lunch plan were less likely to participate in PLTW courses.[26]

Students who participated in PLTW had greater proficiency in 8th grade Measures of Academic Progress (MAP, Missouri state test) math, English, and science achievement by ~10-30%. At the high school level PLTW students scored on average 1.2 points higher on the ACT than nonPLTW students. PLTW students have a 2% higher graduation rate and an 8.5% increase in enrolling in four-year college.[27]

A study at a university in 2019 analyzed engineering students and their retention and graduation rate in comparison to PLTW. The fall 2010 cohort showed no difference between students who had and had not participated in PLTW. For the fall 2015 cohort there were some differences. PLTW students had a higher retention rate than nonPLTW students from first to

---

[26] 10 Camburn, Eric, Karin Chang, Takako Nomi, Michael Podgursky, Darrin DeChane, Anwuli Okwuashi, Mark Ehlert, Jeongmi Moon, and Xinyi Mao. 2023. Review of Final Report of the Impact of Project Lead the Way on Missouri High School Students.

[27] Camburn, Eric, Karin Chang, Takako Nomi, Michael Podgursky, Darrin DeChane, Anwuli Okwuashi, Mark Ehlert, Jeongmi Moon, and Xinyi Mao. 2023. Review of *Final Report of the Impact of Project Lead the Way on Missouri High School Students.*

second year of college. Majority of the enrolled students were white and male. There was no difference found in the retention rate and PLTW participation when controlling for ethnicity. An increase in retention rate was determined for racial minority students who had participated in PLTW than those who had not. No difference could be observed in female students due to all female students having not participated in PLTW.[28]

Research on STEM Curriculum:

Project Lead the Way is a STEM program that can be implemented by any school. Most high schools can be categorized as either a STEM school, a school with no STEM program, a school with a mandatory STEM program, or a school with an optional STEM program. Highland Prep Academies are STEM schools that are STEM certified by Cognia.[29]

A survey from 2019 analyzed engagement and achievement from 2,695 high school students from schools with varying STEM programs. The High School Survey of Student Engagement was used to measure cognitive, emotional, and social engagement of students. Grade point average (GPA) and standardized test scores were used to measure student academic achievement. It was determined that students in STEM programs or STEM schools had a statistically significant increase in achievements compared to non-STEM students. Unexpectedly the increase in achievement not only included mathematics and science, but also social studies, reading, writing, and overall GPA.[30]

---

[28] Juliana Utley, Toni Ivey, John Weaver, “How Professional Development in Project Lead the Way Changes High School STEM Teachers’ Beliefs about Engineering Education.”

[29] Madison Highland Prep, “Homepage.”

[30] Patel, Nimisha H., M. Suzanne Franco, and Larry G. Daniel, “Student Engagement and Achievement: A Comparison of STEM Schools, STEM Programs, and Non-STEM Settings.”

A large correlation between engagement and achievement was observed for students in STEM schools. The smallest correlation was found for students in a STEM program. This was surprising as these two instructional programs have the most in common. The correlation between engagement and achievement had similar levels for students in a non-STEM school or students opting to not participate in a STEM program.[31]

Another study evaluated the main considerations for teaching integrated STEM education, such as PLTW. Four teachers at a middle school in a midwestern state participated in the study. Data was collected through field notes, three structured observations, and weekly interviews. Observations included the teachers not always completely confident with the PLTW curriculum and implementation. The teachers weren't sure of the longevity of the curriculum, considering the teaching position as short-term. It stated that "One teacher made several comments throughout the year that she just wanted to teach a mathematics class because she did not go to school to teach STEM.". The researchers developed a "s.t.e.m. model of considerations for teaching integrated STEM education" that include key factors for support, teaching (lesson planning and classroom practices), efficacy, and materials.[32]

Having four participants limited the study to fewer data points. Furthermore, all teachers were from the same middle school in a midwestern state. Though limited by number of participants and location, the teachers had varying backgrounds including two in science, one in mathematics, and one in technology. Another limitation is that the number of years they had

---

[31] Patel, Nimisha H., M. Suzanne Franco, and Larry G. Daniel, "Student Engagement and Achievement: A Comparison of STEM Schools, STEM Programs, and Non-STEM Settings."

[32] Stohlmann, Micah, Tamara J. Moore, and Gillian H. Roehrig, "Considerations for Teaching Integrated STEM Education."

taught PLTW was not mentioned.[33] This is an important factor as confidence in teaching a subject comes with the number of years taught.[34]

Implementing STEM curriculum can create challenges and have complexities that need to be addressed. Three female teachers implementing mathematical decision-making (MDM) participated in a study that was conducted through observations and interviews. When using a prepackaged curriculum, such as MDM, set methods of implementing and presenting activities are included. It was determined that teachers who had negative perceptions of their students' abilities, backgrounds, and engagement tended to use low presentation fidelity. This was due to teachers using more direct instruction, including guided lectures or questioning techniques that were not mentioned in the curriculum. Teachers' belief about teaching affected their implementation fidelity but was primarily related to high presentation fidelity. In addition, a lack of content knowledge was related to low presentation fidelity.[35]

Project Lead the Way is a prepackaged curriculum that provides activities and presentations. A teacher guide goes over how concepts are to be presented and suggests methods for facilitating activities. Though there is no requirement to keep high fidelity with the curriculum from the organization, the cost of using the curriculum encourages proper use of all activities. However, activities can be adjusted when needed, such as due to lack of equipment. For example, in the Principles of Engineering curriculum an activity called "Project 4.2.2

---

[33] Stohlmann, Micah, Tamara J. Moore, and Gillian H. Roehrig, "Considerations for Teaching Integrated STEM Education."

[34] Odette Umugiraneza, Sarah Bansilal, and Delia North, "An Analysis of Teachers' Confidence in Teaching Mathematics and Statistics."

[35] Holstein, Krista A., and Karen Allen Keene, "The Complexities and Challenges Associated With the Implementation of a STEM Curriculum."

Waterwheel Design" has students design and construct a device that uses running water to produce electricity. For the source of water, the teacher guide states, "Use whatever source of moving water is available, whether that is a creek on the school grounds or water from a faucet.".[36] Due to not all classrooms having access to a suitable water source, sink or creek, this activity can be switched to a windmill design. Since this project is part of a unit on renewable energy, this adjustment maintains good fidelity to the original curriculum.

Teachers' perspective on their students not only affects their curriculum fidelity, but also the grade they give to students. A study observed whether biases based on STEM stereotypes were related to teachers' evaluations of student performance in mathematics. Biases can be explicit with the individual being consciously aware of them or implicit which automatically occurs based on observations. One of the most common STEM stereotypes is that white men have greater ability in mathematics and any other math-based studies.[37]

413 teachers reviewed eighteen student responses that were assigned a name distinct to a gender and ethnicity. Though the teachers were primarily white and female, they did vary in age, years of experience, and school region. Based on student gender and ethnicity there was no difference in how teachers graded the responses. It was found that there was a significant difference in grades and a teacher's belief on gender discrimination. Teachers that had strong beliefs (75th percentile) that gender discrimination was no longer a problem gave a higher score to students with a male name. While teachers who believed that gender discrimination was still

---

[36] Project Lead the Way, "Project 4.2.2 Teacher Resources."

[37] Yasemin Copur-Gencturk, Ian Thacker, and Joseph R. Cimpian, "Teachers' race and gender biases and the moderating effects of their beliefs and dispositions."

an issue (below 50th percentile) had no statistically significant difference in grades based on student gender.[38]

Gender and ethnic biases can affect whether a student would pursue a career in STEM. This stereotype threat is the most cited factor for the reason why female students do not go into STEM. A study in 2024 analyzed the relationship between student gender and their sense of belonging in STEM. 290 students from Durham University, University of Birmingham, and University of Oxford completed a survey. Of these students 48.6% were female and 44.8% were male. 23 students from Durham University participated in one-to-one interviews. It was determined that mostly female students defined STEM belonging as "feeling safe and comfortable in the STEM community and settings". Furthermore, a majority of female, first-generation, and non-binary students had thought of dropping out of college occasionally or frequently.[39]

With a majority, 79%, of students being white, no definitive results were found for the relationship between ethnicity and STEM belonging. All participants came from chemistry, physics, or mathematical-science departments. Therefore, no data was collected for other fields in STEM like biology, engineering, or computer science.[40] Though high schools do not assign

---

[38] Yasemin Copur-Gencturk, Ian Thacker, and Joseph R. Cimpian, "Teachers' race and gender biases and the moderating effects of their beliefs and dispositions."

[39] Dost, Gulash, "Students' perspectives on the 'STEM belonging' concept at A-level, undergraduate, and postgraduate levels: an examination of gender and ethnicity in student descriptions."

[40] Dost, Gulash, "Students' perspectives on the 'STEM belonging' concept at A-level, undergraduate, and postgraduate levels: an examination of gender and ethnicity in student descriptions."

students to different fields of STEM, creating a sense of belonging in STEM at this age impacts their future in the fields.

The study determined key themes for students integrating into the STEM fields based on survey and interview responses. "These themes include (1) feeling safe and comfortable in the STEM community and settings, (2) having a shared passion and an interest in STEM, (3) building, bridging, bonding [...], (4) receiving adequate support from members of the STEM community, (5) building and maintaining individual resilience." In addition, key themes for students to continue in the STEM fields are "(1) equity, inclusion, and diversity in STEM fields, (2) being valued, appreciated, and respected in STEM environments, (3) individuals' beliefs in their capacity/ability and inquisitiveness in STEM areas, (4) STEM literacy—advancing knowledge in and of STEM."[41]

Another study evaluated the themes of conceptualizations of STEM education. Thirteen teachers and administration from a STEM-focused high school, twelve teachers from two traditional middle schools, and nine STEM educators and stakeholders participated by creating concept maps of STEM education and completing a follow-up interview. 85% of participants mentioned connections across disciplinary subjects, 74% mentioned focusing on what "teachers must attend to instructionally when implementing a STEM approach", and 71% mentioned making connections between classroom content and real-world problems.[42]

---

[41] Dost, Gulash, "Students' perspectives on the 'STEM belonging' concept at A-level, undergraduate, and postgraduate levels: an examination of gender and ethnicity in student descriptions."

[42] Tamara D. Holmlund, Kristin Lesseig, and David Slavit. "Making sense of "STEM education" in K-12 contexts."

A study from 2016 compiled a list of essential elements of a STEM high school. Twenty schools from Ohio, Washington, California, North Carolina, and Tennessee participated through interviews. The eight elements were personalization of learning, problem-based learning, rigorous learning, career, technology, and life skills; school community and belonging, external community, staff foundations, essential factors".[43] These elements are reiterated through other studies, and some can be found in the Highland Prep Academies student handbook. Specifically, problem-based learning, rigorous learning, and career, technology, and life skills.[44]

Research on Teacher Impact:

A study in Jamaica on three school districts investigated the relationship between teacher competencies, student gender, school location, and student standardized academic test results. 623 students from 43 primary schools in grade levels three and four participated in the study. 36% of the third-grade teachers and 43% of the fourth-grade teachers had taught between 1 to 10 years of teaching. Though no relationship was found between teacher competencies and third-grade test scores, two relationships were statistically significant for the fourth-graders. Students were 1.8 times more likely to attain higher proficiency when their teacher had qualifications in education. Furthermore, students were 3.13 times more likely to attain higher

[43] Melanie LaForce, Elizabeth Noble, Heather King, Jeanne Century, Courtney Blackwell, Sandra Holt, Ahmed Ibrahim, and Stephanie Loo, "The eight essential elements of inclusive STEM high schools."

[44] Madison Highland Prep, "Student Handbook."

proficiency when their teacher had taught between 1 to 10 years compared to teachers who had taught 31 to 45 years.[45]

In the 2015-16 academic school year, the average years of teaching of an American teacher was 13.7 years. The majority (42.3%) of teachers had taught more than 15 years, while 19.4% taught 10-14 years, 23.2% taught 4-9 years, and 15.0% taught less than 4 years.[46] Therefore, the Jamaican study does not completely extend to American schools. Very few teachers have taught 31-45 years and grouping teachers with experience between 1 and 10 years means that no significance can be determined in the earlier years.

An Australian study focused on the initial years of teacher experience in early childhood education. Classroom observations were conducted with a 7-point scale rating on ten dimensions of teaching. These ten dimensions compose three domains, which the 80 participating teachers scored highest in Emotional Support (M = 5.24) and Classroom Organization (M = 4.90). They scored lowest in Instructional Support (M = 3.60). 25 of the teachers taught between 0-3 years while the rest taught over 3 years. An ANCOVA was used to analyze the relationship between teacher experience and the domains. There was no statistical difference in domain scores across the two groups of teachers. A deeper investigation showed the same results for the individual dimensions.[47]

---

[45] Armstrong, Melva, "The Effects of Teacher Competencies, Gender, and School Location on Primary School Standardised Academic Test Results in Three Districts in Jamaica."

[46] National Center for Education Statistics, "Percentage of public school teachers based on years of teaching experience, average total years of teaching experience, percentage of teachers based on years teaching at current school, and average years teaching at current school, by selected school characteristics: 2015–16."

[47] Graham, Linda J., Sonia L.J. White, Kathy Cologon, and Robert C. Pianta, "Do Teachers' Years of Experience Make a Difference in the Quality of Teaching?"

This study touched on factors beyond knowledge for teacher competencies. Another study investigated the positive and negative effects of teacher attitudes and behaviors on student learning. 164 female and 65 male participants from two Turkish universities completed a survey that broke down positive and negative behaviors. Ninety-nine reported negative classroom management and communication with 45 falling under the category of humiliation or insult. Eighty-three reported discrimination and injustice with 25 of the instances of discrimination based on achievement level. Twenty-three reported professional inadequacy and irresponsibility with 17 being inefficient course management. These negative teacher behaviors can cause students to disengage from lessons, which would inhibit their success.[48]

Seventy-six reported effective communication and ethical attitude with 52 participants feeling valued by their teacher. Seventy-three reported professional competence and commitment with 22 stating their teacher had subject matter expertise and effective teaching. Forty-seven reported individual support and trust with 25 identifying that their teacher gave moral and material support. Teachers with positive attitudes and behaviors can establish good relationships with students and a safe classroom environment. Even teachers who are strict can be appreciated by students for a fair classroom environment and avoiding discrimination.[49]

In the Highland Prep Academies' student handbook, it highlights similar expected behaviors for staff including teachers. Showing respect for students and providing a positive learning environment are a few of the first ones listed. Towards the end of the specified

---

[48] Kahveci, Hakkı, "The Positive and Negative Effects of Teacher Attitudes and Behaviors on Student Progress."

[49] Kahveci, Hakkı, "The Positive and Negative Effects of Teacher Attitudes and Behaviors on Student Progress."

expectations, it states “To uphold and understanding that nobody has the right to interfere with the learning of others regardless of background, race, gender or age and to uphold the understanding that nobody has the right to impose physical or mental harm on another regardless of background, race, gender, or age.”. Therefore, staff have the responsibility to not discriminate, humiliate, or insult any students, staff, parents, etc.[50]

Other aspects of positive teacher behavior are enthusiasm, engagement, creativity, commitment, and flexibility. This encompasses the term passionate teaching. A study from 2023 reviewed the impact of such teachers on student outcomes. Students achieve, learn, and engage more when being taught by a passionate teacher. By creating positive and engaging learning environments in a classroom, these teachers can promote higher academics in their students.[51]

In addition, passionate teachers are more likely to stay at a school when dealing with challenges. The study delves into what schools and districts must do to retain these high-quality teachers. Creating a supportive and rewarding environment is key to growing teacher passion and satisfaction. Providing professional development opportunities allows teachers to grow career skills and increase enthusiasm for their content specialty. Competitive salaries and benefits help teachers feel valued and appreciated. Administration support in managing job demands allows teachers to focus on their passion of teaching. All these factors promote passionate teaching and higher retention rates.[52]

---

[50] Madison Highland Prep, “Student Handbook.”

[51] Levitt, Greg, Steven Grubaugh, Joseph Maderick, and Donald Deever, “The Power of Passionate Teaching and Learning: A Study of Impacts on Social Science Teacher Retention and Student Outcomes.”

[52] Levitt, Greg, Steven Grubaugh, Joseph Maderick, and Donald Deever, “The Power of Passionate Teaching and Learning: A Study of Impacts on Social Science Teacher Retention and Student Outcomes.”

Teacher retention rates affect student achievement, similarly to teacher behavior, attitudes, and enthusiasm. A large study conducted in New York State and New York City reviewed 850,000 fourth and fifth grade students' state test scores. The data consisted of eight academic years, including fall 2001 to spring 2003 and fall 2005 to spring 2011. The math and English language art test scores were linked from student to teacher. Majority (70%) of students were either black or Hispanic and 72% of students were on the free/reduced lunch program. [53]

On average, 4% of teachers transferred to different schools within New York and 86% of teachers stayed at the same school. It was determined that the relationship between student test scores and teacher turnover is statistically significant and negative. This means the students perform poorly when a school experiences many teachers leaving. Math scores, when there is 100% turnover compared to none, are 8.2% to 10.2% standard deviations lower. Similarly, English language art test scores are 4.9% to 6.0% standard deviations lower. The study mentions that schools with large populations of low-performing students are more negatively impacted by teacher turnover.[54]

A teacher's content expertise includes content knowledge and common student misconceptions. Investigating the relationship between student learning and teacher knowledge, a study surveyed 9,556 middle school students and 181 physical science teachers. 62% of the students were white, 10% black, and 14% Hispanic. The majority of the teachers (78%) had degrees in physical science, science education, or another science. The teacher survey contained

---

[53] Ronfeldt, Matthew, Susanna Loeb, and James Wyckoff, "How Teacher Turnover Harms Student Achievement."

[54] Ronfeldt, Matthew, Susanna Loeb, and James Wyckoff, "How Teacher Turnover Harms Student Achievement."

subject matter knowledge (SMK) that teachers would try to answer correctly and then identify the most common wrong student answer using their knowledge of student misconceptions (SMK).[55]

40.7% of teacher responses were correct in terms of SMK and KOSM. 41.8% of teacher responses were correct with SMK, but not with KOSM. 2.0% of teacher responses were correct with KOSM, but not with SMK. 15.5% of teacher responses were incorrect in terms of SMK and KOSM. For students with high math and reading scores, they benefited from teachers having SMK only and benefited more so when their teacher had both SMK and KOSM. For students with low math and reading scores, they benefited from having teachers with KOSM and SMK. When a teacher only had SMK, the low scoring students performed more poorly in comparison to a teacher with no SMK and no KOSM.[56]

Content knowledge and understanding how to teach that knowledge are key components of being a teacher. A review of studies in 2022 investigated the impact of math teachers' competence, knowledge and pedagogy, on student learning. One study of 373 primary school teachers from Cyprus determined that content knowledge could be a prerequisite to pedagogical knowledge. Another study in the United States of 200 fourth and fifth graders found that advanced content knowledge and pedagogical knowledge were both needed for a teacher to be competent. One study examined thirty-nine novice and expert teachers' classroom management

[55] Sadler, Philip M., Gerhard Sonnert, Harold P. Coyle, Nancy Cook-Smith, and Jaimie L. Miller, "The Influence of Teachers' Knowledge on Student Learning in Middle School Physical Science Classrooms."

[56] Sadler, Philip M., Gerhard Sonnert, Harold P. Coyle, Nancy Cook-Smith, and Jaimie L. Miller, "The Influence of Teachers' Knowledge on Student Learning in Middle School Physical Science Classrooms."

perceptions, interpretations, and decision-making skills. It was determined that expert teachers were more adaptable in their course of action in the classroom. Furthermore, a cross-sectional study in China evaluated preservice, early career, and experienced teachers' noticing skills. A linear growth was observed from preservice to early career to experienced teachers' skill level. Teacher classroom-management skills positively affected student engagement. Overall, it was determined that there was a strong relationship between student outcome and instructional quality.[57]

Teacher Gender Research:

It is commonly known that the majority of teachers are female. A 2020-21 survey in the United States showed that 89% of elementary (kindergarten to sixth grade) school teachers were female. For secondary (seventh thru twelfth grade) school teachers have 64% female.[58] Research has been conducted on the impact of teacher gender on student test scores and ... Concern has been stated in regard to male students not having male teachers as role models. Similarly, concern of female students not having female teacher role models in mathematics, engineering, and physics are mentioned.

A U.S. study investigated the effects of teacher gender on student achievement in elementary schools. The 17 schools that participated were disadvantaged and had teacher shortages. 97% of the 1900 student participants were on free/reduced lunch. Pretests and

---

[57] Yang, Xinrong, and Gabriele Kaiser, "The Impact of Mathematics Teachers' Professional Competence on Instructional Quality and Students' Mathematics Learning Outcomes."

[58] National Center for Education Statistics, "Characteristics of Public School Teachers."

posttests were completed, and due to missing data the final participants included 1664 students and 95 teachers. Though 75% of the teachers were female the students had a 50/50 gender ratio.[59]

It was noted that in a 2010 negative effect was determined from female teachers on female students' math achievements. In a 2013 study, there was no relationship between teacher gender and student achievement. In the U.S. study it was determined that female teachers have a negative impact on mathematics outcomes of female students. This relationship was not observed for reading test scores. However, if the female teacher has a strong math background, then the negative impact is not observed. A suggestion on the reasoning of this relationship is the math anxiety hypothesis, which states "math anxiety among primary school female teachers in conjunction with female student endorsement of gender stereotypes may be leading to poorer math achievement among female students but not male students.".[60]

Primary school is the first interaction of teachers and students while a four-year university is typically the last. A 2022 study examined the career outcomes of students from the United States Air Force Academy based on professor gender in students' first year math and science classes. Participants graduated between 2004 and 2008, and included 838 female and 3,925 male students. Without taking teacher gender into consideration it was determined that 22% of female graduates worked in a STEM occupation compared to 20% of male students. STEM bachelor's

---

[59] Antecol, Heather, Ozkan Eren, and Serkan Ozbeklik, "The Effect of Teacher Gender on Student Achievement in Primary School."

[60] Antecol, Heather, Ozkan Eren, and Serkan Ozbeklik, "The Effect of Teacher Gender on Student Achievement in Primary School."

degrees were obtained by 28% of female students and of those with a STEM degree 42% pursued a STEM occupation.[61]

This study determined that teacher gender mostly impacts high-ability students. Female students of female professors have significantly higher academics than female students of male professors. Specifically, female students score on average 14.4% of a standard deviation lower than male students when their professor is male. It was also observed that female students were 37.1% less likely to graduate with a STEM degree than male students when they had a male professor for their freshman year math and science classes. Female students were more likely to switch to STEM occupations in two to six years after graduating if they had female math/science professors freshman year.[62]

In a 2016 study twelve New Zealand elementary schools participated in an investigation of teacher expectations about mathematics based on gender. 73% of the teachers that participated were female. Overall students with male teachers had slightly lower achievement, but it was not statistically significant ($p = 0.14$). However, female students had statistically significant ($p < 0.04$) lower achievement than male students when assigned to a male teacher. Though male students had slightly lower achievement than female students when assigned to a female teacher it was not statistically significant.[63]

---

[61] Mansour, Hani, Daniel I. Rees, Bryson M. Rintala, and Nathan N. Wozny, “The Effects of Professor Gender on the Postgraduation Outcomes of Female Students.”

[62] Mansour, Hani, Daniel I. Rees, Bryson M. Rintala, and Nathan N. Wozny, “The Effects of Professor Gender on the Postgraduation Outcomes of Female Students.”

[63] St J. Watson, Penelope W., Christine M. Rubie-Davies, Kane Meissei, Elizabeth R. Peterson, Annaline Flint, Lynda Garrett, and Lyn McDonald, “Gendered Teacher Expectations of Mathematics Achievement in New Zealand: Contributing to a Kink at the Base of the STEM Pipeline.”

Using a survey, there was no difference in teacher expectations of students' mathematics achievement based on student gender. When expectations of students' mathematics achievement was based on teacher gender, it was found that male teachers had lower expectations. Since these lower expectations by male teachers were observed for all students, then there are other factors affecting female students having significantly lower achievement when assigned to a male teacher. A possibility posed by the study is that a male teacher unintentionally reiterated to female students the stereotype of women having inferior mathematics ability.[64]

Another study in Indiana evaluated how matching teacher and student gender impacted academic achievement. Students in third to eighth grade during the school years 2010-2011 and 2016-2017 participated in the state's standardized test over general mathematics and English language arts. The Indiana Department of Education also includes teacher demographic, which allows connecting student information to their respective teacher. A total of 766,519 students from 1,957 schools participated in the assessment.

Around 87% of the elementary teachers, both math and ELA, were female. In middle school 69.7% of the math teachers and 82.7% of the ELA teachers were female. The study determined a significant trend of an increase in student achievement when assigned to female teachers. This impact was most notable in female middle school students for mathematics. Specifically, for female elementary teachers, the coefficient in mathematics was 0.025 SD for

[64] St J. Watson, Penelope W., Christine M. Rubie-Davies, Kane Meissei, Elizabeth R. Peterson, Annaline Flint, Lynda Garrett, and Lyn McDonald, "Gendered Teacher Expectations of Mathematics Achievement in New Zealand: Contributing to a Kink at the Base of the STEM Pipeline."

female students compared to 0.016 SD for male students. For middle school mathematics the female teacher coefficient was 0.033 SD for female students while for male students it was 0.020 SD. These differences in mathematics test scores were statistically significant ($p < 0.001$). For ELA the differences in test scores were not significant across gender.[65]

A study in Spain focused specifically on the effect teacher gender has on student mathematics achievement. Participants included 2,083 high school students and 90 teachers from 90 different schools. Of the ninety teachers, 49.2% were female. It was found that both male and female students had improved test scores when taught by a female teacher. For male students, having a female teacher improved their score by 12 points and was statistically significant ($p < 0.05$). In contrast, test scores for female students with female teachers decreased by 10 points, but were not statistically significant.[66]

Teacher gender affects more than student ELA and mathematics achievements. A study investigated how teacher gender impacts citizenship education, which includes knowledge of rights, responsibilities to society, and roles of a democratic community. The first portion of the study was a Likert scale survey with 223 teacher responses, 30.5% male and 69.5% female. It was observed that teacher gender had statistical significance ($p = 0.01$) on the choice of guest speaker. Male and female teachers were equally likely to have a police officer as a guest speaker. Male teachers were more likely (10% difference) to have a community leader or politician as a

[65] Hwang, NaYoung, and Brian Fitzpatrick, "Student-Teacher Gender Matching and Academic Achievement."

[66] Escardíbul, Josep-Oriol, and Toni Mora, "Teacher Gender and Student Performance in Mathematics. Evidence from Catalonia (Spain)."

guest speaker. Female teachers were more likely (20% difference) to have a representative from a non-governmental agency as a guest speaker.[67]

An open-ended question survey had 206 teacher responses, 74% female and 26% male. Overall, female teachers were more likely to reference social awareness and student voice. While male teachers were more likely to reference citizenship, rights, and responsibility. The study also found some evidence that female teachers were more likely to promote greater student participation in class. Furthermore, female teachers believed that student councils were more effective than male teachers. It was determined that there was little difference in the teachers' method of teaching and perspective about civil education.[68]

Student Gender and Ethnicity Research:

Education begins in early childhood with parents and guardians introducing numbers, the alphabet, etc. This can impact a child's future in how they perceive different subjects such as mathematics and reading. A study in 2024 interviewed ten Latina mothers about their beliefs and attitudes towards mathematics. This study is important as 57% of Hispanic students who take the SAT score less than 490 in the math section.[69] In previous studies, it has been observed that Latine

[67] O'Brien, Gearóid, "Teacher Gender in Citizenship Education: Does It Make a Difference?"

[68] O'Brien, Gearóid, "Teacher Gender in Citizenship Education: Does It Make a Difference?"

[69] Ember Smith and Richard V. Reeves, "SAT math scores mirror and maintain racial inequity".

parents tend to have limited formal math education, which causes difficulties with introducing the concepts to their children.[70]

All ten participants spoke Spanish and only a few spoke English. It was quickly evident during the interviews that literacy, reading and writing English, were emphasized more in the households. The primary reason for this was to help their children adjust to American culture and achieve the American dream. All participants mentioned negative experiences with learning mathematics, which led to their lack of confidence and mathematics anxiety. This led to the participants believing there was an inherent reason why they could not understand math. Both the mathematics anxiety and misconception of the math "gene" impacted the participants ability to help their children learn early mathematical concepts.[71]

At the beginning of 2020 COVID-19 caused the lockdown of most countries. The impacts on students' education due to online learning is still being studied. A 2021 study investigated how online learning during the lockdown affected the gender gap at the college level in engineering education. The study took place at Universidad Politécnica de Madrid with the computer engineering department and included students and professors, of which 27% were female. One of the largest factors that affected female students was difficulties in managing domestic and academic tasks. This caused challenges in attending and participating in class. It was observed that the female students' performed worse academically than their male counterparts during the lockdown. This was further observed in other studies, focusing on varying academic subjects.

[70] Beltrán-Grimm, Susana, "Latina Mothers' Cultural Experiences, Beliefs, and Attitudes May Influence Children's Math Learning."

[71] Beltrán-Grimm, Susana, "Latina Mothers' Cultural Experiences, Beliefs, and Attitudes May Influence Children's Math Learning."

Furthermore, the gender gap in computer engineering increased as the dropout rate of female students increased statistically significant ($p < 0.05$) while there was no significant change in the dropout rate of male students.[72]

For some academic subjects the racial gap is more pressing than the gender gap. The medical field is white and Asian dominant, while African Americans, Latinos, and others are underrepresented. A 2023 study surveyed 192 medical students on their number of Medical College Admission Test (MCAT) attempts. 63% of the students were white, 15% Asian, 9% African American, 10% Hispanic, and 5% multiple races. The underrepresented students had more MCAT attempts than their white and Asian classmates. Additional investigation showed no statistically significant ($p < 0.05$) difference in students' use of MCAT preparation resources, attendance to a university with MCAT preparation support, cost for test, and final test scores.[73]

Another university study investigated how student gender and ethnicity affected the likelihood of earning a STEM degree. A total of 15,600 students from a research-focused institution in the southeastern United States participated. This included 7423 male students and 8177 female students. 1309 of the students were white, 1032 African American, 488 Hispanic, 366 Asian, and 105 Native Americans. International students and students who did not indicate their race were not included. This study categorized ethnic groups together in order to increase statistical power for the analysis. Hispanic, African American, and Native American students are

[72] Bordel, Borja, Ramon Alcarria, Tomás Robles, and Diego Martin, "The Gender Gap in Engineering Education During The COVID-19 Lockdown: A Study Case."

[73] Gely, Yumiko I, Ikenna H Ifearulundu, Melissa Rangel, Johanna S Balas, Yuanqing Liu, Gwyneth Sullivan, Edie Chan, Jose Velasco, and Rosalinda Alvarado, "Effects of Race and Test Preparation Resources on Standardized Test Scores, a Pilot Study."

grouped as “persons excluded due to their ethnicity or race” (PEER), while white and Asian students are in the non-PEER group.[74]

Asian students were more likely to graduate with a STEM degree than white students. However, white and Asian students are 30% more likely to receive a STEM degree than Hispanic, African American, and Native American students. Minority students were more likely than non-minority students to leave college with no degree instead of switching majors. In addition, male students were 30% more likely to earn a STEM degree than female students. Although female students are less likely to earn a STEM degree, they are more likely to earn a college degree than male students.[75]

The 2020 study in Jamaica, that included three school districts, investigated how student gender impacted standardized test scores. 623 third and fourth grade students participated in the study. For the third graders, female students were 1.92 times more likely to score mastery on the standardized test than male students. Similarly, fourth grade female students were 2.5 times more likely to score mastery on the standardized test than male students.[76]

Dual-credit courses in high school can help students obtain college degrees. Therefore, open enrollment of such courses is an important part of educational equity. A study in eastern North Carolina investigated the demographics of enrollment in Advanced Placement (AP) courses

---

[74] Robin A. Costello, Shima Salehi, Cissy J. Ballen, and Eric Burkholder, “Pathways of opportunity in STEM: comparative investigation of degree attainment across different demographic groups at a large research institution.”

[75] Robin A. Costello, Shima Salehi, Cissy J. Ballen, and Eric Burkholder, “Pathways of opportunity in STEM: comparative investigation of degree attainment across different demographic groups at a large research institution.”

[76] Armstrong, Melva, “The Effects of Teacher Competencies, Gender, and School Location on Primary School Standardised Academic Test Results in Three Districts in Jamaica.”

at five high schools. This included a total of 5,470 students, of which 21.92% were African American male, 23.77% were African American female, 24.84% were white male, and 24.15% were white female. White female students had the highest enrollment (43.4 - 59.0%) in all five subject areas (math, physical science, English, social science, and foreign language). White male students had the second highest enrollment (29.6 - 42.3%) in all five subject areas with foreign language being the smallest. African American female students had low enrollment (7.6 - 12.3%) in all five subject areas. African American male students had the lowest enrollment (3.8 - 6.3%) in all five subject areas. [77]

AP courses not only give college credit, but also prepare students for taking college entrance exams like the SAT. The five high schools have an average verbal SAT score of 498 and an average math SAT score of 504. African American male students average 390.4 and 407.2, while white male students average 530.4 and 557.2. African American female students average 425.2 and 429.6, while white female students average 502 and 502.4. This discrepancy is carried into college.[78]

Summary:

A gap in the published research allows this study to be impactful. Project Lead the Way research needs to be investigated for students of all demographics and types of schools. By analyzing test scores of individual PLTW courses Project Lead the Way, teachers, and

---

[77] Corra, Mamadi, J. Scott Carter, and Shannon K. Carter, "The Interactive Impact of Race and Gender on High School Advanced Course Enrollment."

[78] Corra, Mamadi, J. Scott Carter, and Shannon K. Carter, "The Interactive Impact of Race and Gender on High School Advanced Course Enrollment."

administration can provide required support. Curriculum such as PLTW allows schools an additional tool to implement STEM education. The knowledge of how STEM curriculum can be beneficial to students is a driving force behind schools such as the Highland Prep Academies.

Since fields of STEM have been traditionally male dominated, research on the correlation of teacher gender and student achievement can help schools know how to support change in these STEM gender stereotypes. In addition, understanding the impact of student gender and ethnicity on academic success can help schools know how to improve educational equity. Ensuring that all students have access to quality education is key to cultivating a brighter future.

CHAPTER III: METHODOLOGY

Introduction

The focus of this study is determining the significant predictors of student Project Lead the Way test scores at the Highland Prep Academies. Information on the setting and participants involved in the study is in Subsection 1, as well as limitations and the primary research question's power. Instrumentation details on the PLTW test, and the data's reliability and validity are described in Subsection 2. The procedure of how data was collected and information about the Institutional Review Board (IRB) application is given in Subsection 3. Lastly, Subsection 4 covers how each research question will be analyzed and citations on the variables used in previous studies.

Subsection 1: Setting and Participants

The Highland Prep Academies are STEM charter high schools located in Arizona, United States. Specifically, Madison Highland Prep (MHP) is in Phoenix, Highland Prep (HPS) is in Surprise, and Highland Prep West (HPW) is in Avondale. These are schools with open, limited enrollment that focus on preparing students for college. Majority of students are Hispanic at MHP (52.63%) and HPW (58.15%), while majority of students are white at HPS (46.5%). The second majority of students are white at MHP (34.3%) and HPW (24.46%), while the second majority of students are Hispanic at HPS (37.16%).

During the academic year 2022-2023, HPW only had ninth grade as the school had opened in the fall of 2022. HPS and MHP had ninth through twelfth grade students in attendance. Only MHP had Title I status due to the high percentage of students from low-income families. In total

1066 students participated in the study, though 27 students were removed due to missing data. Of the remaining 1039 students, 464 are from MHP, 438 are from HPS, and 137 are from HPW. 607 of the students are male and 432 are female. 576 of the students are Caucasian, 406 are Hispanic, 29 are African American, 10 are Native American, and 18 are Asian. 388 of the students are in ninth grade, 323 are in tenth grade, 201 are in eleventh grade, and 127 are in twelfth grade.

Students were enrolled into one of the following classes, Introduction to Engineering Design (IED), Aerospace Engineering (AE), Principles of Engineering (POE), Cybersecurity (CSC), Civil Engineering and Architecture (CEA), Digital Electronics (DE), Biomedical Science (BMS), and AP Computer Science (APCS). Of the 1039 student participants, 157 students took AE, 352 took IED, 123 took POE, 141 took CSC, 56 took DE, 108 took BMS, 102 took CEA, and 27 took APCS.

Eight teachers participated in the study by teaching the different classes. To anonymize teacher names, they are identified by letters. At MHP Teacher A taught AE, POE, and CSC at MHP, Teacher B taught BMS, and Teacher C taught IED, CEA, and APCS. AT HPW Teacher D taught IED. AT HPS Teacher E taught AE and IED, Teacher F taught CSC, DE, and CEA, Teacher G taught POE, and Teacher H taught BMS. Two of the teachers (A and B) are female while the others are male.

The results of this investigation are beneficial to the administration of Highland Prep Academies or other similar high schools that utilize Project Lead the Way curriculum. Threats to this generalization are that other schools may not have the same ratio of ethnic groups or percent of students in the free/reduced lunch program. It would be best to generalize specifically to other STEM schools but could be possibly applied to non-STEM schools. The issue with applying to non-STEM schools would be that non-STEM schools tend to not be as focused on project-based learning, which is the fundamental of PLTW.

For the main research question the desired sample size is 92. This value was determined using G*Power 3.1.9.7 with an effect size $f^2 = 0.15$, alpha level = 0.05, power = 0.80, and number of tested predictors = 5. Due to 1039 student participants, sample size is not a concern. When running a post hoc with effect size $f^2 = 0.15$, alpha level = 0.05, total sample size = 1039, and number of tested predictors = 5 a power value of 1.00 is calculated. The effect size value was selected since it is the default value in G*Power 3.1.9.7 for the statistical test of linear multiple regression.

Subsection 2: Instrumentation

Project Lead the Way tests are provided digitally by PLTW though the software Kite Portal and are given to students at the end of each course. This is a standardized test proctored similarly regardless of the school following guidelines given by PLTW. Each test is completed over two days with each day having 20 – 25 questions, which are a mix of short answer and multiple–choice questions. During the test, students can use an equation sheet, provided by PLTW, and a calculator.

If a student has an IEP or 504 that specifies a testing accommodation of extended time, alternative testing room, or questions to be read aloud, these are met through the special education department. Accommodations such as fewer questions or fewer answers in multiple-choice are unavailable since teachers are unable to edit the tests. This causes validity concerns for special education students that their PLTW scores may not accurately reflect their conceptual understanding of the curriculum.

In terms of reliability, there may be difficulty in duplicating results in other schools due to the class schedule of the Highland Prep Academies. Most traditional public schools have six to seven classes a day that are each slightly shorter than an hour. A PLTW class at such a school would be a yearlong course and PLTW's curriculum pacing guide is formulated for this. At HPA, students have four classes a day, each 90 minutes long, and most are a semester except AP classes. The curriculum's pacing is accelerated at HPA due to the difference in class schedule.

Subsection 3: Procedure

Since Highland Prep Academies has semester long courses, final exams are administered at the end of each semester. Project Lead the Way final exams are administered digitally through the Kite Portal over a two-day period. A score is then reported to the students' teachers along with a ranking on their proficiency. PLTW exams are the norm at HPA as all students must complete three PLTW courses to graduate. The scores used for this study are from 2022-23 and required no direct interaction with students as the data had been previously collected.

From the PLTW exams anonymized student scores, course, and teacher were reported. The administration of HPA provided anonymized student ethnicity, gender, grade, and entrance math exams, teacher gender, number of times the teacher had taught the course, enrolled school, and semester. All data was deidentified, ensuring participant anonymity. The identification of participants will not be available during or after the study.

The Shawnee State University's Institutional Review Board (IRB) approved an exempt review application for this study on November 7, 2023. A copy of the IRB approval form can be found in the Appendices.

Subsection 4: Data Processing and Analysis

The primary research question, "Are the number of times a teacher has taught a course, student grade, gender, ethnicity; course, teacher, teacher gender, enrolled school, and semester significant predictors of student PLTW test scores?", will use multiple linear regression (MLR) test. This test will be run with and without the covariant of entrance math exam scores. The MLR will create a model that estimates the relationship between the student PLTW test scores and the other listed variables. The variables student gender and ethnicity have been used in a study about medical certification exams.[79] Teacher gender was used in a 2021 study to evaluate the relationship in student achievement to teacher-student gender matching.[80] Though not specific to the Highland Prep Academies, other studies have investigated how different schools impact student achievement.[81] The number of times a teacher has taught a course is related to the number of years teaching which is a variable used in a study about teacher impact on emotional support, classroom organization, and instructional support.[82] A study on scientific reasoning ability investigated how student grade level relates to it.[83] Teacher and semester have been used previously but are not common. The variable teacher is included to give insight on if a specific teacher is more proficient at teaching a course. The variable semester is due to the block schedule followed by HPA such that classes only last semester.

---

79 Haq I, Higham J, Morris R, and Dacre J, "Effect of Ethnicity and Gender on Performance in Undergraduate Medical Examinations."
80 Hwang, NaYoung, and Brian Fitzpatrick, "Student-Teacher Gender Matching and Academic Achievement."
81 Patel, Nimisha H., M. Suzanne Franco, and Larry G. Daniel, "Student Engagement and Achievement: A Comparison of STEM Schools, STEM Programs, and Non-STEM Settings."
82 Graham, Linda J., Sonia L.J. White, Kathy Cologon, and Robert C. Pianta, "Do Teachers' Years of Experience Make a Difference in the Quality of Teaching?"
83 Luo, Ma, Daner Sun, Liying Zhu, and Yuqin Yang, "Evaluating Scientific Reasoning Ability: Student Performance and the Interaction Effects between Grade Level, Gender, and Academic Achievement Level."

The secondary research question, "Is there a significant difference in student PLTW test scores across student ethnicity and gender?", will use two-way analysis of variance (ANOVA). This test will be run with and without the covariant of entrance math exam scores. An ANOVA is a statistical test that analyzes the difference between the means of more than two groups. Specifically, a two-way ANOVA uses two independent variables, and for this research question those variables are student ethnicity and gender. The dependent variable is the student PLTW test scores. For this question, the PLTW test scores will be analyzed as a whole and not by course. An analysis like this was completed in a 2005 study that evaluated the mean difference in undergraduate medical examinations across student gender and ethnicity. Two-way ANOVA was used to determine that white female students performed best on all tests.[84]

The third research question, "Is there a significant difference in student PLTW test scores across teacher gender and student gender?", will use two-way analysis of variance (ANOVA). This test will be run with and without the covariant of entrance math exam scores. As stated previously a two-way ANOVA use two independent variables, student gender and teacher gender, to analyze the difference between the mean of the dependent variable, student PLTW test scores. Similarly, for this question, the PLTW test scores will be analyzed as a whole and not by course. Student-teacher gender matchings effect on academic achievement has been previously investigated in a 2021 study. Two-way ANOVA was used to determine if there was a significant difference in mean student achievement across student and teacher gender.[85]

---

[84] Haq I, Higham J, Morris R, and Dacre J, "Effect of Ethnicity and Gender on Performance in Undergraduate Medical Examinations."
[85] Hwang, NaYoung, and Brian Fitzpatrick, "Student-Teacher Gender Matching and Academic Achievement."

The fourth research question, "Is there a significant difference in student PLTW test scores across the Highland Prep Academies?", will use multivariate analysis of variance (MANOVA). This test will be run with and without the covariant of entrance math exam scores. A MANOVA is used to analyze the differences between two or more groups when there are multiple dependent variables. The three groups are the Highland Prep Academies, MHP, HPS, and HPW. The dependent variables are the student PLTW test scores for each of the PLTW classes, AE, IED, POE, CSC, DE, BMS, CEA, APCS. A study in 2019 used the same technique with four groups (traditional school, STEM program non-participating, STEM program participating, and STEM school) and analyzing if there was a significant difference across the dependent variables, which varied from student scores in subject areas, student engagement, and student GPA.[86] By using MANOVA to analyze the student PLTW test scores across the Highland Prep Academies, any significant differences in student test scores will be identified for the courses across the schools.

Summary

Most of the participants are Hispanic and majority of participants attend Madison Highland Prep or Highland Prep Surprise. There are fewer participants from Highland Prep West since when data was collected the school only had ninth graders. Using G*Power 3.1.9.7, it was determined that with a participant pool size of 1036, there was no concern about there being too few participants. Since test scores are collected through PLTW's Kite Portal there are concerns for validity of special education students' test scores. A concern for reliability is due to

[86] Patel, Nimisha H., M. Suzanne Franco, and Larry G. Daniel, "Student Engagement and Achievement: A Comparison of STEM Schools, STEM Programs, and Non-STEM Settings."

the block schedule used by the Highland Prep Academies that includes classes only lasting one semester. A requirement of the HPA is all students must take at least three PLTW courses. Therefore, students are not exposed to any additional stressors by participating in the study. All information was provided directly by the HPA administration and was anonymized for the safety of participants. Shawnee State University's IRB approved an exempt review application for this study on November 7, 2023.

The primary research question focuses on determining significant predictors of student PLTW test scores. This will be done through multiple linear regression. The second and third research questions will use two-way analysis of variance. Question two investigates the mean difference in scores across student gender and ethnicity while question three investigates the mean difference in scores across student gender and teacher gender. The last research question analyzes the mean difference in course scores across the three schools in the HPA by using multivariate analysis of variance. Each research question will be analyzed with and without the covariant of student entrance math exam scores.

CHAPTER IV: RESULTS

Introduction:

The results of this study will be presented in this chapter. The primary goal of this study was to determine if there are significant predictors of students Project Lead the Way test scores at the Highland Prep Academies. The research questions investigated were:

1. Are the number of times a teacher has taught a course, student grade, gender, ethnicity; course, teacher gender, enrolled school, and semester significant predictors of student PLTW test scores?

2. Is there a significant difference in student PLTW test scores across student ethnicity and gender?

3. Is there a significant difference in student PLTW test scores across teacher gender and student gender?

4. Is there a significant difference in student PLTW test scores across the Highland Prep Academies (MHP, HPS, HPW)?

The following sections will go over data cleaning, description of the participants, and then addressing each of the research questions with and without the covariant entrance math exam scores. Significance levels were set at 0.05. The following references were selected for qualitative variables: C for Ethnicity, APCS for Course, MHP for school, and A for teacher.

Data Cleaning:

Initially, there were 1066 students that completed a PLTW course at one of the Highland Prep Academies. Some students did not have a recorded entrance math exam scores available. However, since this exam is very similar in concepts and set up to freshman students beginning of course exam in their mathematics course, the entrance math exam score could be replaced with their BOC score. A total of 27 students were dropped due to no recorded entrance math exam score or BOC score. The following students were dropped from the study: 80, 81, 178, 207, 233, 279, 296, 300, 337, 342, 397, 420, 457, 543, 562, 730, 745, 769, 789, 892, 920, 926, 943, 956, 981, 1032, and 1043.

Description of Participants:

The Highland Prep Academies consists of three schools: Madison Highland Prep (MHP), Highland Prep Surprise (HPS), and Highland Prep West (HPW). MHP and HPS have 9th through 12th grade students, while HPW only has 9th graders. This is due to the school having just opened for the 2022-23 academic year. Table 1 describes the number of students and their PLTW percentiles across multiple variables.

Table 1. Number of students and mean (standard deviation) of PLTW percentiles

Course	Number Students	Percentile	Gender	Number Students	Percentile
AE	157	35.567 (24.509)	F	432	37.787 (20.752)
APCS	27	57.852 (16.002)	M	607	40.361 (22.956)
BMS	108	50.907 (26.268)	Ethnicity		
CEA	102	41.304 (23.724)	A	18	43.667 (22.829)
CSC	114	38.719 (28.269)	B	29	24.793 (16.653)
DE	56	45.554 (20.047)	C	576	43.101 (22.565)
IED	352	38.759 (13.159)	H	406	34.879 (20.372)
POE	123	27.301 (21.407)	NAm	10	33.100 (25.921)
School			Grade		
MHP	464	37.646 (22.739)	9	388	40.000 (15.717)

HPS	438	38.372 (11.307)	10	323	38.025 (24.182)
HPW	137	41.114 (23.716)	11	201	36.139 (22.940)
			12	127	45.331 (29.562)

In the Highland Prep Academies there are eight teachers that teach PLTW courses. Table 2 details the information about the teachers, including mean PLTW percentiles.

Table 2. Teacher information

Teacher	Gender	School	Courses Taught	Semesters Taught	Student Percentile
A	F	MHP	AE, CSC, POE	3 and 4	35.307 (25.356)
B	F	MHP	BMS	0 and 1	55.679 (25.843)
C	M	MHP	IED, CEA, APCS	3 and 4	41.661 (16.931)
D	M	HPW	IED	0 and 1	38.372 (11.307)
E	M	HPS	AE, IED	4 and 5	36.094 (18.374)
F	M	HPS	CSC, DE, CEA	2 and 3	41.807 (25.113)
G	M	HPS	POE	4 and 5	25.457 (22.034)
H	M	HPS	BMS	0	38.500 (23.497)

Research Question 1 without Covariant:

Initially, the multiple linear regression equation was incomplete due to independent variables having perfectly collinear. Teacher was one such variable and the ones that had coefficients calculated were not statistically significant. Semester had collinearity with SemestersTaught. Dropping both variables allows a complete multiple linear regression equation. Further investigation on non-statistically significant variables, Grade ($p = 0.545$) and TeacherGender ($p = 0.197$), produced the largest adjusted R-squared value, resulting in the equation described in Table 3.

Table 3. Coefficients of RQ1 w/o Covariant

Coefficients	Estimate	Std. Error	t value	p value	2.5% CI	97.5% CI
(intercept)	62.6460	4.1230	15.194	< 0.001	54.5555	70.7365
Course AE	-16.9565	4.4028	-3.851	< 0.001	-25.5960	-8.3170
Course BMS	-3.7512	4.4502	-0.843	0.3995	-12.4838	4.9814
Course CEA	-13.1984	4.5778	-2.883	< 0.01	-22.1814	-4.2155

Course CSC	-15.0938	4.4747	-3.373	< 0.001	-23.8745	-6.3131
Course DE	-8.8445	5.0209	-1.762	0.0784	-18.6969	1.0079
Course IED	-14.6312	4.2898	-3.411	< 0.001	-23.0490	-6.2134
Course POE	-25.8984	4.4525	-5.817	< 0.001	-34.6356	-17.1613
School HPS	-3.2794	1.5271	-2.148	< 0.05	-6.2760	-0.2829
School HPW	-6.9902	2.6666	-2.621	< 0.01	-12.2229	-1.7575
SemestersTaught	-1.3222	0.3556	-3.718	< 0.001	-2.0201	-0.6244
StudentGender M	2.7951	1.3024	2.146	< 0.05	0.2393	5.3508
Ethnicity A	-0.8936	4.9126	-0.182	0.8557	-10.5335	8.7463
Ethnicity B	-15.5474	3.9307	-3.955	< 0.001	-23.2605	-7.8343
Ethnicity H	-8.2562	1.3395	-6.163	< 0.001	-10.8847	-5.6276
Ethnicity Nam	-9.9913	6.5652	-1.522	0.1284	-22.8742	2.8915

This model of calculating percentiles using the above variables is statistically reliable, $F(15, 1023) = 12.49$, $p < 0.001$, and explained 14.24% of the variance in percentile based on the regression of the other variables.

Focusing on percentiles based on course when controlling for other variables, all but two courses were not statistically significant. The reference factor for Course was chosen to be APCS as this is the highest academic level engineering course since it is an Advanced Placement course. POE students had a statistically significant, $p < 0.001$, lower percentile by about 26 points than APCS students. This was the largest difference in percentile with APCS, while CEA students had the smallest in percentile. CEA students had a statistically significant, $p < 0.001$, lower percentile by about 13 points than APCS students. AE, CSC, and IED students all had statistically significant lower percentiles than APCS students by 13 to 26 points (specific values and p-values are listed in Table 3). DE, $p = 0.0784$, and BMS, $p = 0.3995$, were not statistically significant.

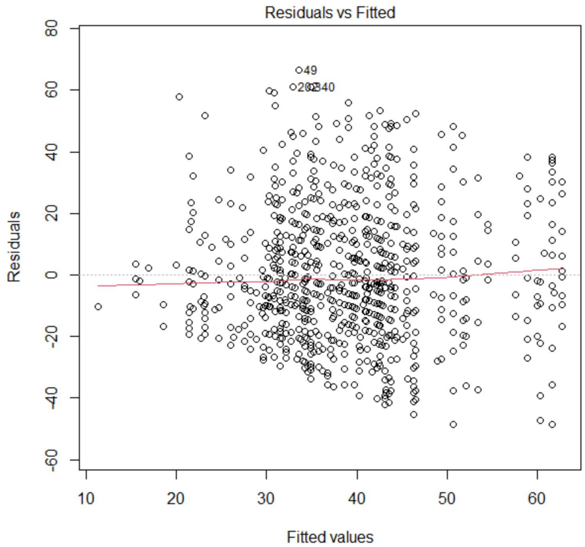
The reference factor for School is MHP since it is the founding school of the Highland Prep Academies. Controlling for other variables, HPS students had a statistically significant, $p < 0.05$, lower percentile by about 3 points than MHP students. HPW students had a statistically significant, $p < 0.01$, lower percentile by 7 points than MHP students.

Though MHP was founded a few years before HPS, HPS has an average number of semesters taught by teachers of 4.1 while MHP has an average of 3.6 semesters taught. In contrast, the average number of semesters taught by teachers is 0.4 at HPW. The number of semesters taught is statistically significant, $p < 0.001$, and indicates that for every semester a teacher has taught a course their students percentiles decrease by about 1 point.

41.6% of students at HPA are female. When controlling for other variables, this model determined that male students have a statistically significant, $p < 0.05$, greater percentile by about 3 points than female students.

For Ethnicity, Caucasian is the reference factor since 55.4% of all HPA students are Caucasian. Controlling for other variables, African American students had a statistically significant, $p < 0.001$, lower percentile by about 16 points than Caucasian students. Hispanic students had a statistically significant, $p < 0.001$, lower percentile by about 8 points than Caucasian students. Native American, $p = 0.128$, and Asian, $p = 0.856$, students were not statistically significant.

Assumptions for MLR include y-values (errors) are independent and y-values can be expressed as a linear function of the x-values. The Residuals vs. Fitted graph (*Figure 1*) below indicates that a linear relationship between Percentile and the other variables may not be the best fit. The Standardized Residuals vs. Theoretical Quantiles graph (Figure 2) suggests some concern for normality assumption. Using the Shapiro Wilks test it is determined that the data does not come from a normally distributed population, $W = 0.98336$ and $p < 0.001$.



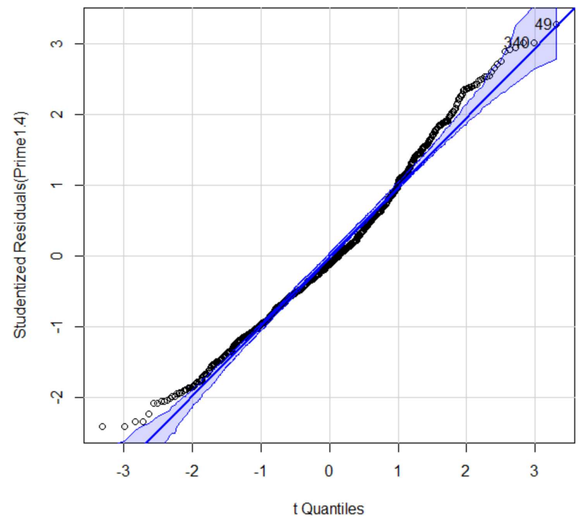


Figure 1. Graph of Residuals vs. Fitted for MLR Percentile ~ Course + School +SemestersTaught + StudentGender + StudentEthnicity

Figure 2. Graph of Standardized Residuals vs. Theoretical Quantiles for MLR Percentile ~ Course + School +SemestersTaught + StudentGender + StudentEthnicity

This model produces 50 outliers based on standard residuals being greater than 2 or less than -2. Using Cooks distance greater than 1, no outliers are determined. There are a total of 180 students that are leverages with a large difference between their percentile and the average percentile. Furthermore, this model has 691 influential points where deleting the student's data would significantly change the slope of the linear regression.

Using G*Power 3.1.9.7 with an effect size of 0.15 and an alpha error of 0.05, a total sample size of 85 participants is required to have a power of 0.80. The study has 1039 participants so having enough participants is not a concern. However, the post-hoc power with 1039 participants is 1.00.

Research Question 1 with Covariant:

Using a similar multiple linear regression equation to the previous section, a covariant is added as a baseline for students' academic levels. Entrance mathematics exams occur before students start 9th grade and allow the HPAs to adjust a student's course schedule to fit their academic levels. By adding a covariant, 27.46% of the variance in percentile based on the regression of the other variables. Therefore adding the covariant enables percentile to be more accurately predicted by the variables than without it. This model of calculating percentiles is statistically reliable, $F(16, 1022) = 25.56$, $p < 0.001$.

Table 4 Coefficients of RQ1 w/ Covariant

Coefficients	Estimate	Std. Error	t value	p value	2.5% CI	97.5% CI
(intercept)	32.2778	4.3928	7.348	< 0.001	23.6579	40.8977
Course AE	-9.2500	4.0881	-2.263	< 0.05	-17.2720	-1.2281
Course BMS	-0.6699	4.0990	-0.163	0.870	-8.7132	7.3724
Course CEA	-5.2018	4.2504	-1.224	0.221	-13.5424	3.1387
Course CSC	-6.5767	4.1620	-1.580	0.114	-14.7438	1.5904
Course DE	-2.6542	4.6397	-0.572	0.567	-11.7586	6.4502
Course IED	-6.5689	3.9889	-1.647	0.100	-14.3963	1.2585
Course POE	-17.9579	4.1358	-4.342	< 0.001	-26.0735	-9.8424
School HPS	-4.7103	1.4083	-3.345	< 0.001	-7.4738	-1.9469
School HPW	-6.8869	2.4524	-2.808	< 0.01	-11.6993	-2.0745
SemestersTaught	-1.0647	0.3276	-3.250	< 0.01	-1.7075	-0.4218
StudentGender M	2.3279	1.1983	1.943	0.052	-0.0235	4.6793
Ethnicity A	-2.8741	4.5203	-0.636	0.525	-11.7442	5.9961
Ethnicity B	-13.6675	3.6176	-3.778	< 0.001	-20.7662	-6.5688
Ethnicity H	-6.3608	1.2397	-5.131	< 0.001	-8.7935	-3.9282
Ethnicity Nam	-10.8863	6.0383	-1.803	0.072	-22.7351	0.9625
EntMathScore	0.4748	0.0347	13.693	< 0.001	0.4067	0.5428

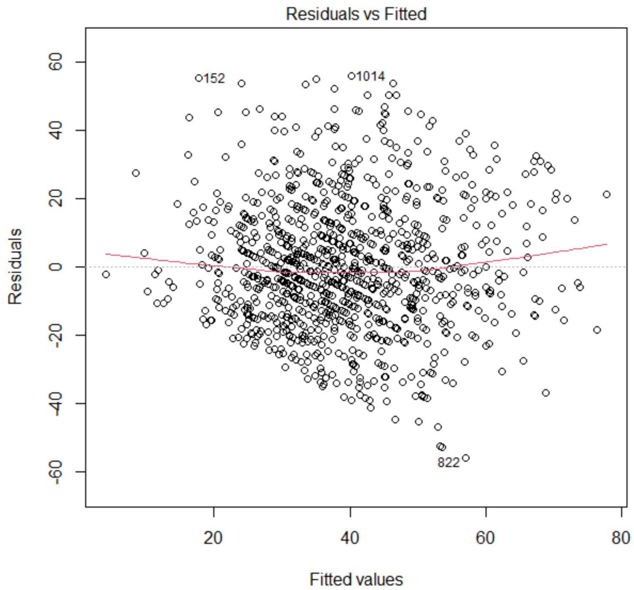
When controlling for all variables except for course, there are only two courses with statistical significance for student percentiles. POE students have a statistically significant, $p < 0.001$, lower percentile by 18 points than APCS students. AE students have a statistically significant, $p < 0.05$, lower percentile by about 9 points than APCS students. The other courses were not statistically significant and the corresponding p-values are listed in Table 4.

Both HPS and HPW are still statistically significant, $p < 0.001$ and $p < 0.01$ respectively, when controlling for other variables. HPS students score about 5 points lower than MHP students while HPW students score about 7 points lower than MHP students. Similarly, the number of semesters a teacher has taught a course is statistically significant, $p < 0.01$. For every semester a teacher has taught a course their students percentiles decrease by about 1 point. However, student gender is not a statistically significant, $p = 0.052$, variable when including the covariant in the model.

When controlling for other variables except for student ethnicity, it is found that two ethnic groups are statistically significant. Native American and Asian students are not a statistically significant, $p = 0.072$ and $p = 0.525$ respectively, predictor of percentile compared to Caucasian students. African American students score about 14 points less than Caucasian students and are statistically significant, $p < 0.001$. Likewise, Hispanic students are statistically significant, $p < 0.001$, and score about 6 points less than Caucasian students.

The covariant of entrance mathematics exam score is a statistically significant, $p < 0.001$, predictor of student PLTW percentiles. For every point on the entrance exam a student's percentile increases by half a point.

Assumptions for MLR include y-values (errors) are independent and y-values can be expressed as a linear function of the x-values. The Residuals vs. Fitted graph (Figure 3) below indicates that a linear relationship between Percentile and the other variables may not be the best fit. The Standardized Residuals vs. Theoretical Quantiles graph (Figure 4) suggests some concern for normality assumption. Using the Shapiro Wilks test it is determined that the data does not come from a normally distributed population, W = 0.98995 and $p < 0.001$.



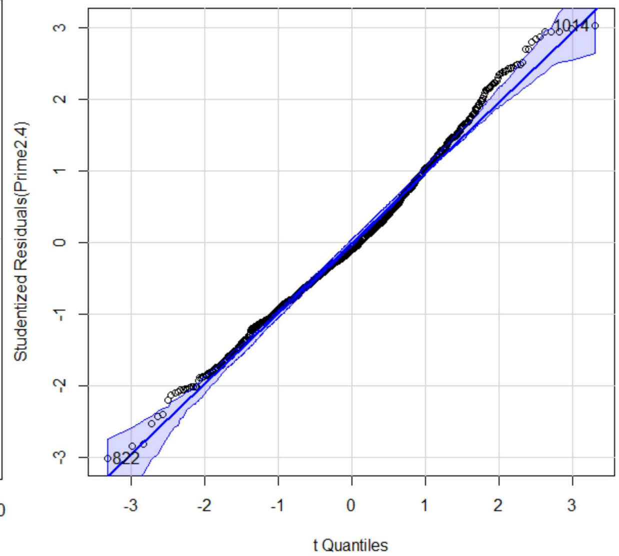


Figure 3. Graph of Residuals vs. Fitted for MLR Percentile ~ Course + School +SemestersTaught + StudentGender + StudentEthnicity + EntMathScore

Figure 4. Graph of Standardized Residuals vs. Theoretical Quantiles for MLR Percentile ~ Course + School +SemestersTaught + StudentGender + StudentEthnicity + EntMathScore

This model produces 58 outliers based on standard residuals being greater than 2 or less than -2. Using Cooks distance greater than 1, no outliers are determined. There are a total of 144 students that are leverages with a large difference between their percentile and the average percentile. Furthermore, this model has 664 influential points where deleting the student's data would significantly change the slope of the linear regression.

Using G*Power 3.1.9.7 with an effect size of 0.15 and an alpha error of 0.05, a total sample size of 92 participants is required to have a power of 0.80. The study has 1039 participants so having enough participants is not a concern. However, the post-hoc power with 1039 participants is 1.00.

Research Question 2 without Covariant:

The focus of the secondary research question is determining if there is a significant difference in student PLTW percentiles across student ethnicity and gender. Mean percentiles across student ethnicity and gender are listed in Table 5. Male, African American students had the lowest mean percentile while male, Native American students had the highest mean percentile. It's important to note there are less than 20 Native American, African American, and Asian students for each gender. This may cause misrepresentation of mean percentiles across student ethnicity and gender. Furthermore, since the groups are not evenly sized, this causes an unbalanced design.

Table 5. Student mean percentiles across student ethnicity and gender

Ethnicity	Gender	Number of Students	Mean Percentile
C	F	225	41.427 (21.259)
A	F	6	41.667 (27.156)
B	F	10	34.900 (22.358)
H	F	184	33.995 (19.231)
NAm	F	7	21.286 (11.528)
C	M	351	44.174 (23.330)
A	M	12	44.667 (21.609)
B	M	19	19.474 (9.737)
H	M	222	35.613 (21.288)
NAm	M	3	60.667 (31.565)

Table 6 details the results of the two-way ANOVA, investigating variables Ethnicity, StudentGender, and their interaction. There is a statistically significant mean difference in percentile across student ethnicity, $F(4, 1029) = 12.151$, $p < 0.001$. Though there is no statistically significant mean difference across student gender, $F(1, 1029) = 2.447$, $p = 0.118$, there is a statistically significant mean difference across the interaction of student ethnicity and gender, $F(4, 1029) = 2.703$, $p < 0.05$. Therefore focus will be directed towards this interaction.

*Table 6. ANOVA values for Percentile ~ Ethnicity * StudentGender*

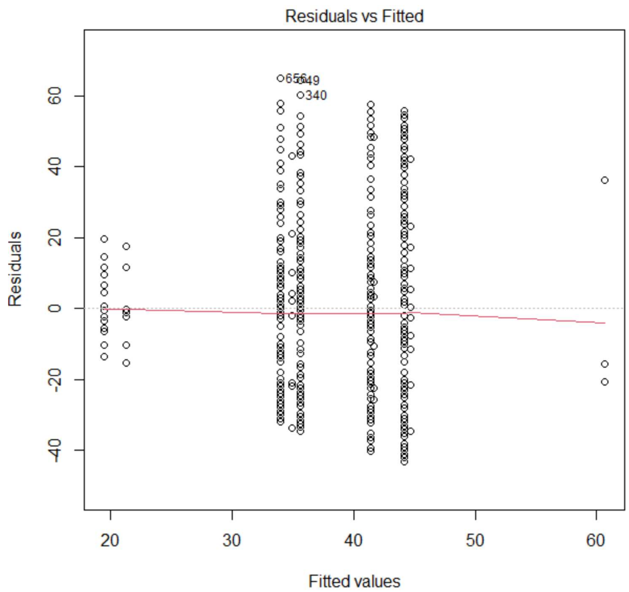
	Sum Sq	df	F-value	p-value
Ethnicity	22548	4	12.151	< 0.001
StudentGender	1135	1	2.447	0.118
Ethnicity:StudentGender	5015	4	2.703	< 0.05
Residuals	477377	1029		

An in-depth analysis of the mean differences for the interaction of student ethnicity and gender was completed using Tukey Honest Significant Differences. Results of this test are given in Table 7. Most differences are not statistically significant and have p-values listed in Table 7, while six interactions are statistically significant. Hispanic female students score on average about 7% less than Caucasian female students, $p < 0.05$. African American male students score on average 22% less than Caucasian female students, $p < 0.001$, and score on average about 25% less than Caucasian male students, $p <0.001$. In addition, African American male students score on average 25% less than Asian male students, $p < 0.05$. Caucasian male students score on average 10% higher than Hispanic female students, $p < 0.001$, and score on average about 9% higher than Hispanic male students, p <,0.001.

*Table 7. Tukey multiple comparisons of means for the two-way ANOVA of Percentile ~ Ethnicity * StudentGender based on the interaction of Ethnicity and StudentGender*

Group 1	Group2	Difference	2.5% CI	97.5% CI	p-value
A:F	C:F	0.240	-28.010	28.490	1.000
B:F	C:F	-6.527	-28.597	15.544	0.995

H:F	C:F	-7.432	-14.220	-0.644	< 0.05
NAm:F	C:F	-20.141	-46.352	6.070	0.305
C:M	C:F	2.747	-3.085	8.579	0.895
A:M	C:F	3.240	-16.993	23.473	1.000
B:M	C:F	-21.953	-38.269	-5.637	< 0.001
H:M	C:F	-5.814	-12.274	0.646	0.120
NAm:M	C:F	19.240	-20.451	58.931	0.877
B:F	A:F	-6.767	-42.033	28.500	1.000
H:F	A:F	-7.672	-36.003	20.659	0.998
NAm:F	A:F	-20.381	-58.375	17.614	0.795
C:M	A:F	2.507	-25.611	30.625	1.000
A:M	A:F	3.000	-31.146	37.146	1.000
B:M	A:F	-22.193	-54.174	9.788	0.457
H:M	A:F	-6.054	-34.309	22.201	1.000
NAm:M	A:F	19.000	-29.290	67.290	0.964
H:F	B:F	-0.905	-23.081	21.270	1.000
NAm:F	B:F	-13.614	-47.269	20.041	0.957
C:M	B:F	9.274	-12.628	31.175	0.943
A:M	B:F	9.767	-19.475	39.008	0.988
B:M	B:F	-15.426	-42.107	11.254	0.714
H:M	B:F	0.713	-21.365	22.790	1.000
NAm:M	B:F	25.767	-19.189	70.723	0.724
NAm:F	H:F	-12.709	-39.008	13.590	0.879
C:M	H:F	10.179	3.964	16.395	< 0.001
A:M	H:F	10.672	-9.675	31.019	0.816
B:M	H:F	-14.521	-30.977	1.936	0.138
H:M	H:F	1.618	-5.190	8.427	0.999
NAm:M	H:F	26.672	-13.077	66.421	0.508
C:M	NAm:F	22.888	-3.180	48.956	0.143
A:M	NAm:F	23.381	-9.099	55.861	0.401
B:M	NAm:F	-1.812	-32.007	28.383	1.000
H:M	NAm:F	14.327	-11.889	40.543	0.777
NAm:M	NAm:F	39.381	-7.746	86.507	0.196
A:M	C:M	0.493	-19.556	20.541	1.000
B:M	C:M	-24.700	-40.786	-8.614	< 0.001
H:M	C:M	-8.561	-14.417	-2.705	< 0.001
NAm:M	C:M	16.493	-23.104	56.090	0.949
B:M	A:M	-25.193	-50.375	-0.011	< 0.05
H:M	A:M	-9.054	-29.294	11.186	0.922
NAm:M	A:M	16.000	-28.083	60.083	0.979
H:M	B:M	16.139	-0.185	32.463	0.056
NAm:M	B:M	41.193	-1.235	83.621	0.066
NAm:M	H:M	25.054	-14.640	64.748	0.598



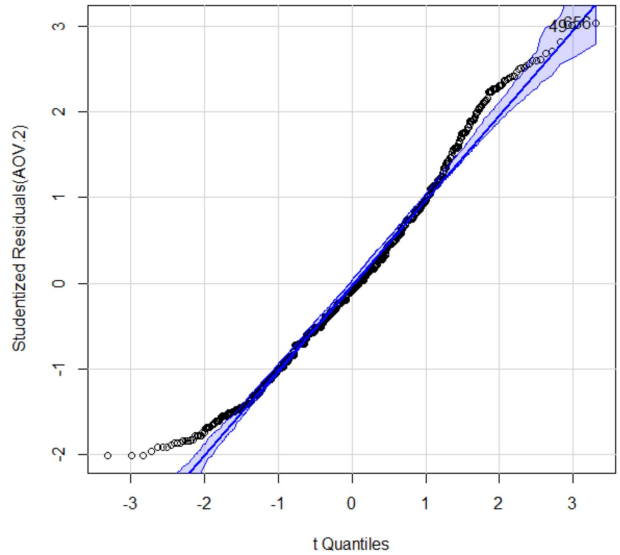


*Figure 5. Graph of Residuals vs Fitted values for two-way ANOVA Percentile ~ Ethnicity * StudentGender*

*Figure 6. Graph of Standardized Residuals vs. Theoretical Quantiles of two-way ANOVA Percentile ~ Ethnicity * StudentGender*

The first assumption checked is homogeneity of variance through a graph of residuals vs. fitted values, depicted in Figure 5. Based on the graph there is concern for the homogeneity of the data. Using the Levene Test, $F(9, 1029) = 2.8147$, $p < 0.01$, it is clear that the assumption of homogeneity of variance is false. A deeper dive into the variances of the interactions results in the data under *Table 8*. The variances for female Native American and male African American students are smaller compared to the others. Variances for male Native American and female Asian students are much larger compared to the other variances. The second assumption is normality, which is depicted in a graph of standardized residuals vs theoretical quantiles (Figure 6). This graph presents concerns for the normality assumption and using the Shapiro-Wilk test, $W = 0.982$, $p < 0.001$, it is confirmed that the data does not come from a normally distributed population.

Table 8. Variances across StudentGender and Ethnicity

Gender	Ethnicity	Variance
F	C	451.933
M	C	544.281
F	A	737.467
M	A	466.970
F	B	499.878
M	B	94.819
F	H	369.820
M	H	453.161
F	NAm	132.905
M	NAm	996.333

Using G*Power 3.1.9.7 with an effect size of 0.102 and an alpha error of 0.05, a total sample size of 1152 participants is required to have a power of 0.80. The study has 1039 participants so there are not enough participants to meet a power of 0.80. The post-hoc power with 1039 participants is 0.752.

Research Question 2 with Covariant:

Following the same model as the previous section, a covariant of entrance math exam score is added. *Table 9* details the mean entrance math exam scores across student gender and ethnicity. Female Asian students had the highest mean at 55.917 while male African American students had the lowest mean at 41.758.

Table 9. Mean Entrance Math Scores across student gender and ethnicity

Ethnicity	Gender	Number of Students	Mean Entrance Math Score
C	F	225	47.488 (17.766)
A	F	6	55.917 (17.472)
B	F	10	50.140 (14.662)
H	F	184	44.959 (17.604)
NAm	F	7	49.929 (20.858)
C	M	351	49.757 (17.130)
A	M	12	53.992 (19.024)

B	M	19	41.758 (12.544)
H	M	222	44.155 (17.762)
NAm	M	3	51.500 (3.593)

Table 10 details the results of the ANCOVA for percentile across student gender and ethnicity with entrance math exam scores as the covariant. Student gender is not statistically significant, $F(40, 907) = 0.115$, $p = 0.735$, and student ethnicity is statistically significant, $F(5435, 907) = 3.900$, $p < 0.01$. The main focus will be the interaction between student ethnicity and gender since it is statistically significant, $F(4, 907) = 3.008$, $p < 0.05$.

*Table 10. ANCOVA values for Percentile ~ Ethnicity * StudentGender + EntMathScore*

	Sum Sq	df	F-value	p-value
(Intercept)	9941	1	28.535	< 0.001
StudentGender	40	1	0.115	0.735
Ethnicity	5435	4	3.900	< 0.01
EntMathScore	161382	122	3.797	< 0.001
StudentGender:Ethnicity	4191	4	3.008	< 0.05
Residuals	315995	907		

Nine mean differences across student gender and ethnicity are statistically significant. The mean differences and p-values for all groups are listed in *Table 11*. There is a significant mean difference between male African American students and female Caucasian students, $p < 0.001$, with male African American students scoring 19 percent lower on PLTW exams. The mean difference between female Hispanic students and female Caucasian students is statistically significant, $p < 0.001$, with female Hispanic students scoring 8 percent lower. The mean difference between male Hispanic students and female Caucasian students is statistically significant, $p < 0.05$, with male Hispanic students scoring 6 percent lower. The mean difference between male African American students and male Caucasian students is statistically significant, $p < 0.001$, with male African American students scoring 21 percent lower. The mean difference between female Hispanic students and male Caucasian students is statistically significant, $p < 0.001$, with female Hispanic students scoring 10 percent lower. The mean difference between male Hispanic students and male Caucasian students is statistically significant, $p < 0.001$, with male Hispanic students scoring 8 percent lower. The mean difference between female Native American students and male Caucasian students is statistically significant, $p < 0.05$, with female Native American students scoring 23 percent lower. The mean difference between male African American students and male Asian students is statistically significant, $p < 0.05$, with male African American students scoring 24 percent lower. The mean difference between male African American students and male Native American students is statistically significant, $p < 0.05$, with male African American students scoring 39 percent lower.

*Table 11. Tukey multiple comparisons of means for the two-way ANCOVA of Percentile ~ Ethnicity * StudentGender + EntMathScore based on the interaction of Ethnicity and StudentGender*

Group 1 - Group 2	Difference	2.5% CI	97.5% CI	p-value
M:C-F:C	1.815	-3.241	6.870	0.981
F:A-F:C	-5.043	-29.531	19.445	1.000
M:A-F:C	5.029	-12.510	22.568	0.996
F:B-F:C	-13.182	-32.314	5.950	0.468
M:B-F:C	-19.317	-33.460	-5.174	< 0.001
F:H-F:C	-8.195	-14.079	-2.311	< 0.001
M:H-F:C	-6.221	-11.821	-0.620	< 0.05
F:NAm-F:C	-21.105	-43.826	1.615	0.095
M:NAm-F:C	19.596	-14.810	54.002	0.731
F:A-M:C	-6.858	-31.232	17.516	0.997
M:A-M:C	3.215	-14.165	20.594	1.000
F:B-M:C	-14.997	-33.983	3.988	0.267
M:B-M:C	-21.132	-35.076	-7.188	< 0.001
F:H-M:C	-10.010	-15.398	-4.622	< 0.001
M:H-M:C	-8.035	-13.112	-2.959	< 0.001

F:NAm-M:C	-22.920	-45.517	-0.323	< 0.05
M:NAm-M:C	17.781	-16.543	52.106	0.827
M:A-F:A	10.072	-19.527	39.672	0.987
F:B-F:A	-8.139	-38.710	22.431	0.998
M:B-F:A	-14.274	-41.997	13.449	0.832
F:H-F:A	-3.152	-27.711	21.407	1.000
M:H-F:A	-1.177	-25.670	23.315	1.000
F:NAm-F:A	-16.062	-48.998	16.873	0.873
M:NAm-F:A	24.639	-17.221	66.500	0.692
F:B-M:A	-18.212	-43.559	7.136	0.404
M:B-M:A	-24.346	-46.175	-2.518	< 0.05
F:H-M:A	-13.225	-30.862	4.413	0.340
M:H-M:A	-11.250	-28.795	6.295	0.575
F:NAm-M:A	-26.135	-54.289	2.020	0.095
M:NAm-M:A	14.567	-23.646	52.780	0.971
M:B-F:B	-6.135	-29.263	16.993	0.998
F:H-F:B	4.987	-14.235	24.210	0.998
M:H-F:B	6.962	-12.176	26.099	0.979
F:NAm-F:B	-7.923	-37.097	21.251	0.997
M:NAm-F:B	32.779	-6.191	71.748	0.189
F:H-M:B	11.122	-3.143	25.387	0.285
M:H-M:B	13.097	-1.054	27.247	0.097
F:NAm-M:B	-1.788	-27.963	24.386	1.000
M:NAm-M:B	38.913	2.135	75.692	< 0.05
M:H-F:H	1.975	-3.927	7.877	0.988
F:NAm-F:H	-12.910	-35.707	9.887	0.738
M:NAm-F:H	27.792	-6.665	62.248	0.239
F:NAm-M:H	-14.885	-37.610	7.841	0.544
M:NAm-M:H	25.817	-8.592	60.226	0.339
M:NAm-F:NAm	40.701	-0.150	81.553	0.052

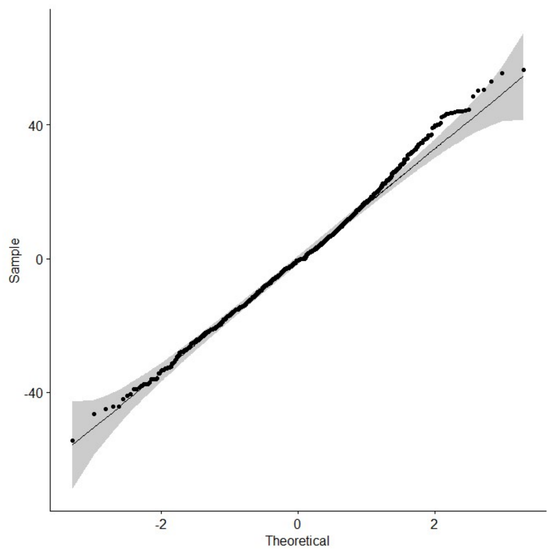


*Figure 7. Graph of Standardized Residuals vs. Theoretical Quantiles of two-way ANCOVA Percentile ~ Ethnicity * StudentGender + EntMathScore*

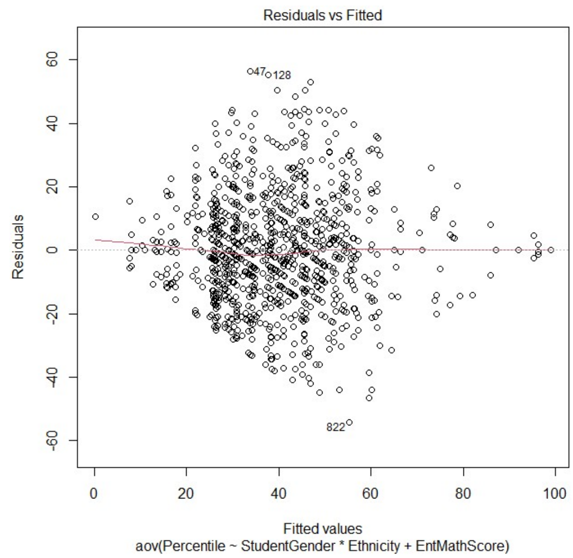


*Figure 8. Graph of Residuals vs Fitted values for two-way ANCOVA Percentile ~ Ethnicity * StudentGender + EntMathScore*

Graphing standardized residuals vs. theoretical quantiles, *Figure 7*, it is apparent that there is some concern for the normality assumption. The Shapiro-Wilk test, W = 0.994, $p < 0.001$, makes it clear that the data does not come from a normally distributed population. Based on *Figure 8*, a graph of residuals vs fitted values, it is discerned that the equal variances assumption cannot be held true. This is further proven by looking at *Table 8*.

Using G*Power 3.1.9.7 with an effect size of 0.102 and an alpha error of 0.05, a total sample size of 1152 participants is required to have a power of 0.80. The study has 1039 participants so there are not enough participants to meet a power of 0.80. The post-hoc power with 1039 participants is 0.752.

Research Question 3 without Covariant:

The third research question focuses on determining if there is a significant mean difference in student PLTW percentiles across student and teacher genders. Mean percentiles across student and teacher genders are presented in Table 12. The lowest mean percentile is from female students with male teachers, while the highest mean percentile is male students with female teachers. The number of students with female teachers is low in comparison to the number of students with male teachers due to there only being two female PLTW teachers at the Highland Prep Academies.

Table 12. Number of students and mean (standard deviation) percentiles across student and teacher genders

Teacher Gender	Student Gender	Number of Students	Mean Percentile
F	F	124	39.387 (25.347)
M	F	308	37.143 (18.593)
F	M	166	41.831 (28.209)
M	M	441	39.807 (20.646)

Using a two-way ANOVA it is determined that neither the interaction nor individual variables are statistically significant. Specific p-values are listed in Table 13. Therefore, no further investigation into the mean differences across the variables will be completed.

Table 13. Two-way ANOVA of StudentGender and TeacherGender

	Sum Sq	df	F-value	p-value
(Intercept)	192367	1	395.038	< 0.001
StudentGender	424	1	0.871	0.351
TeacherGender	445	1	0.914	0.339
StudentGender:TeacherGender	2	1	0.005	0.943
Residuals	504001	1035		

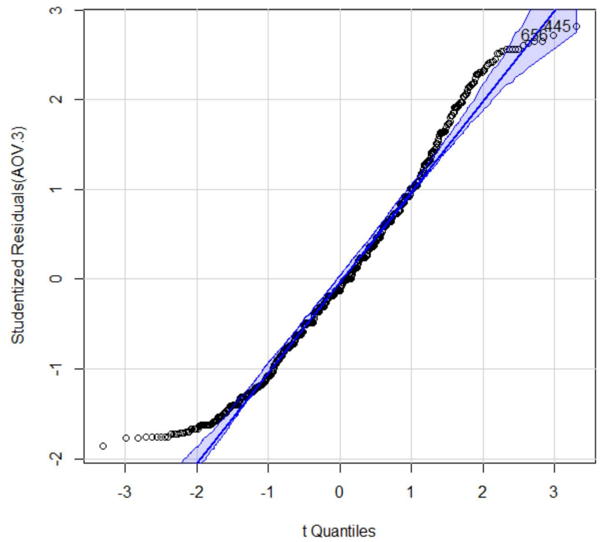


*Figure 9. Graph of Standardized Residuals vs. Theoretical Quantiles of two-way ANOVA Percentile ~ TeacherGender * StudentGender*

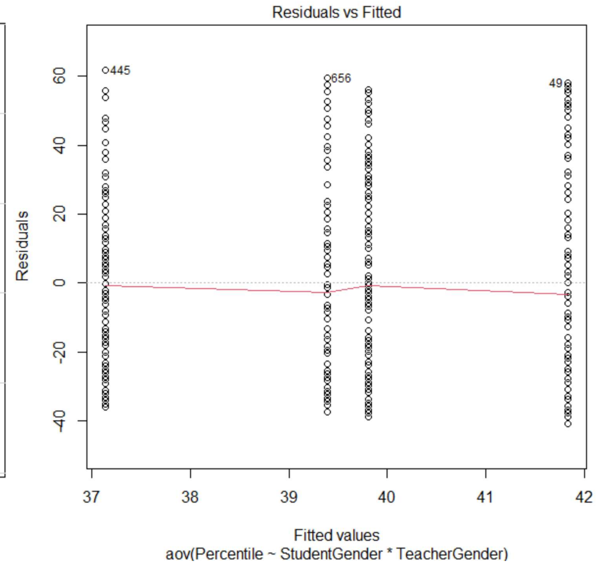


Figure 10. Graph of Residuals vs Fitted values for two-way ANOVA Percentile ~ TeacherGender StudentGender*

The graph of standardized residuals vs. theoretical quantiles (*Figure 9*) raises concerns for the normality assumption. Using the Shapiro-Wilk's test, W = 0.982, $p < 0.001$, it is determined that the data does not come from a normally distributed population. *Figure 10* depicts residuals vs. fitted values for the model and does not appear too concerning in regard to the equal variances' assumption. A Levene's test, F(3) = 22.915, $p < 0.001$, however makes it clear that the assumption is rejected. Furthermore, *Table 14* lists the variances across student and teacher genders showing a large range in values from 345.699 to 795.741.

Table 14. Variances across student and teacher genders

Teacher Gender	Student Gender	Variance
F	F	642.482
M	F	345.699
F	M	795.741
M	M	426.247

Using G*Power 3.1.9.7 with an effect size of 0.0022 and an alpha error of 0.05, a total sample size of 1,621,668 participants is required to have a power of 0.80 for the interaction of StudentGender and TeacherGender. The study has 1039 participants so there are not enough participants to meet a power of 0.80. The post-hoc power with 1039 participants is 0.051.

Research Question 3 with Covariant:

The mean entrance math exam scores across student and teacher genders is listed in *Table 15*. The range in means is very small, 46.572 – 47.725. Adding the variable of entrance math exam scores to the previous model as a covariant results in an ANCOVA where no statistically significant mean difference of PLTW percentiles across the interaction variable occurs, $F(1,913) = 1.199$, $p = 0.274$. In addition, there is no statistically significant mean difference of PLTW percentiles across student gender either, $F(1, 913) = 0.221$, $p = 0.639$. A statistically significant mean difference of PLTW percentiles across teacher gender does exist, $F(1, 913) = 4.773$, $p < 0.05$. More details on the ANCOVA results are listed in *Table 16*.

Table 15. Mean Entrance Math Score across student gender and teacher gender

Teacher Gender	Student Gender	Number of Students	Mean Entrance Math Score
F	F	124	46.768 (18.236)
M	F	308	46.572 (17.496)
F	M	166	47.085 (18.102)
M	M	441	47.725 (17.228)

*Table 16. ANCOVA values for Percentile ~ TeacherGender * StudentGender + EntMathScore*

	Sum Sq	df	F-value	p-value
(Intercept)	9388	1	26.299	< 0.001
StudentGender	79	1	0.221	0.639
TeacherGender	1704	1	4.773	< 0.05

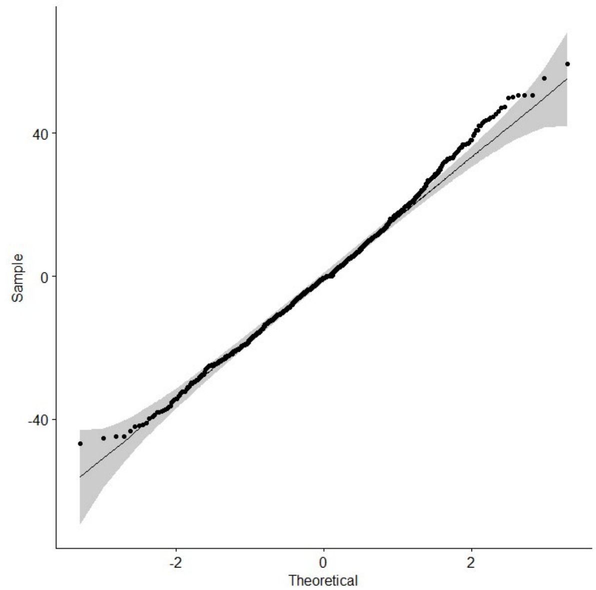
EntMathScore	178096	122	4.090	< 0.001
StudentGender:TeacherGender	428	1	1.199	0.274
Residuals	325905	913		

Focusing on the mean difference of PLTW percentiles across teacher gender, a Tukey HSD results are listed in *Table 17*. Though the mean difference across teacher gender is statistically significant, the difference from students with male teachers to students with female teachers is not statistically significant, p = 0.106.

*Table 17. Tukey multiple comparisons of means for the two-way ANCOVA of Percentile ~ TeacherGender * StudentGender + EntMathScore based on the variable TeacherGender*

Group 1 - Group 2	Difference	2.5% CI	97.5% CI	p-value
M-F	-2.117	-4.681	0.448	0.106

Figure 11 is a graph of standardized residuals vs. theoretical quantiles and shows some concern for the normality assumption. The Shapiro-Wilks test, W = 0.995, p < 0.001, indicates that the data does not come from a normally distributed population. The graph of residuals vs fitted values, *Figure 12*, shows concern for the equal variance assumption. From the previous section and *Table 14* it is clear that the equal variance assumption cannot be made for the ANCOVA model.



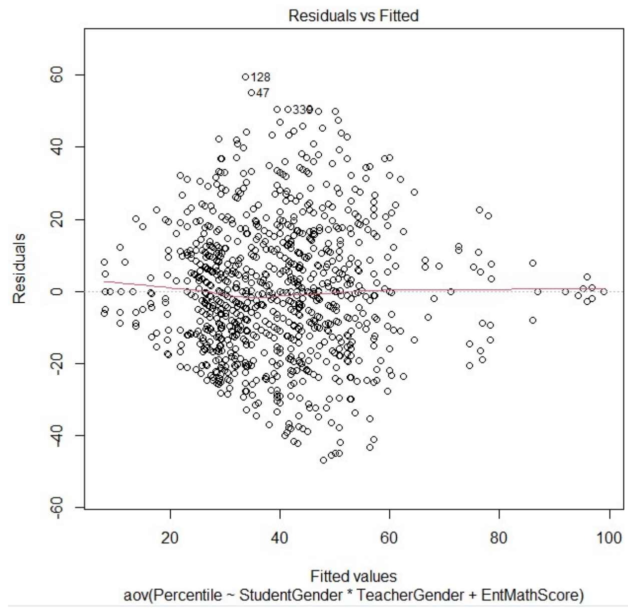


*Figure 11. Graph of Standardized Residuals vs. Theoretical Quantiles of two-way ANCOVA Percentile ~ TeacherGender * StudentGender + EntMathScore*

*Figure 12. Graph of Residuals vs Fitted values for two-way ANCOVA Percentile ~ TeacherGender * StudentGender + EntMathScore*

Focusing on TeacherGender and using G*Power 3.1.9.7 with an effect size of 0.068 and an alpha error of 0.05, a total sample size of 1700 participants is required to have a power of 0.80. The study has 1039 participants so there are not enough participants to meet a power of 0.80. The post-hoc power with 1039 participants is 0.591.

Research Question 4 without Covariant:

The Highland Prep Academies consist of three schools: Madison Highland Prep, Highland Prep Surprise, and Highland Prep West. MHP had 464 students complete PLTW courses in 2022-23 with a mean percentile of 41.1, which is the highest average of the three schools. HPS has the lowest mean percentile of 37.6 with 438 students completing PLTW courses in the same year. Values for the schools are listed in *Table 18*.

Table 18. Mean Percentiles across Highland Prep Academies

School	Number of Students	Mean Percentile
HPS	438	37.646 (22.739)
HPW	137	38.372 (11.307)
MHP	464	41.114 (23.716)

The results of the ANOVA investigating the percentile mean difference across the schools is detailed in *Table 19*. The mean difference across the schools is not statistically significant, F(2, 1036) = 2.923, p = 0.054.

Table 19. ANOVA values for Percentile ~ School

	Sum Sq	df	F-value	p-value
(Intercept)	784336	1	1612.985	< 0.001
School	2843	2	2.923	0.054
Residuals	503769	1036		

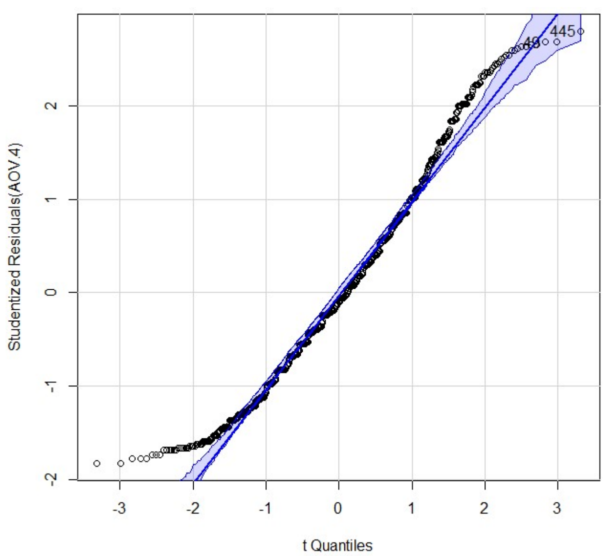


Figure 13. Graph of Standardized Residuals vs. Theoretical Quantiles of ANOVA Percentile ~ School

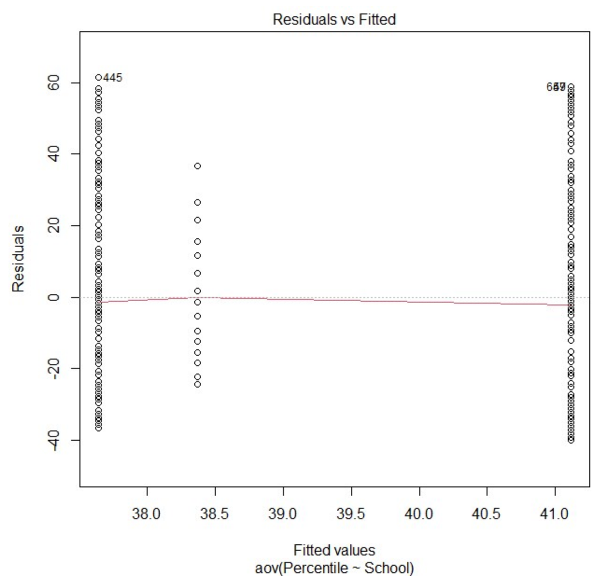


Figure 14. Graph of Residuals vs Fitted values for ANOVA Percentile ~ School

The graph of standardized residuals vs. theoretical quantiles,

Figure 13, indicates major concerns regarding the normality assumption. The Shapiro-Wilk test proves that the data cannot be assumed to come from a normally distributed population, W = 0.979, $p < 0.001$. Concern for the equal variance assumption is apparent in *Figure 14*. The Levene's Test for Homogeneity of Variance indicates that variances cannot be assumed to be equal, $F(2, 1036) = 36.077$, $p < 0.001$. *Table 20* lists the percentile variances for each school. MHP and HPS have similar variances, while HPW does not.

Table 20. Percentile variances at each school

School	Variance
MHP	562.464
HPS	517.076
HPW	127.838

Using G*Power 3.1.9.7 with an effect size of 0.075 and an alpha error of 0.05, a total sample size of 1716 participants is required to have a power of 0.80. The study has 1039 participants so there are not enough participants to meet a power of 0.80 for the School variable. The post-hoc power with 1039 participants is 0.571.

Research Question 4 with Covariant:

Following the previous section, the covariant of entrance math exam score is added to the ANOVA. *Table 21* details the mean and standard deviation of entrance math score for each of the schools. Highland Prep Surprise had the highest mean of 48.276 for the entrance math score, while Highland Prep West had the lowest mean of 45.580.

Table 21. Mean Entrance Math Score across Highland Prep Academies

School	Number of Students	Mean Entrance Math Score
HPS	438	48.276 (16.919)
HPW	137	45.580 (17.261)
MHP	464	46.588 (18.188)

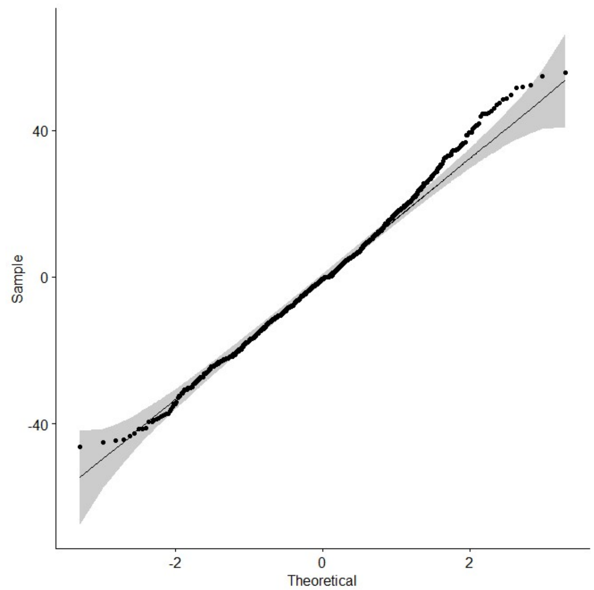
By adding the covariant of entrance math exam score, the mean difference in PLTW percentiles across the schools is statistically significant, $F(2, 914) = 6.771$, $p < 0.01$. Other values from the ANCOVA are listed in *Table 22*. Using a Tukey multiple comparisons of means for the ANCOVA, a significant mean difference is observed between Highland Prep Surprise and Madison Highland Prep, $p < 0.05$. HPS students score 3.5% less than MHP on PLTW. The other comparisons did not have statistically significant mean differences; values detailed in *Table 23*.

Table 22. ANCOVA values for Percentile ~ School + EntMathScore

	Sum Sq	df	F-value	p-value
(Intercept)	8965	1	25.344	< 0.001
School	4791	2	6.771	< 0.01
EntMathScore	180452	122	4.181	< 0.001
Residuals	323317	914		

Table 23. Tukey multiple comparisons of means for the ANCOVA of Percentile ~ School + EntMathScore

Group 1 - Group 2	Difference	2.5% CI	97.5% CI	p-value
HPS-MHP	-3.468	-6.410	-0.527	< 0.05
HPW-MHP	-2.742	-7.035	1.551	0.292
HPW-HPS	0.726	-3.596	5.048	0.918



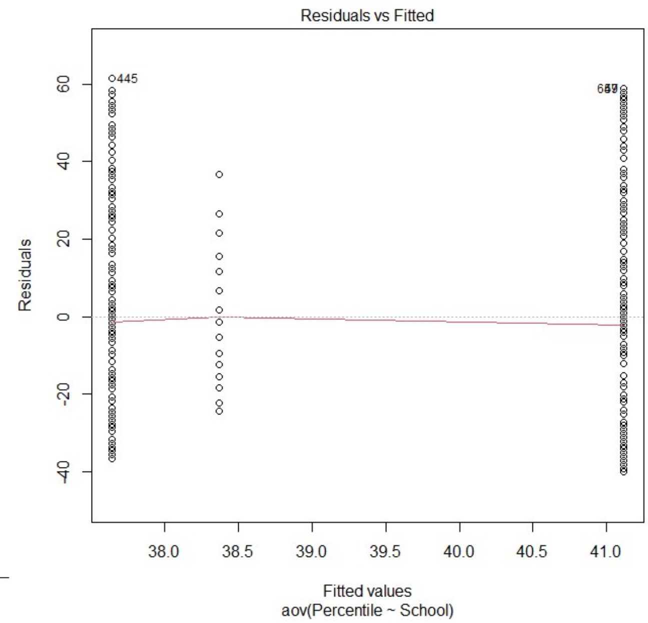


Figure 15. Graph of Standardized Residuals vs. Theoretical Quantiles of ANCOVA Percentile ~ School + EntMathScore

Figure 16. Graph of Residuals vs Fitted values for ANCOVA Percentile ~ School + EntMathScore

The graph of standardized residuals vs. theoretical quantiles,

Figure 15, indicates there is concern for the normality assumption. The Shapiro-Wilk normality test results, W = 0.994, $p < 0.001$, confirms that the data comes from a population that is not normally distributed. The graph of residuals vs. fitted values, *Figure 16*, shows concern for the equal variance assumption. From the previous section's Levene Test and *Table 20*, it is clear that equal variance cannot be assumed.

Using G*Power 3.1.9.7 with an effect size of 0.114 and an alpha error of 0.05, a total sample size of 1152 participants is required to have a power of 0.80. The study has 1039 participants so there are enough participants to meet a power of 0.80. The post-hoc power with 1039 participants is 0.956.

Summary:

Below are the research questions with a summary of results for the models with and without covariant:

1. Are the number of times a teacher has taught a course, student grade, gender, ethnicity; course, teacher, teacher gender, enrolled school, and semester significant predictors of student PLTW test scores?
    - Without Covariant: Course AE, CEA, CSC, IED, and POE; School HPS and HPW, SemestersTaught, StudentGender M, and Ethnicity B and H were all significant predictors of students' PLTW percentile. This model explained 14.24% of the variance in PLTW percentiles.
    - With Covariant: Course AE and POE; School HPS and HPW, SemestersTaught, Ethnicity B and H, and EntMathScore were all significant predictors of students' PLTW percentile. This model explained 27.46% of the variance in PLTW percentiles.
2. Is there a significant difference in student PLTW test scores across student ethnicity and gender?
    - Without Covariant: The interaction variable between student ethnicity and gender is statistically significant, $p < 0.05$. Specifically, the mean difference between six interactions were statistically significant. The largest mean difference was between male African American students and male Caucasian students with male African American students scoring 25% less than male Caucasian students.

- With Covariant: The interaction variable between student ethnicity and gender is statistically significant, $p < 0.05$. Specifically, the mean difference between nine interactions were statistically significant. The largest mean difference was between male Native American students and male African American students with male African American students scoring 39% less than male Native American students.

3. Is there a significant difference in student PLTW test scores across teacher gender and student gender?
    - Without Covariant: The interaction variable between student gender and teacher gender was not statistically significant. Focus was shifted to the individual variables, except those were not statistically significant either. Therefore, there was no statistically significant mean difference in student PLTW percentiles across student and teacher genders.
    - With Covariant: The interaction variable between student gender and teacher gender was not statistically significant. Focus was shifted to the individual variables, and TeacherGender is statistically significant, $p < 0.05$. Using Tukey comparison it was determined the students with male teachers score 2% less than students with female teachers.
4. Is there a significant difference in student PLTW test scores across the Highland Prep Academies?

- Without Covariant: The mean difference across the schools was not statistically significant, $p = 0.054$.
- With Covariant: The mean difference across the schools was statistically significant, $p < 0.01$. A Tukey comparison determined that the mean difference between HPS and MHP was statistically significant, $p < 0.05$. Specifically, HPS students score 3.5% lower than MHP students. The other mean difference between the three schools (HPS, HPW, and MHP) were not statistically significant.

For all models in this study the normality assumption could not be made. Therefore, it could not be assumed that the data came from a normally distributed population. In addition, the equal variance assumption was proven false for all models.

CHAPTER V: SUMMARY

Introduction:

Summary of findings, conclusion, and recommendations for future research will be covered in this chapter. The summary of findings will go through the results from the analysis of data, while the conclusion will connect the results to the literature and theoretical framework. Lastly, recommendations will be made on future research, including actions that should be taken and who should be conducting the research.

Summary of Findings:

The primary research question was "Are the number of times a teacher has taught a course, student grade, gender, ethnicity; course, teacher, teacher gender, enrolled school, and semester significant predictors of student PLTW test scores?". Due to multicollinearity semester, student grade, teacher, and teacher gender were dropped from the analysis. Both models, with and without the covariant, did not meet the normality or equal variance assumptions.

A multiple linear regression analysis without a covariant was used and the independent variables explained 14.24% of the variance in student PLTW percentiles. The significant predictors included Course AE, CEA, CSC, IED, and POE; School HPS and HPW, SemestersTaught, StudentGender M, and Ethnicity B and H. AE, CEA, CSC, IED, and POE students had statistically significant lower PLTW percentiles than AP Computer Science students. Students enrolled at Highland Prep West and Surprise had lower PLTW percentiles than students enrolled at Madison Highland Prep. For each semester a teacher taught a course, their students PLTW score percentile decreased by 1%. Male students scored higher than female students, while African American and

Hispanic students scored lower than Caucasian students. The post-hoc power of this model was 1.00.

A multiple linear regression analysis with a covariant of student entrance math exam scores was used and the independent variables explained 27.46% of the variance in student PLTW percentiles. The significant predictors included Course AE, IED, and POE; School HPS and HPW, SemestersTaught, Ethnicity B and H, and EntMathScore. Aerospace Engineering and Principles of Engineering students had statistically significant lower PLTW percentiles than AP Computer Science students. Similarly, to the model with no covariant, it was found that HPW and HPS had lower percentiles than MHP, African American and Hispanic students had lower percentiles than Caucasian students, and that for each semester a teacher taught a course their students percentiles decreased by about 1%. The covariant was statistically significant as well, indicating that for each percent students got correct on the entrance math exam score their PLTW percentile increased by 0.5%. The post-hoc power of this model was 1.00.

The secondary research question was "Is there a significant difference in student PLTW test scores across student ethnicity and gender?". A two-way analysis of variance was used to answer this question. Both models, with and without the covariant, did not meet the normality or equal variance assumptions.

The two-way ANOVA determined that the interaction of student ethnicity and gender was statistically significant. Six group mean differences were statistically significant: H:F – C:F, B:M – C:F, C:M – H:F, B:M – C:M, H:M – C:M, and B:M – A:M. Overall, Caucasian students scored higher than Hispanic and African American students. In addition, male Asian students scored higher than African American students. The post-hoc power of this model was 0.752.

The two-way ANCOVA determined that the interaction of student ethnicity and gender was statistically significant with the covariant of student entrance math exam scores. Nine group mean differences were statistically significant: M:B – F:C, F:H – F:C, M:H – F:C, M:B – M:C, F:H – M:C, M:H – M:C, F:NAm – M:C, M:B – M:A, and M:NAm – M:B. Regardless of gender, Caucasian students scored higher than Hispanic, Native American, and African American students. In addition, male Asian and male Native American students scored higher than male African American students. The post-hoc power of this model was 0.752.

The third research question was “Is there a significant difference in student PLTW test scores across teacher gender and student gender?”. A two-way analysis of variance was used to answer this question. Both models, with and without the covariant, did not meet the normality or equal variance assumptions.

The two-way ANOVA determined that the interaction of student gender and teacher gender and the individual variables were not statistically significant. The post-hoc power of this model was 0.051. The two-way ANCOVA determined that the interaction of student gender and teacher gender were not statistically significant with the covariant of student entrance math exam scores. However, the teacher gender was statistically significant. Students with male teachers had lower scores than students with female teachers. The post-hoc power of this model was 0.591.

The fourth research question was “Is there a significant difference in student PLTW test scores across the Highland Prep Academies?”. An analysis of variance was used to answer this question. Both models, with and without the covariant, did not meet the normality or equal variance assumptions. The ANOVA determined that there was no statistically significant mean difference across the schools. When a covariant of student entrance math exam scores was added, there was a statistically significant mean difference across the schools. Specifically, Highland Prep Surprise's average scores were less than Madison Highland Prep's. The ANOVA had a post-hoc power of 0.571 and the ANCOVA had a post-hoc power of 0.956.

Conclusion:

Educational equity is the concept that all students have the right to quality education. This does not mean using the same curriculum, activities, lessons, etc. for all students, but meeting students at their educational level. Identifying the additional needs of groups of students starts with research. Many previous studies focused on Project Lead the Way were from schools with majority (70% - 90%) Caucasian students. At the Highland Prep Academies, the majority of students are Hispanic with a small percentage of Asian, Native American, and African American students. It was found that Hispanic, Native American, African American, and female students had statistically significant lower PLTW scores than male Caucasian students. Similar results were found in other studies that investigated mathematics, ACT, etc.

Two of the PLTW courses were found to have statistically significant lower scores than AP Computer Science. Principles of Engineering is a course that goes over a wide range of concepts from computer programming, simple machines, thermal mechanics, circuitry, and more. At the beginning of the 2023-24 school year, PLTW released a new version of POE that is more project focused. Some of the same concepts from the original curriculum are used, but many of the activities are new. Therefore, the results for POE from this study do not correlate to this new version of the curriculum.

The other course with statistically significant lower scores than AP Computer Science is Aerospace Engineering. Airplanes, gliders, rocketry, and rovers are all included in this course's activities. Though not a mathematics heavy course, the math that is involved uses quite tedious calculations such as for lift, drag, potential energy of a satellite, air pressure, etc. This maybe what is causing lower scores, but further investigation is required.

In previous studies it was found that student scores did not significantly change the more years of experience a teacher had. Unless a teacher had been teaching for forty to fifty years, then student test scores decreased. At HPA it was found that student PLTW test scores decreased statistically significant each time a teacher taught a course. Further investigations would be needed to determine more information.

The relationship between student and teacher gender and student PLTW test scores was somewhat inconclusive. The ANOVA determined no statistically significant mean difference, while the ANCOVA found statistically significant mean difference based only on teacher gender. Previous studies found that students performed better academically with female teachers, and specifically that female students did better with female teachers in mathematic classes. The results maybe influenced by the limited number of teacher participants and 20% of them were female.

Lasty, it was found that when not taking student entrance math exam scores into account as the covariant there was no statistically significant mean difference in student PLTW scores across the Highland Prep Academies. When the covariant was added there was a statistically significant mean difference in the student PLTW scores from Highland Prep Surprise and Madison Highland Prep. Specifically, HPS students score lower than MHP students on PLTW tests. This was surprising since HPS students on average score higher on the entrance math exam than MHP students.

There are several limitations to take into consideration for this study. Most schools do not use a semester long block schedule with four classes a day. The Highland Prep Academies also use additional academic support such as mandatory tutoring and homework support that may not be available in most schools. Though HPA has a high percentage of Hispanic students, the percent of Asian, African American, and Native American students is small. All HPA schools are located in urban Maricopa County of Arizona. Lastly, the students that participated had different online learning circumstances for COVID-19 quarantine in 2020 – 21.

Recommendations:

Continued research will need to be conducted about Project Lead the Way test scores. There is still a gap in available research about the relationship between test scores and students of African American and Native American ethnicity. Ideally, Project Lead the Way would publish a detailed analysis of scores based on student ethnicity and gender similar to how American College Testing (ACT) and College Board do.

Project Lead the Way needs to continue research on their curriculums and the impact of it on a school's community. In addition, it is important that outside organizations conduct their own research. Schools have firsthand experience on the impacts of PLTW curriculum and by publishing research can assist in refining how the curriculum is utilized. Data driven schools, like the Highland Prep Academies, have the resources and skills to pave the way for future research of PLTW curriculum.

In the future, restructuring the analysis of Highland Prep Academies' PLTW test scores to use a repeated measures ANOVA may yield more informative results. With this sort of analysis students' can be tracked as they take different PLTW courses, since HPA requires students to complete three PLTW courses to graduate. In addition, using the breakdown of the PLTW scores for each course might yield insight into which concepts need more support.

REFERENCES

Marco Learning. “Why Some States Have Higher Teacher Turnover Rates Than Others.” Copyrighted 2024. https://marcolearning.com/teacher-turnover-rate-by-state/#:~:text=According%20to%20data%20from%20the,%2C%20just%20below%20with%2023%25.

Antecol, Heather, Ozkan Eren, and Serkan Ozbeklik. “The Effect of Teacher Gender on Student Achievement in Primary School.” *Journal of Labor Economics 33*, no. 1 (January 2015): 63–89. doi:10.1086/677391.

Armstrong, Melva. “The Effects of Teacher Competencies, Gender, and School Location on Primary School Standardised Academic Test Results in Three Districts in Jamaica.” Journal of Arts Science & Technology 13, no. 1 (March 2020): 190–206. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=b7h&AN=142759239&site=eds-live&scope=site.

Armstrong, Melva. “The Effects of Teacher Competencies, Gender, and School Location on Primary School Standardised Academic Test Results in Three Districts in Jamaica.” Journal of Arts Science & Technology 13, no. 1 (March 2020): 190–206. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=b7h&AN=142759239&site=eds-live&scope=site.

AZ School Report Cards. “Highland Prep West.” Copyrighted 2022 – 2023. https://azreportcards.azed.gov/schools/detail/1001524.

AZ School Report Cards. “Highland Prep.” Copyrighted 2022 – 2023. https://azreportcards.azed.gov/schools/detail/703390.

AZ School Report Cards. “Madison Highland Prep.” Copyrighted 2022 – 2023. https://azreportcards.azed.gov/schools/detail/92605.

Beltrán-Grimm, Susana. “Latina Mothers’ Cultural Experiences, Beliefs, and Attitudes May Influence Children’s Math Learning.” Early Childhood Education Journal 52, no. 1 (January 2024): 43–53. doi:10.1007/s10643-022-01406-2.

Bordel, Borja, Ramon Alcarria, Tomás Robles, and Diego Martin. “The Gender Gap in Engineering Education During The COVID-19 Lockdown: A Study Case.” International Journal of Engineering Pedagogy 11, no. 6 (November 2021): 117–31. doi:10.3991/ijep.v11i6.24945.

Camburn, Eric, Karin Chang, Takako Nomi, Michael Podgursky, Darrin DeChane, Anwuli Okwuashi, Mark Ehlert, Jeongmi Moon, and Xinyi Mao. 2023. Review of *Final Report of the Impact of Project Lead the Way on Missouri High School Students*. University of Missouri - Kansas City. https://info.umkc.edu/uerc/wp-content/uploads/2023/04/Final-MO-PLTW-Report-FINAL.pdf.

Corra, Mamadi, J. Scott Carter, and Shannon K. Carter. "The Interactive Impact of Race and Gender on High School Advanced Course Enrollment." Journal of Negro Education 80, no. 1 (Winter 2011): 33–46. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=eft&AN=62607837&site=eds-live&scope=site.

Daniel M. McNeish, Justine Radunzel, and Edgar Sanchez. "A Multidimensional Persepective of College Readiness: Relating Student and School Characteristics to Performance on the ACT." *ACT Research Report Series* 2015*,* no. 6 (2015). https://www.act.org/content/dam/act/unsecured/documents/ACT_RR2015-6.pdf

Dost, Gulash. "Students' perspectives on the 'STEM belonging' concept at A-level, undergraduate, and postgraduate levels: an examination of gender and ethnicity in student descriptions." *International Journal of STEM Education 11*, no. 12 (2024): https://doi.org/10.1186/s40594-024-00472-9.

Ember Smith and Richard V. Reeves. "SAT math scores mirror and maintain racial inequity". *Brookings*. December 1, 2020. https://www.brookings.edu/articles/sat-math-scores-mirror-and-maintain-racial-inequity/#:~:text=Despite%20a%20wide%20range%20of,gap%20narrowed%20to%2093%20points.

Escardíbul, Josep-Oriol, and Toni Mora. "Teacher Gender and Student Performance in Mathematics. Evidence from Catalonia (Spain)." *Journal of Education and Training Studies 1*, no. 1 (April 1, 2013): 39–46. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=eric&AN=EJ1054826&site=eds-live&scope=site.

Gely, Yumiko I, Ikenna H Ifearulundu, Melissa Rangel, Johanna S Balas, Yuanqing Liu, Gwyneth Sullivan, Edie Chan, Jose Velasco, and Rosalinda Alvarado. "Effects of Race and Test Preparation Resources on Standardized Test Scores, a Pilot Study." American Journal of Surgery 225, no. 3 (March 2023): 573–76. doi:10.1016/j.amjsurg.2022.10.047.

Graham, Linda J., Sonia L.J. White, Kathy Cologon, and Robert C. Pianta. "Do Teachers' Years of Experience Make a Difference in the Quality of Teaching?" Teaching and Teacher Education 96 (November 1, 2020). doi:10.1016/j.tate.2020.103190.

Haq I, Higham J, Morris R, and Dacre J. "Effect of Ethnicity and Gender on Performance in Undergraduate Medical Examinations." Medical Education 39, no. 11 (November 2005): 1126–28. doi:10.1111/j.1365-2929.2005.02319.x.

Holstein, Krista A., and Karen Allen Keene. "The Complexities and Challenges Associated With the Implementation of a STEM Curriculum." *Teacher Education & Practice 26*, no. 4 (Fall 2013): 616–36. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=eue&AN=95456131&site=eds-live&scope=site.

Hwang, NaYoung, and Brian Fitzpatrick. "Student-Teacher Gender Matching and Academic Achievement." *AERA Open 7*, no. 1 (January 1, 2021). doi:10.1177/23328584211040058.

Juliana Utley, Toni Ivey, John Weaver. "How Professional Development in Project Lead the Way Changes High School STEM Teachers' Beliefs about Engineering Education." Journal of Pre-College Engineering Education Research 2019(9), no. 2 (2019): Article 3. doi: https://doi.org/10.7771/2157-9288.1209

Kahveci, Hakkı. "The Positive and Negative Effects of Teacher Attitudes and Behaviors on Student Progress." Journal of Pedagogical Research (JPR) 7, no. 1 (March 2023): 290–306. doi:10.33902/JPR.202319128.

Kolb, D. A. *Experiential learning : experience as the source of learning and development (Second edition).* Pearson Education LTD, 2015.

Learning Policy Institute. "What's the Cost of Teacher Turnover?." Published September 13, 2017. https://learningpolicyinstitute.org/product/the-cost-of-teacher-turnover.

Levitt, Greg, Steven Grubaugh, Joseph Maderick, and Donald Deever. "The Power of Passionate Teaching and Learning: A Study of Impacts on Social Science Teacher Retention and Student Outcomes." Technium Social Sciences Journal 41 (January 1, 2023): 82–85. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=edshol&AN=edshol.hein.journals.techssj41.8&site=eds-live&scope=site.

Luo, Ma, Daner Sun, Liying Zhu, and Yuqin Yang. "Evaluating Scientific Reasoning Ability: Student Performance and the Interaction Effects between Grade Level, Gender, and Academic Achievement Level." Thinking Skills and Creativity 41 (September 1, 2021). doi:10.1016/j.tsc.2021.100899.

Madison Highland Prep. "Homepage." Copyrighted 2024. https://madisonhighlandprep.com.

Madison Highland Prep. "Student Handbook." Edition 2023-24. https://madisonhighlandprep.com/wp-content/uploads/2024/01/student-handbook-mhp.pdf.

Mansour, Hani, Daniel I. Rees, Bryson M. Rintala, and Nathan N. Wozny. "The Effects of Professor Gender on the Postgraduation Outcomes of Female Students." *ILR Review 75*, no. 3 (May 2022): 693–715. doi:10.1177/0019793921994832.

Melanie LaForce, Elizabeth Noble, Heather King, Jeanne Century, Courtney Blackwell, Sandra Holt, Ahmed Ibrahim, and Stephanie Loo. "The eight essential elements of inclusive STEM high schools." *International Journal of STEM Education 3*, no. 21 (2016): https://doi.org/10.1186/s40594-016-0054-z.

Mitchell J. Nathan, Amy K. Atwood, Amy Prevost, L. Allen Phelps, Natalie A. Tran. "How Professional Development in Project Lead the Way Changes High School STEM Teachers' Beliefs about Engineering Education." *Journal of Pre-College Engineering Education Research 2011(1)*, no. 1 (2011): Article 3. doi: https://doi.org/10.7771/2157-9288.1027

National Center for Education Statistics. "Characteristics of Public School Teachers." Updated May 2023. https://nces.ed.gov/programs/coe/indicator/clr/public-school-teachers

National Center for Education Statistics. “Eight Percent of Public School Teachers Left Teaching in 2021, a Rate Unchanged Since Last Measured in 2012.” Published December 13, 2023. https://nces.ed.gov/whatsnew/press_releases/12_13_2023.asp#:~:text=Overall%2C%2084%20percent%20of%20public,profession%20(%E2%80%9Cleavers%E2%80%9D.

National Center for Education Statistics. “Percentage of public school teachers based on years of teaching experience, average total years of teaching experience, percentage of teachers based on years teaching at current school, and average years teaching at current school, by selected school characteristics: 2015–16.” Accessed March 3, 2024. https://nces.ed.gov/surveys/ntps/tables/ntps1516_18051504_t1n.asp.

O’Brien, Gearóid. “Teacher Gender in Citizenship Education: Does It Make a Difference?” *Citizenship, Social and Economics Education 22*, no. 1 (April 1, 2023): 3–17. doi:10.1177/14788047231153822.

Odette Umugiraneza, Sarah Bansilal, and Delia North. “An Analysis of Teachers’ Confidence in Teaching Mathematics and Statistics.” *Statistics Education Research Journal 3,* no. 21 (November 2022). https://doi.org/10.52041/serj.v21i3.422.

Patel, Nimisha H., M. Suzanne Franco, and Larry G. Daniel. “Student Engagement and Achievement: A Comparison of STEM Schools, STEM Programs, and Non-STEM Settings.” *Research in the Schools 26*, no. 1 (Spring 2019): 1–11. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=eue&AN=139170318&site=eds-live&scope=site.

Pew Research Center. “STEM Jobs See Uneven Progress in Increasing Gender, Racial and Ethnic Diversity.” Published April 1, 3032. https://www.pewresearch.org/science/wp-content/uploads/sites/16/2021/03/PS_2021.04.01_diversity-in-STEM_REPORT.pdf.

Project Lead the Way. “Core Training Registration Fees.” Copyrighted 2024. https://knowledge.pltw.org/s/article/Does-this-cost-more.

Project Lead the Way. “End-of-Course Assessment Scale Score Reports FAQ.” Copyrighted 2020. https://ed.sc.gov/instruction/career-and-technical-education/professional-development/end-of-course-assessment/.

Project Lead the Way. “PLTW Score Interpretation Guide.” Copyrighted 2019. https://ed.sc.gov/instruction/career-and-technical-education/professional-development/pltw-score-interpretation/.

Project Lead the Way. “Professional Development for Teachers.” Copyrighted 2024. https://www.pltw.org/professional-development/training-schedules?program=*&course=*&type=%22Online%22.

Project Lead the Way. “Project 4.2.2 Teacher Resources.” Copyrighted 2024. https://pltw.read.inkling.com/a/b/fd4b4de6f1214b17bd563d01de52a6ef/p/cedd2f741af547ffa56905d20a386b07.

Project Lead the Way. “See Our Student Opportunities.” Copyrighted 2024. https://www.pltw.org/experience-pltw/student-opportunities?.

Project Lead the Way. “Understanding End-of-Course Assessment Results.” Copyrighted 2024. https://s3.amazonaws.com/assets.pltw.org/pdf/Understanding_EoC_Assessment_Scores_2022_23.pdf.

Public School Review. “Madison Highland Prep.” Copyrighted 2023-2024. https://www.publicschoolreview.com/madison-highland-prep-profile.

Rethwisch, D., (2014) “A Study of the Impact of Project Lead the Way on Achievement Outcomes in Iowa”, 2014 ASEE North Midwest Section Conference 2014(1), 1-18. doi: https://doi.org/10.17077/aseenmw2014.1033

Rethwisch, D., (2014) “A Study of the Impact of Project Lead the Way on Achievement Outcomes in Iowa”, 2014 ASEE North Midwest Section Conference 2014(1), 1-18. doi: https://doi.org/10.17077/aseenmw2014.1033

Robin A. Costello, Shima Salehi, Cissy J. Ballen, and Eric Burkholder. “Pathways of opportunity in STEM: comparative investigation of degree attainment across different demographic groups at a large research institution.” *International Journal of STEM Education 10,* no. 46 (2023): https://doi.org/10.1186/s40594-023-00436-5.

Rogers, George E. “The Perceptions of Indiana High School Principals Related to Project Lead The Way.” *Journal of Industrial Teacher Education* 44, no. 1 (March 15, 2007): 49–65. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=eric&AN=EJ830475&site=eds-live&scope=site.

Rogers, George E. “The Perceptions of Indiana High School Principals Related to Project Lead The Way.” Journal of Industrial Teacher Education 44, no. 1 (March 15, 2007): 49–65. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=eric&AN=EJ830475&site=eds-live&scope=site.

Ronfeldt, Matthew, Susanna Loeb, and James Wyckoff. “How Teacher Turnover Harms Student Achievement.” American Educational Research Journal 50, no. 1 (February 1, 2013): 4–36. doi:10.2307/23319706.

Sadler, Philip M., Gerhard Sonnert, Harold P. Coyle, Nancy Cook-Smith, and Jaimie L. Miller. “The Influence of Teachers’ Knowledge on Student Learning in Middle School Physical Science Classrooms.” American Educational Research Journal 50, no. 5 (October 1, 2013): 1020–49. doi:10.2307/23526122.

Shields, C. J. “Barriers to the Implementation of Project Lead the Way as Perceived by Indiana High School Principals.” *Journal of Industrial Teacher Education* 44, no. 3 (September 15, 2007): 43–70. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=eric&AN=EJ830484&site=eds-live&scope=site.

Shields, C. J. "Barriers to the Implementation of Project Lead the Way as Perceived by Indiana High School Principals." Journal of Industrial Teacher Education 44, no. 3 (September 15, 2007): 43–70. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=eric&AN=EJ830484&site=eds-live&scope=site.

Social Security Administration. "Average Wage Index (AWI)." Accessed January 17, 2024. https://www.ssa.gov/oact/cola/awidevelop.html.

Society of Women Engineers. "Employment." Copyrighted 2023. https://swe.org/research/2023/employment/.

St J. Watson, Penelope W., Christine M. Rubie-Davies, Kane Meissei, Elizabeth R. Peterson, Annaline Flint, Lynda Garrett, and Lyn McDonald. "Gendered Teacher Expectations of Mathematics Achievement in New Zealand: Contributing to a Kink at the Base of the STEM Pipeline." *International Journal of Gender, Science & Technology 8*, no. 1 (January 2016): 82–102. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=qth&AN=114526600&site=eds-live&scope=site.

Stebbins, Melissa, and Tatiana Goris. "Evaluating STEM Education in the U.S. Secondary Schools: Pros and Cons of the «Project Lead the Way» Platform." *International Journal of Engineering Pedagogy 9*, no. 1 (January 2019): 50–56. doi:10.3991/ijep.v9i1.9277.

Stebbins, Melissa, and Tatiana Goris. "Evaluating STEM Education in the U.S. Secondary Schools: Pros and Cons of the «Project Lead the Way» Platform." International Journal of Engineering Pedagogy 9, no. 1 (January 2019): 50–56. doi:10.3991/ijep.v9i1.9277.

Stohlmann, Micah, Tamara J. Moore, and Gillian H. Roehrig. "Considerations for Teaching Integrated STEM Education." *Journal of Pre-College Engineering Education Research 2*, no. 1 (April 2012): 28–34. doi:10.5703/1288284314653.

Tamara D. Holmlund, Kristin Lesseig, and David Slavit. "Making sense of "STEM education" in K-12 contexts." *International Journal of STEM Education 3,* no. 32 (2018): https://doi.org/10.1186/s40594-018-0127-2.

Walker, Tim. "Teacher Salaries Not Keeping Up With Inflation, NEA Report Finds." *neaToday*, April 24, 2023. https://www.nea.org/nea-today/all-news-articles/teacher-salaries-not-keeping-inflation-nea-report-finds#:~:text=Key%20Takeaways,2.6%20percent%20in%202022%2D23.

Werner, Gary, Todd R. Kelley, and George E. Rogers. "Perceptions of Indiana Parents Related to Project Lead The Way." *Journal of STEM Teacher Education* 48, no. 2 (January 1, 2011): 137–54. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=eric&AN=EJ952049&site=eds-live&scope=site.

Werner, Gary, Todd R. Kelley, and George E. Rogers. “Perceptions of Indiana Parents Related to Project Lead The Way.” Journal of STEM Teacher Education 48, no. 2 (January 1, 2011): 137–54. https://search-ebscohost-com.proxy01.shawnee.edu/login.aspx?direct=true&db=eric&AN=EJ952049&site=eds-live&scope=site.

Wilson, A. T., Wang, X., Galarza, M. O., Knight, J., and Patino, E.. “Math attitudes and identity of high schoolers impacted through participating in informal, near-peer mentoring.” *International Journal of Research in Education and Science (IJRES)* 9, no. 2 (2023): 535-545. https://doi.org/10.46328/ijres.3093.

Yang, Xinrong, and Gabriele Kaiser. “The Impact of Mathematics Teachers’ Professional Competence on Instructional Quality and Students’ Mathematics Learning Outcomes.” Current Opinion in Behavioral Sciences 48 (December 2022). doi:10.1016/j.cobeha.2022.101225.

Yasemin Copur-Gencturk, Ian Thacker, and Joseph R. Cimpian. “Teachers’ race and gender biases and the moderating effects of their beliefs and dispositions.” *International Journal of STEM Education 10*, no. 31 (2023): https://doi.org/10.1186/s40594-023-00420-z.

Yilmaz Can, Dilara and Kesebir, Gülcenur. “Evaluation of Mathematical Modeling Activity of 4th-Grade Students: A Case of Experiential Learning.” *Ankara University Journal of Faculty of Educational Sciences* 56, no. 1 (May 2023): 585-611. https://doi.org/10.30964/auebfd.1037725.

Zippia. “BIOLOGIST DEMOGRAPHICS AND STATISTICS IN THE US.” Copyrighted 2024. https://www.zippia.com/biologist-jobs/demographics/.

Zippia. “CHEMIST DEMOGRAPHICS AND STATISTICS IN THE US.” Copyrighted 2024. https://www.zippia.com/chemist-jobs/demographics/.