8-8-2023

Effects of high school engineering course availability and participation on engineering school recruitment, discipline selection, persistence attitudes, and self-efficacy

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A Dissertation
Submitted to the Faculty of
Mississippi State University
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy
in Engineering Education
in the Bagley College of Engineering

Mississippi State, Mississippi

August 2023

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Date of Degree: August 8, 2023

Institution: Mississippi State University

Major Field: Engineering Education

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Title of Study: Effects of high school engineering course availability and participation on engineering school recruitment, discipline selection, persistence attitudes, and self-efficacy

Pages in Study: 118

Candidate for Degree of Doctor of Philosophy

The need for engineers in the workforce continues to grow. Filling this need requires recruiting future engineers to colleges and universities and retaining them through to degree completion. However, this is easier said than done. Universities are tasked with attempting to keep up with the demand for new engineers and companies are searching for new engineers to recruit. One avenue that has been established in the attempt to reach students for engineering is offering engineering or STEM classes in K-12 schools.

This dissertation looked at engineering classes offered at the high school level. These courses were analyzed for relationships with the steps in producing new engineers – recruitment and persistence. Historical data was used to study the effect of high school engineering courses on engineering recruitment. The availability of engineering courses in Mississippi high schools was analyzed against the percentage of graduates from those high schools entering the largest engineering school in the state. The influence of high school engineering participation on engineering discipline selection was also studied using a nationwide sample of current undergraduate engineering students. This same survey sample was used to study two factors related to engineering persistence – persistence attitudes and engineering self-efficacy.

Analysis found significant relationships between high school engineering courses and engineering recruitment. Engineering availability correlated to a higher percentage of students entering engineering. Participation in these engineering courses was also significantly associated with choice in certain engineering disciplines. However, once students have chosen their path in engineering and entered their undergraduate journey, the high school courses do not impact persistence factors. No relationships were found between high school engineering participation and persistence attitudes or overall engineering self-efficacy.

DEDICATION

This dissertation is dedicated to my reason why – my son Ethan.

ACKNOWLEDGEMENTS

I cannot thank Dr. Jean Mohammadi-Aragh, my major professor, enough for her guidance and support through this dissertation process. She has given of her time and expertise, and I truly appreciate the wealth of knowledge and kindness she has given. She has helped keep me realistic while empowering me to push myself. A big thank you to my committee, Dr. Jenna Johnson, Dr. Shane Brauer, and Dr. Deborah Eakin, for giving of their time, support, and perspectives.

My family has been there with me each step of the way. They never hesitated to jump in with help or a hug, whatever was needed! I am so thankful for their love and encouragement. Even on the very long days, they never ceased to show me grace and keep me motivated. I love you and appreciate you! Thank you specifically to my husband Gene, who made me laugh when I wanted to cry and kept me grounded. Thank you to my friends who let me vent, checked on me, prayed for me, and helped any way they could!

Finally, thanks to God through whom all things (including this dissertation) are possible. This is all for His glory!

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CHAPTER I

INTRODUCTION

What did you first want to be when you grew up? Many common answers exist for this question – firefighter, dolphin trainer, baseball player, ballerina, doctor – the list goes on and on. However, most people would probably tell you that their life plan changed at some point after they wrote their first "When I Grow Up" essay. The ability to influence a person's future career path could be greatly beneficial for certain professional fields.

The demand for professionals in the science, technology, engineering, and math (STEM) fields is growing each year. From May 2009 to May 2015, the number of STEM jobs increased by 10.5% while non-stem jobs only increased 5.2% (Utley et al., 2019). Increased demand requires an increase in people entering STEM programs. The National Society of Professional Engineers reported in 2021 that the number of engineers must grow by 15% to meet increasing demand and account for attrition (Roman). The difficulty filling engineering positions has been cited as a risk to the United States global competitiveness (Sorge and Hess, 2017). Universities have the daunting challenge of attempting to keep up with the demand for graduates with engineering degrees and corporations are searching high and low for top engineering talent.

One path that has been established in the attempt to attract more engineering majors is offering engineering or STEM classes in K-12 schools. Pinelli and Haynie offer three arguments to support the need for engineering in the K-12 curriculum. These reasons are "to support the engineering pipeline", "to enhance and enrich the teaching and learning of STEM", and "to create a technologically literate citizenry and society" (2010). This study is particularly interested in supporting the engineering pipeline.

Study Overview

The three studies in this research look at engineering courses at the high school level. Research conducted by Mountain and Riddick aimed to determine the minimum age at which detail-oriented engineering concepts can be successfully introduced. They found that 13-year-old students were much more engaged and enjoyed the detail-oriented aspects of the projects more than 12-year-old students (2005). Most middle school students range in age anywhere from 11-14 years old. With such significant differences seen at the 12-13-year-old age gap, it is desirable to steer research toward an older audience. A study conducted by R. Tai, Qi Liu, Maltese, and Fan analyzed data from 1988 to 2000 and found that students with goals for a STEM career at the age of 14 were 3.4 times more likely to earn a degree in science or engineering than those without STEM aspirations (Moote et al., 2020). These findings lead to a focus on high school engineering classes.

Though research has been conducted into engineering at the high school level, there are a number of significant gaps. The existing research largely centers on Project Lead the Way (PLTW). Project Lead the Way is the largest of the K-12 engineering programs. PLTW has 15,000 programs in over 12,200 schools in all 50 states, Washington D.C., and the U.S. territories. Millions of students have been reached through PLTW and close to 77,500 teachers have been trained (PLTW, 2022). With this broad reach it is understandable that PLTW is the center of the majority of the research; however other programs exist in the United States. Some of these programs include Engineering by Design, Engineering4USA, EPICS High, and Project

ExCITE. The other research found on engineering in K-12 relies on implementation of stand-alone engineering programs in certain schools or school districts. In order to fill this gap, the present study accounted for all high school engineering programs when looking at both availability and participation.

The majority of existing research has been conducted using data from a single state, school district, institute of higher education, or combination of the three. Even when accounting only for PLTW, most of the states that participate in the program have no research sample. Hess and colleagues identified the need for a large scale, cross-state investigation into secondary school engineering (2016). This gap drove the current research to seek to gather data from higher education institutions from all 50 states.

Research Questions

The three present studies aimed to address these and other gaps in the literature that are discussed in the remaining chapters. The goal of these studies is to answer the following research questions related to high school engineering availability and participation factors and their effect on engineering school recruitment, discipline selection, persistence attitudes, and self-efficacy.

RQ1: Does engineering class availability in high school impact graduates' recruitment into engineering school?

RQ2: Is there an association between high school engineering class participation and engineering discipline selection?

RQ3: Does high school engineering class participation impact engineering students' persistence attitudes?

RQ4: Does the depth of the high school engineering participation or program of participation relate to engineering discipline selection?

RQ5: Does the depth of the high school engineering participation or program of participation impact engineering and discipline specific persistence attitudes?

RQ6: Is there a correlation between high school engineering class participation and engineering self-efficacy?

RQ7: Does the depth of high school engineering participation or program of participation impact engineering self-efficacy?

There has been a push by the engineering community to understand how to advance engineering education and to understand the K-12 factors that lead students to enter the engineering "pipeline" (Reid and Feldhaus, 2007). Research shows that K-12 students' cognitive development and interest in engineering can be influenced by engineering classes and enrichment experiences (Yates, 2013; Lammi et al., 2022; Jenkins-Stark and Chklovski, 2010; Overschelde, 2013; Salas-Morera et al., 2013). This effect has also been found to significantly contribute to students choosing to major in engineering (Nite et al., 2020; Salzman et al., 2012; Salas-Morera et al., 2013; Voicheck, 2012; Pike and Robbins, 2019b).

The lack of consistent literature and identified gaps make it difficult to draw conclusions on high school engineering that can be applied on a broad scale. More conclusions can be drawn by looking not only at engineering participation but also at factors associated with that participation, by accounting for all high school engineering programs, by addressing availability along with participation, and by involving a large, nationwide sample. Understanding the impacts related to these variables will help universities and companies that are looking to or are already partnering with K-12 programs to better assess the benefits and areas needing improvement (Reid and Feldhaus, 2007). These impacts also reveal avenues for future research based on the impacts of different programs. This research could include further program comparisons and curriculum studies.

CHAPTER II

STUDY 1: INFLUENCE OF HIGH SCHOOL ENGINEERING AVAILABILITY ON ENGINEERING SCHOOL RECRUITMENT

Just as people try to sit next to or gravitate toward people they know in a large group; students are also more comfortable and confident with topics they "know". Taking a class about the major you are interested in seems like a great way to determine if you really like it; however, even the availability of an engineering class in high school might be enough to introduce engineering as an option or provide the opportunity for peer influence. The transition from high school to college is a difficult one that is full of decision points with seemingly unlimited options. Recruiting students to engineering requires reaching them prior to this transition and empowering them to choose engineering from the start. It is harder to reach students once they have already entered college and declared another major. Students feeling empowered to select engineering at the juncture prior to college relies heavily on students' self-beliefs (Godwin et al., 2016).

Increasing recruitment into engineering is the first step in combating the engineer shortage in the United States (Pinelli and Haynie, 2011). Engineering programs in K-12 curriculum have grown in popularity and implementation. With the costs and barriers associated with implementation of these programs, universities and companies often become involved in the implementation plans and funding (Reid and Feldhaus, 2007). Since high school engineering course participation is generally not a curriculum requirement, there is no way to ensure participation in the program by all or even a certain number of students. This study researched the impact of the availability of such classes on engineering recruitment. Establishing a relationship based on availability without looking at actual participation provides a better understanding of the actual cost versus benefit of providing these classes for engineering colleges and companies. This data could also better equip educators to fight for the need for engineering programs in their schools.

Literature Review

The following literature review explores the theoretical frameworks of identity formation and engineering identity. The next lines of literature pertain to the independent variable of engineering availability and the dependent variable of engineering recruitment.

Identity Formation

Identity formation requires a recurring and ever-changing process of building and changing one's own identity. Forming an integrated identity requires exploration of different life paths and careers. Crocetti et al. asserted that commitment, in-depth exploration, and reconsideration of the previous commitment are key components of identity formation. This assertion builds on Marcia's identity formation model (Li et al., 2021). Marcia's 1966 model utilized only two categories – exploration and commitment. Exploration involves seeking out and testing possibilities. This leads to forming perceptions about oneself based on the results of the exploration. These perceptions may in turn lead to commitment. Commitment refers to making decisions about one's identity. A proposed marriage of three models extended from Marcia by Crocetti et al., Luyskx et al., and Berzonsky is the Circumplex of Identity Formation Modes (CIFM) (Topolewska-Siedzik and Cieciuch, 2018).

Each mode in the CIFM is a method of identity management that is implemented while dealing with identity issues. These modes take personality into account when looking at identity formation (Topolewska-Siedzik and Cieciuch, 2018). The definitions of each mode are given in Figure 2.1.

Four basic identity modes distinguished in the CIFM

Mode	Description
Socialization	Defining oneself in such a way as to perform one's life roles well, according to the current stage in one's life. Beliefs concerning oneself form a coherent and stable system associated with a sense of being in the right place
Exploration	An active involvement, agency in building an identity structure and solving identity-relevant dilemmas and problems. The focus is on probing one's possibilities and testing whether a given activity is suitable for oneself
Defiance	The belief that one has not found one's place in life. Because this mode is located between diffusion (identity indetermination) and moratorivity (desire to undertake a commitment), it poses the risk that the adopted commitment will be in stark opposition to social norms
Petrification	A lack of interest in thinking about oneself and developing an identity structure. The characteristic feature is fragmentation of a rather poorly developed cognitive identity structure, with the fragmented elements being rigid or even frozen

Figure 2.1 Identity Modes of the CIFM by Topolewska-Siedzik and Cieciuch (2018)

While the mode of particular interest to this research is "exploration", it is important to recognize that students can transition through multiple or all of the modes simultaneously while forming an identity. The identity being formed is quite broad. This research is interested in factors related to identity formation, but specifically in the formation of an engineering identity.

Engineering Identity and Formation

Engineering identity is a type of role identity. A role identity refers to the perceptions an individual relates to certain roles in culture and society (Watt et al., 2019). Adolescents are forming their identities during high school. Patrick, Prybutok, and Borrego utilized three factors of identity in their study on engineering persistence. Figure 2.2 shows how the role identity of engineering fits into a student's identity. This figure also shows the key factors related to engineering identity.

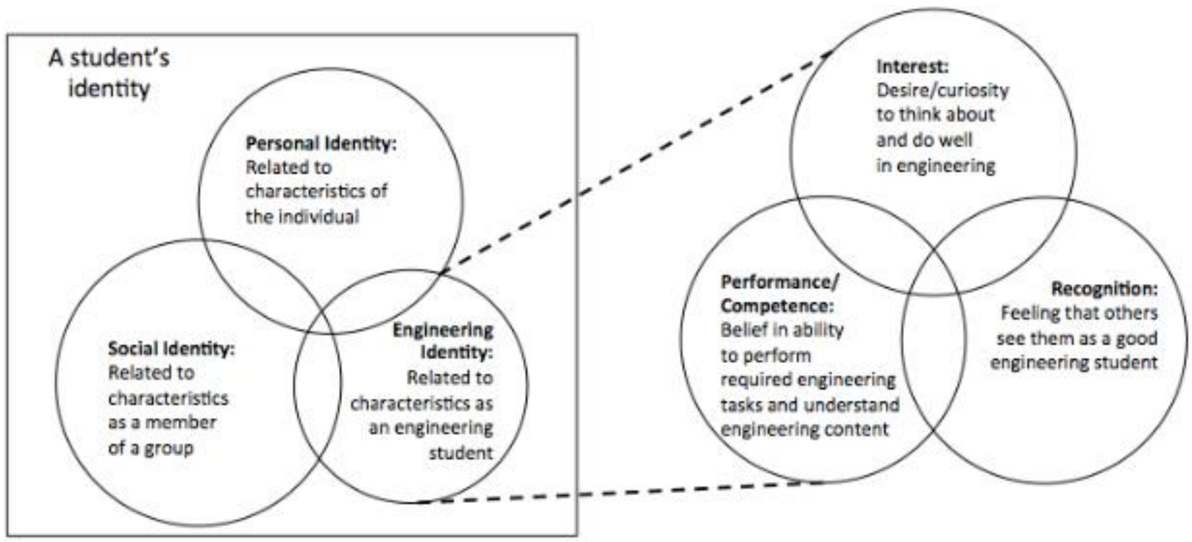

Figure 2.2 Engineering Identity Framework for Students by Patrick, Prybutok, and Borrego (2018)

The framework shown in Figure 2.2 utilizes two of the most cited frameworks when relating identity to STEM fields. One of the frameworks from Carlone and Johnson found identity to be the intersection and interaction of performance, competence, and recognition. Hazari et al. added to this framework by including interest as a key factor (Patrick, Prybutok, and Borrego, 2018). Studies have shown that students who show interest in engineering are more active in and show more skill in math and science. Performance and competence beliefs are related to self-efficacy which research shows to be positively related to persistence in engineering. Students' beliefs about how others "recognize" them is critical to how the students end up seeing themselves. Recognition provides formative messaging toward identity formation.

Studies identify the importance of these identity factors for students at both the college and high school level (Godwin et al., 2016).

High school students are still exploring and forming their career identities. Understanding contributions to the formation of a student's engineering identity will help researchers understand why students gravitate toward engineering or move away from it based on their perceptions of themselves and their career goals (Godwin et al., 2016). The formation of a role identity such as engineering identity is influenced by educational enrichment including in school and extracurricular exposure to the subject area (Verdín and Godwin, 2021). High school students in engineering classes are hopefully exploring the possibility of engineering as a major.

Exploration of a role, when carried out as defined by Topolewska-Siedzik and Cieciuch, can establish or build upon existing interest, give an opportunity for recognition, and form performance and competency beliefs (2018). Interest in engineering could stem from exploration or lead to further exploration of engineering. This interest is key to engineering identity development. Interest can start as situational, based on a student's environment (for example a high school engineering class) and develop into personal interest. Recognition is another key factor to establishing an engineering identity. Engineering classes provide opportunities for students to be recognized for their participation in engineering projects and mastery of engineering content. Students internalize others' perceptions of them related to engineering and use those perceptions as they shape who they are. Performance and competence beliefs are the third key factor to engineering identity. Performance and competence lead to recognition which helps to continually affirm the student's engineering identity. An engineering class is an ideal setting for a high school student to display engineering performance during identity formation (Verdín and Godwin, 2021).

Research has shown that exposure to STEM and engineering at the K-12 level has led to an increase in engineering interest as well as improved performance. A study by Yates modified K-12 curriculum to include more STEM projects, changed math curriculum, and provided engineering mentors and research opportunities for high school students. The participating students were tested pre and post project implementation, and the number of students going to engineering school was collected. Students' test scores improved, and the local engineering school had an increased enrollment of 8-17.9% with 24% of engineering freshmen choosing engineering because they had been involved in an engineering project (2013). Additionally, an experiment conducted in 2018 studied the effect of engineering enrichment activities in high school classrooms. This study showed a 7.4-8.2% positive shift in students' interest in engineering school after the engineering enrichment unit (Autenrieth et al., 2018, p. 26).

High School Engineering Availability

Cost is often cited as a barrier to implementing high school engineering classes. Sorge and Hess studied the cost associated with implementing one PLTW introductory class. They found a wide range in implementation cost from $1,300 for one 12-person section to $400 for four 30-person sections (2017). Research into the barriers associated with implementing PLTW in Indiana sought to catalog the opinions of high school principals. A sample of the non-PLTW high school and middle school principals in the state were surveyed. The results found that the majority felt PLTW is a valid program for technology education and would like to see it offered in their schools. Still 45.3% agreed that the cost of equipment is too high and 42.4% felt cost of training teachers was too high (Shields, 2007).

A study conducted using data from Indiana high schools researched the likelihood of attending engineering school after attending a high school where PLTW was available versus a high school where PLTW was not available. The study found that attending a PLTW high school did have a significant relationship with majoring in STEM. However, this study did not just look at availability. It also controlled for PLTW participation within the PLTW schools. The additional analysis showed that students participating in PLTW were more likely to major in STEM than those who did not. This aligns with the data from other PLTW participation studies. This study used data for a single graduating class and looked only at PLTW schools. No other engineering classes were considered. This study also recognized that other factors contribute to majoring or not majoring in STEM such as socio-economic factors. The results showed that PLTW might help in negating some of these factors (Sorge and Feldhaus, 2019).

Barriers exist to the availability of engineering classes. The only research into the availability of high school engineering looked only at PLTW and only at one graduating class for data. The lack of information on engineering classes that might have been offered by other schools and the lack of evidence from multiple years leaves significant gaps in the only availability study found.

Recruitment of Engineering Students

Multiple studies have been conducted showing that students who participate in PLTW are more likely to major in STEM fields (Nite et al., 2020; Salzman et al., 2012; Salas-Morera et al., 2013; Voicheck, 2012; Pike and Robbins, 2019b). One study by Salzman, Mann, and Ohland found that out of 240 PLTW participants surveyed at Purdue University, 53% chose to major in engineering while an additional 35% were spread over additional STEM fields (2012). However, high school engineering participation is not a prerequisite to recruitment. A qualitative study conducted at a southeastern research university interviewed 21 engineering students about entering the engineering program. One finding in this study was that six of the students were persuaded by friends to take up engineering. Ten of the students' narratives included being familiar with engineering-based tasks pre-college. Only three of the students actually took classes in STEM fields during high school (Cruz and Kellum, 2018).

In summary, the research overwhelmingly supports that participation in high school engineering is correlated to students pursuing engineering. However, research also shows that other factors contribute to majoring in engineering. One of these factors is persuasion from friends.

Present Study

It is important for students to know that engineering is a career option for them to explore. While participation would provide the best exploration for engineering identity formation, the availability of such programs and peer influence from participating students is another avenue for introducing engineering as an option to explore.

The existing literature on high school engineering availability and engineering recruitment was lacking. Participation had a strong relationship with majoring in engineering, but these studies still had gaps. None of the participation studies accounted for all high school engineering programs. Unfortunately, participation cannot be guaranteed, and many factors could prevent students from participating in engineering classes, even if they wanted to. No studies looked at high school engineering availability alone, regardless of program, related to engineering recruitment.

This study considered high school engineering classes from all programs as well as stand-alone, school specific engineering courses. It compared high schools that offer engineering courses with high schools that do not offer engineering courses or programs. Data covering multiple graduating classes was also considered.

Research Question

This study addressed the gaps in literature by answering the question:

> **RQ1:** Does engineering class availability in high school impact graduates' recruitment into engineering school?

The significant relationship that has been shown between PLTW participation and engineering recruitment leads to the hypothesis for this study. The hypothesis is that high schools that offer engineering classes will have higher percentages of students that enter engineering school than high schools that do not offer engineering classes.

Methods

Design

Quantitative research methods were used to analyze the data for this study. This study collected and utilized existing historical data.

Definitions. *Engineering classes* were defined as any a class that is part of any existing nationally recognized engineering program/curriculum or any stand-alone class that focuses on engineering concepts and skills. *Engineering program* referred to a nationally recognized engineering program that the classes are a part of such as Project Lead the Way, Engineering by Design, EPICS, etc.

Data Source

Data was gathered on the engineering class offerings of Mississippi public high schools. The number of engineering classes offered, programs of classes, year classes first became available, and participation requirements were requested for each high school in Mississippi. The data was obtained from the high schools' principals, counselors, or career and technical directors.

Data was collected for 104 high schools out of the 234 public high schools in the state. This study also used available data on all incoming Mississippi State Bagley College of Engineering (BCoE) students from Fall 2013 through Spring of 2020 (both fall and spring semesters). The high school attended and engineering major for each student was gathered from the university.

Participants

Participating high schools accounted for 44.4% of Mississippi public high schools. For the first year in the study, 75 of the high schools did not have engineering and 29 did have engineering courses. By the last year in the study, 48 high schools did not have engineering and 56 did have engineering courses. The data on the participating high schools was gathered using existing databases and school personnel. The participants of the study were all entering Mississippi State engineering students from 2013-2020 who attended the participating high schools. Data on participants was gathered using databases and university enrollment information. The sample covered seven graduating classes. This utilized years with readily available high school graduation data.

Independent Variable

The independent variable in this study was the availability of engineering courses. This availability was gathered for each high school and coded for each year of the study. If a high school started an engineering class in the 2014 – 2015 school year, engineering availability was coded as a 0 (not available) for the 2013 – 2014 and prior school years and coded as a 1 (available) for the 2014 – 2015 and following school years.

Dependent Variable

The dependent variable for this study was engineering school entrance. When measuring engineering school entrance, percentages of graduates who attended the Bagley College of Engineering were calculated for each year for each high school. The number of students who entered engineering from each graduating class was divided by the number of graduates for that high school. This was done for each school year of interest to the study.

Procedure

Once the study received Institutional Review Board (IRB) approval, the web based, Qualtrics questionnaire was sent to each public high school principal in Mississippi (Qualtrics, Provo, UT). The questionnaire can be found in Appendix A. The initial response to the questionnaire was low. Follow-up emails were sent to principals and counselors. Phone calls were also made to the career and technical centers and high schools to request information. The Mississippi Department of Education website was also used. The data collected for each school included:

1. Number of graduating students each year from 2013-2019 (collected from Mississippi Department of Education website)
2. Number of engineering classes available at each school
3. How long engineering classes have been available
4. Whether or not STEM extracurricular activities are available
5. Grade level and requirements for participation in engineering classes

Data was also gathered from Mississippi State by working with the Office of Institutional Research and Effectiveness. Data was obtained on the entering engineering students from 2013-2020. The data collected for each student included:

1. High school attended
2. Year of high school graduation
3. Engineering major
4. High school GPA
5. ACT score

Data was assigned random identification numbers in order to keep records anonymous.

Analysis

Data was analyzed using Statistical Package for Social Sciences (SPSS) software version 28.0 (IBM Corp., Armonk, NY). Calculations were first completed to find the percentage of students from each high school graduating class that went on to attend the Bagley College of Engineering. These percentages were then analyzed for significance with high school engineering availability using Mann-Whitney U tests. The non-normality of the data lead to the use of the nonparametric Mann-Whitney tests. These tests were repeated for each year in the study using engineering class availability for that year and the percentages for that year. Further analysis was conducted on schools that have engineering classes available. The number of engineering courses available was analyzed for significance with percentages for the last year of the study using a Kruskal-Wallis test. The last year was used since all schools with engineering courses available were accounted for by the final year of the study.

Results

This research is based on the availability of high school engineering courses. The analyzed sample consisted of 104 of the 234 public high schools in Mississippi. Table 2.1 shows the number of high schools in the sample that had engineering courses available for each year analyzed in the study.

Table 2.1 Number of High Schools with and without Engineering Classes Available by Year

Number of Schools with	School Year						
	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
Engineering Classes	29	34	40	45	51	54	56
No Engineering Classes	75	70	64	59	53	50	48

The number of schools with engineering courses increased each school year. The dependent variables in this study were the percentage of graduating students who attended the Bagley College of Engineering from each high school in the state. The mean percentage of students attending the BCoE for each year based on availability of high school engineering classes are given in Table 2.2. For each school year, the mean percentage of graduates attending the Bagley College of Engineering is higher for schools that had engineering available than those that did not have engineering.

Table 2.2 Mean Percentages of Graduates Attending BCoE by Year and Engineering Class Availability

Year	Engineering Classes Available	Percent Entering Engineering School	
		Mean	Standard Deviation
2012-2013	Yes	2.21	1.79
	No	1.56	1.57
2013-2014	Yes	2.45	1.58
	No	1.78	1.83
2014-2015	Yes	2.60	1.75
	No	1.46	2.17
2015-2016	Yes	3.35	2.83
	No	1.33	1.39
2016-2017	Yes	2.85	2.10
	No	1.44	1.41
2017-2018	Yes	2.60	1.83
	No	1.40	1.60
2018-2019	Yes	2.20	1.64
	No	1.45	1.62

In order to answer the research question, Mann-Whitney U tests were performed with the engineering availability and percent of graduates entering engineering. These tests were run for each school year. The results are shown in Table 2.3.

Table 2.3 Mann Whitney Test Results for Engineering Class Availability and Percent of Graduates Entering Engineering

Percent of Graduates Entering BCoE in	Mean based on Engineering Class Availability				
	Yes	No	*U*	*z*	*p*
2012-2013	2.21	1.56	1245.50	1.79	0.073
2013-2014	2.45	1.78	1393.50	2.00	0.046
2014-2015	2.60	1.46	1710.50	3.68	<.001
2015-2016	3.35	1.33	2041.50	4.72	<.001
2016-2017	2.85	1.44	1918.50	3.72	<.001
2017-2018	2.60	1.40	1850.50	3.51	<.001
2018-2019	2.20	1.45	1736.50	2.58	0.010

The Mann-Whitney tests found significant differences in percentage of graduates attending engineering school based on engineering class availability for all school years except the 2012-2013 school year. Looking further into the availability of engineering courses, we analyzed for differences in percentage of graduates attending engineering school based on the number of high school engineering courses available. A Kruskal-Wallis test was used to look for differences in the last school year. The differences in percentages was not statistically significant based on number of courses, $H(4) = 8.66$, $p = .070$. A Mann-Whitney U test was performed to look for differences in percentage of graduates attending engineering school based on the availability of STEM extracurricular activities. This test was also run for the last school year to best account for all extracurriculars being implemented. The difference in percentages was not statistically different based on the availability of STEM extracurriculars, $U = 742.50$, $z = 1.80$, $p = 0.072$.

Discussion

The number of high schools with engineering courses in Mississippi is growing. We can see that the number of schools with engineering increased for each school year in our sample. Several schools in the sample have established engineering courses in the years since the study window, but they did not have them for the timeframe being studied.

As expected, we found a significant difference in percentage of students attending the Bagley College of Engineering based on the availability of engineering classes at their high school. This significant relationship was found for six of the seven school years analyzed. The only year that did not show a significant difference based on engineering availability was the 2012-2013 school year. During the 2012-2013 school year, only 29 of the 104 schools had engineering courses. This was the first year of implementation for many of the schools and only the second for a few others. It is not surprising that these courses would not be making a significant impact in their infancy. We see significant results for the remaining school years with more courses available and a larger number of established courses.

Our finding of a significant relationship between high school engineering course availability and engineering school recruitment is supported by a previous study in Indiana on the likelihood of attending engineering school after attending a high school where PLTW was available (Sorge and Feldhaus, 2019). Additional studies show that PLTW participation has an influence on majoring in STEM and participation in not possible without availability (Nite et al., 2020; Salzman et al., 2012; Salas-Morera et al., 2013; Voicheck, 2012; Pike and Robbins, 2019b). High school engineering courses are helping students to explore engineering as a role identity. As Topolewska-Siedzik and Cieciuch found, exploration is key in building identity (2018). The findings of our research show that the availability of engineering classes allows students to establish or build on existing interest in engineering. This interest is a major steppingstone to students beginning to form the engineering identity that will lead them to engineering school.

We looked a little deeper into the availability of engineering courses and analyzed the number of classes available. No significant difference was found in recruitment based on the number of courses available. The program each schools' engineering courses were a part of was also noted. Many of the schools changed their programs during the studied time frame. The state developed a curriculum that replaced many of the PLTW classes throughout the state. Since the significant findings between availability and recruitment continued through these program changes the program does not appear to hold a great deal of significance. Our study included schools implementing stand-alone courses, PLTW, EPICS, EngineeringByDesign, and ExCITE. The number of courses available ranged from one course to four or more courses. This shows that the association between high school engineering courses and engineering recruitment does not hold only for PLTW nor is it tied to a specific number of courses.

By establishing a significant association between the availability of engineering classes and engineering recruitment, we can better make the case for funding and implementing these courses. This significant association was found for six of seven years examined. The number of high schools with engineering available increased during each year examined. Once the engineering classes were established, the availability of the classes in high schools corresponded to higher percentages of students entering the Bagley College of Engineering. This positive relationship held true for the remaining years in the study. Finding significance over six different graduating classes strengthens the results of our study. When significance can be seen based only in availability, without controlling for which students participated or did not participate, the argument for having these courses available in every school is even stronger. Companies and universities can feel confident that when they invest in these programs a certain number of students or grade level of students do not have to participate for there to be a return on their investment.

Limitations

This study utilized existing historical data sets. A portion of the data was self-reported by representatives of the schools. No information was obtained from the students to measure actual engineering influence or other factors contributing to engineering school enrollment. Students' family influence on engineering entrance, out-of-school STEM experiences or hobbies, and previous experiences with engineering were not taken into account. There was also no way to account for the standard of engineering course implementation and teaching at each of the high schools. This study relied on data for incoming freshmen and transfer students. There was no way to account for the influences transfer students experienced during their two-years in community college. This study used historical data from years prior to 2020. This selection attempted to avoid the impacts of COVID-19 but does not use the most recent data. Another limitation of this study is the sample. A study utilizing a sample solely from the state of Mississippi cannot be generalized to other states or the nation as a whole. The only engineering school considered is Mississippi State University's Bagley College of Engineering. This is the largest engineering school in the state. However, students attending other engineering schools were not taken into consideration.

Future Work

A future study that involves every high school in the state including private schools would help to cement these findings. In this study, availability and percentage recruited into engineering school could still be analyzed. However, by surveying graduates about their planned major after graduation, all students entering engineering would be accounted for not just those attending a single institution.

A long-term study that surveyed students as ninth graders on their future career interest and then surveyed the same students as exiting seniors would establish the student's actual change in engineering interest during their time in high school. This change in interest could then be analyzed against engineering class availability.

Conclusion

This study collected data from 104 public high schools in the state of Mississippi on the availability of engineering courses in their schools. The number of graduating students was collected for each school for each year from 2013 – 2019. The number of students from each high school that entered the Bagley College of Engineering during those years was also collected. The percentage of graduates entering the Bagley College of Engineering from each high school was analyzed to identify any relationship with engineering course availability.

The analysis was conducted using Mann-Whitney test for course availability and percentage of students entering engineering. The tests were run for each of the seven graduating classes in the study sample. The tests found significance between high school engineering class availability and the percentage of students entering engineering at Mississippi State for six of the seven graduating classes. The only year that did not show significance was the first year analyzed. This was the first year of implementation for many of the schools with engineering in that school year. The programs were not established enough to have significantly impacted the graduating seniors that year. The significance was found for six different graduating classes, for schools with differing numbers of courses, different curriculum programs, different sizes, and different geographic locations in the state. Overall, the availability of high school engineering courses appears to be a contributing factor to engineering school recruitment.

CHAPTER III

STUDY 2: HIGH SCHOOL ENGINEERING CLASS PARTICIPATION'S INFLUENCE ON DISCIPLINE SELECTION AND COMMITMENT TO PERSIST

Choosing a major is a difficult decision. Often at only 18 years old students are tasked with choosing the path of their future career. That decision has life altering consequences. Even highly motivated and high performing students find the college major decision difficult to navigate. Students making such decisions tend to restrict their focus to a few options (Galotti, 1999). We want engineering to be one of these options for as many students as possible.

Once a student decides to major in engineering, they must then decide on which engineering discipline to pursue. Different engineering disciplines cater to very different interests and skill sets. For example, students who enjoy electrical concepts may dislike chemistry or vice versa. Students finding the right fit in engineering is important to ensuring those students persist into the workforce as engineers. Retention rates are difficult to determine, but the national percentage of first year engineering students who persist in engineering through graduation is estimated to be between 44 and 64 percent (Cole et al., 2013, p. 85). This means that roughly half of students entering engineering school will not complete their degree in engineering.

This study investigates factors related to high school engineering participation that may affect students' choice in engineering discipline. These factors were analyzed to determine their influence on persistence attitudes related to engineering and specific engineering discipline. Understanding how high school engineering participation impacts engineering major choice and retention in that major can help to move students through the “pipeline” and into the world as professional engineers.

Literature Review

The following literature review first explores the theoretical framework of expectancy-value theory. The framework of engineering identity formation is also relevant and was discussed in Chapter 2. The next lines of literature pertain to the independent variables of engineering participation including program of participation and depth of participation. The remaining lines of literature involve the dependent variables of engineering discipline selection and commitment to persist.

Expectancy-Value Theory

Expectancy-value was first developed by Eccles and colleagues as a model to study achievement motivation. Expectancy-value model suggests that one’s choice to attempt a task and subsequent persistence with that task is impacted by one’s belief in themselves to succeed as well as beliefs about the task (Matusovich et al., 2008). A simplified version of Eccles expectancy-value model is shown in Figure 3.1.

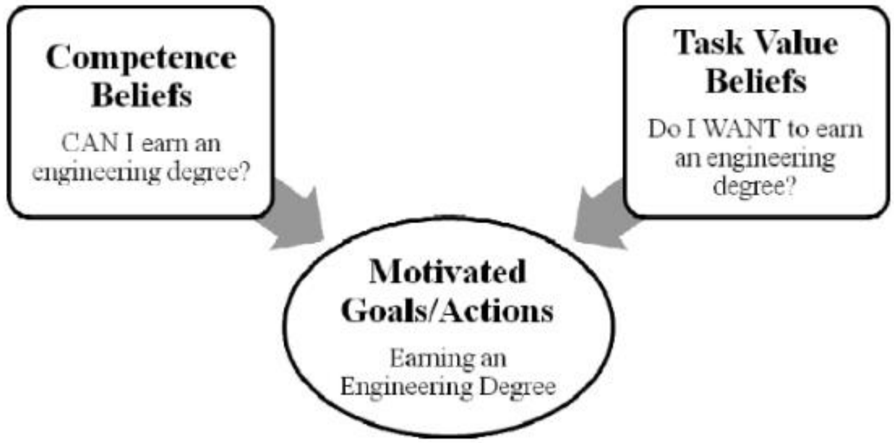

Figure 3.1 Simplified Expectancy-Value Model Related to Engineering by Matusovich, Streveler, and Miller (2010)

Expectancy-value model has been shown to be successful at predicting undergraduate students' choice in major (Galotti, 1999). This study looked at high school students' choice to pursue an engineering major as well as their persistence in their chosen engineering major. Expectancy-value tells us that engineering choice and persistence are determined by students' beliefs in their own abilities and their beliefs about engineering. Research shows that students view their choice of major as a reflection of themselves and believe that it has important ramifications for their future (Galotti, 1999). Matusovich and her counterparts found that students felt the skills most important to their success came from previous experiences. Previous experiences also aided in students' self-assessment of their own abilities (2008). By increasing students' knowledge about engineering and giving them experience with engineering, high school engineering classes can contribute to students' choices to pursue and persist in a specific engineering major.

Participation in High School Engineering

Research into K-12 engineering participation has been approached from a few different avenues. One avenue is the influence of high school engineering participation on college entrance. A study by Rethwisch, et al. conducted a study on Iowa high school students graduating in 2009. The study included 16,000 students with approximately 1,000 of those students participating in Project Lead the Way. The results found that 70% of PLTW students and 50% of non-PLTW students went into higher education immediately after high school (2013).

As has been discussed, several studies have been conducted on the influence of Project Lead the Way participation on recruitment into engineering school. One such study involving a single college and school district in Missouri showed low interest in engineering as a major among PLTW participants (Odun-Ayo and Obafemi-Ajayi, 2017). On the other hand, a dissertation study surveyed students who had participated in the PLTW program at a Pennsylvania High School. Results from the 40 respondents gave their perceptions on the influence of the program. The results showed that 92.5% of the students felt PLTW participation had given them a firm college foundation and 77.5% strongly or mostly agreed that PLTW had influenced their decision to study engineering (Voicheck, 2012). A Pike and Robbins study found that students who participated in Project Lead the Way were more likely to pursue STEM majors (2019b).

Program of Participation. Many different K-12 engineering programs exist in the United States. Twenty of these programs existed in schools across the country in 2009. Sorge and Hess found a lack of research into the impacts of the different programs (2017). This makes it challenging to pick one program to focus on; however, an overwhelming majority of existing research centers around the largest of the programs, Project Lead the Way. Most of the studies cited in this research rely on PLTW alone which creates a gap for students who participated in other programs.

Depth of Participation. The depth of participation in an engineering program is the number of engineering courses taken during high school. Very few studies account for depth of participation in high school engineering programs. Utley, et al. accounted for depth of PLTW participation in their study on retention. No significant relationship was found between depth of participation and retention in engineering school (2019). A study into PLTW's role in improving minority recruitment into engineering school also utilized the number of courses taken. This study utilized data on over 3000 minority students who graduated in 2010. A positive relationship was found between PLTW participation and entering college with a STEM major; however, there was no significant relationship found between number of courses completed and engineering recruitment (Pike and Robbins, 2019a). On the other hand, another Pike and Robbins study found that taking more PLTW classes increased the likelihood of majoring in a STEM field with a dosage effect (2019b). A Purdue University study into student perceptions on PLTW looked for significance between taking one course or two or more courses when analyzing students' perceptions. Statistically significant differences were seen between the two groups with students who took more PLTW classes agreeing more strongly with the positive impacts of PLTW (Salzman, Mann, and Ohland, 2012).

In summary, the majority of existing literature showed a strong relationship between high school engineering (specifically PLTW) and college entrance and engineering recruitment. The existing literature is primarily single state or institution focused and only investigated one engineering program or curriculum. Research into programs other than PLTW is severely lacking. No existing studies looked at all high school engineering programs and classes as a whole. The few existing studies into depth of participation were exclusively PLTW studies. These studies looked at retention, engineering recruitment, and project impact with mixed results as to the influence of taking multiple high school engineering classes.

Engineering Discipline Selection

Choosing a major can be a stressful undertaking and for engineering students it can be a two-tier process. Once a student has decided on engineering, he or she must next choose a discipline. Research exists into choice of engineering major that associates academic achievement in high school with engineering major choice (Main et al., 2022).

A study by Godwin, Sonnert, and Sadler looked at the relationship between engineering disciplines and out-of-school activities. A significant relationship was found between the types of out-of-school activities students took part in and the engineering disciplines they were interested in (2016). Several studies have focused on the motivation of students' choice in engineering discipline. These studies, conducted all over the world, have all concluded that the primary influence on engineering major selection is intrinsic motivation. Intrinsic motivation includes students' perceptions, feelings, intentions, and attitudes (Alexan, 2022; Shabban, 2016; Kolmos et al., 2013; Altman et al., 2010).

No existing research was found to be interested specifically in high school engineering participation and engineering discipline selection. Programs like PLTW include curriculum that focuses on items related to different engineering disciplines. For example, PLTW includes classes like Civil Engineering and Architecture, Computer Integrated Manufacturing, Digital Electronics, Biotechnology, and Aerospace (Shields, 2017; Ncube, 2006). A study by Salzman, Mann, and Ohland noted the discipline of all PLTW respondents as part of their research. They found that the most popular majors for PLTW alumni at Purdue were Mechanical, Electrical and Computer, Civil, and Aeronautical Engineering. They felt these were the majors most aligned with PLTW coursework and indicated this could imply that PLTW influenced their respondents engineering discipline selection (2012).

High school factors and engineering experiences have been tied to engineering major selection. Research agrees that engineering major selection is tied to students' perceptions, feelings, intentions, and attitudes. Engineering programs contain curriculum that is geared toward specific engineering disciplines. Existing literature laid the groundwork to investigate high school engineering influence on engineering major selection. Although no research had been conducted with the purpose of determining this relationship, researchers recognized the potential for such a study.

Commitment to Persist in Selected Discipline

An archival data study conducted by Utley, et al. used transcript data and enrollment information from the college of engineering at one university to look for a relationship between Project Lead the Way participation and engineering retention. While PLTW students were retained at a higher rate from first to second year, no difference was found in degree completions for PLTW versus non-PLTW students (2019). This study agrees with the findings by Cole, Highland, and Weinland in their study at the same university in earlier years (2013). The existing degree persistence studies looked only at PLTW participants and at overall engineering degree persistence.

An interesting effect studied by Lachney and Nieusma is the "engineering bait-and-switch". This idea proposes that students are "baited" into engineering by the fun projects and problem solving of K-12 engineering education. Once they are in a college engineering program the “switch” occurs to curriculum that starts with complex theory and fundamentals. This mismatch between K-12 engineering and collegiate engineering could drive students to leave engineering at the college level (2015). Mountain and Riddick also urge that while a focus on fun hands-on projects helps to spark interest in engineering, it could also cause a slanted perception of engineering. This could cause students who have the knowledge to succeed in engineering to end up dropping out (2005).

Research is lacking in retention and high school engineering at the engineering discipline level. Current retention studies focused on degree completion or retention from year one to two. These studies are not survey-based so students’ commitment to persist is unknown. The existing research also only accounts for PLTW and no other high school engineering curriculum. The unintended “bait-and-switch” effect could be one explanation as to why previous research has not seen higher persistence for PLTW participants.

Present Study

Multiple large gaps in high school engineering literature are addressed by this study. This study surveyed a large population of undergraduate engineering students across the United States on their high school engineering participation. All high school engineering classes, both stand-alone and part of programs, were included. This is the first study focused on high school engineering and college engineering discipline selection. This study analyzes the persistence attitudes of engineering students toward engineering school and their intended major. Many unforeseen circumstances could cause students to drop out of engineering or college. Studying students’ commitment to persist gives a better understanding of the impact of high school engineering participation on students’ desire to persist.

Research Questions

This study addresses these gaps in literature by answering research questions 2, 3, 4, and 5:

RQ2: Is there an association between high school engineering class participation and engineering discipline selection?

RQ3: Does high school engineering class participation impact engineering students' persistence attitudes?

RQ4: Does the depth of the high school engineering participation or program of participation relate to engineering discipline selection?

RQ5: Does the depth of the high school engineering participation or program of participation impact engineering and discipline specific persistence attitudes?

The lack of existing research into high school engineering classes and engineering discipline selection made forming a hypothesis difficult. The mismatched results of the research related to these classes and persistence also kept us from a hypothesis. These difficulties led us to utilize the null hypothesis.

Methods

Design

Quantitative research methods were used to analyze gathered survey data for all four research questions.

Definitions. *Depth of participation* was defined as the number of semester-long engineering classes a student completes during high school. A yearlong course counted as two classes. *Engineering program* referred to a nationally recognized engineering program that the classes are a part of such as Project Lead the Way, Engineering by Design, EPICS, etc.

Engineering discipline referred to the specific engineering discipline the student is studying. All majors within the student's college of engineering were recognized as an engineering discipline. *Commitment to persist (persistence attitude)* referred to the students' own feelings about their likelihood to persist in engineering and their current major. This was addressed on the survey instrument.

Data Source

An online survey solicitation was sent via email to over 700 engineering deans and department heads across the country for distribution to their undergraduate engineering students. The survey was to remain open until at least 300 student responses were received with usable data. A 90% confidence level, standard deviation of 0.5, and 5% error were used to calculate a necessary sample size of 270. This calculation assumed a national engineering student population of about 800,000. The United States graduated close to 200,000 engineering students per year from 2017-2020 (Data USA, 2020). The desired number of responses was increased to ensure an appropriate, usable sample was attained. The study received a usable sample size of 1612 responses.

Participants

The survey solicitation was distributed to 100+ higher education engineering programs for distribution to their undergraduate engineering students. Undergraduate engineering students across all engineering disciplines were targeted. The higher education institutions included public universities, private colleges, and HBCUs. The goal was for all regions of the United States to be represented. Responses were received from 1612 participants from 37 states. There were 840 (52.1%) male respondents and 722 (44.8%) female respondents while 45 respondents preferred not to give their gender. Minority participation (African/Black American, American Indian/Alaskan Native, and Latino/Hispanic) made up 19.48% of the respondents. Other represented ethnicities included Asian and Pacific American with 14.02% of responses and White American representing 65.57% of participants. Some participants selected “Other” or chose not to select an ethnicity. The classification breakdown of respondents was 339 (21%) first-year, 392 (24.3%) second-year, 383 (23.8%) third-year, 356 (22.1%) fourth year, and 142 (8.8%) fifth-year or above.

Instrument

The Assessing Women and Men in Engineering (AWE) Longitudinal Assessment of Engineering Self-Efficacy Survey was utilized for this study. The survey was modified for use in this study; however, no changes impacted the subscales. All changes either added or eliminated necessary background questions.

The modified survey called, “Engineering Self-efficacy and Persistence Survey”, included background items for students’ engineering major, year in school, and demographic information. Background items were added to ask students about their participation in high school engineering classes, program affiliation of the classes (e.g. PLTW), motivation for taking the class (e.g. required course or personal desire), and their depth of participation (number of classes taken). All background items are multiple choice. The modified survey is included in Appendix B.

This study focused on the students’ engineering majors and responses to the confidence in persistence/commitment to persist survey items as dependent variables. The confidence in persistence items asked students about their happiness with and confidence in remaining in their current engineering major, confidence that they will remain in engineering, and confidence that they will complete a degree. These responses were coded as 5-point Likert items. The AWE Longitudinal Assessment of Engineering Self-Efficacy instrument has been validated via testing with both male and female students (AWE, 2007). Content validity was verified by external expert reviews (Marra et al., 2009). AWE considers these commitment to persist items as specific, activity-related questions and not part of the self-efficacy subscales, so no reliability values were given (AWE, 2007). These persistence items are given below in Figure 3.2.

1. At the present time, how satisfied are you with your decision about your specific engineering major? (Circle a number from the scale below)

Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
0	1	2	3	4

2. At the present time, how confident are you that you will keep your chosen engineering major through college? (Check one from the items below)
   - ☐ Not at all confident; I am already planning to change my major
   - ☐ Not very confident; it is highly likely that I will change my major
   - ☐ There's about a 50% chance that I'll change my major
   - ☐ I'm fairly confident that I will keep my current choice as my major
   - ☐ I'm very confident that I will keep my current choice as my major

3. At the present time, how confident are you that you will be enrolled in any major in the college or school of engineering in the next academic year? (Check one)
   - ☐ Not at all confident; I am already planning to change out of engineering.
   - ☐ Not confident; it is likely that I will not be in engineering then.
   - ☐ There's about a 50% chance that I'll still be in engineering.
   - ☐ I'm fairly confident that I will still be in engineering then.
   - ☐ I'm very confident that I will still be in engineering then.

4. At the present time, how confident are you that you will graduate with your current engineering major? (Check one)
   - ☐ Not at all confident; I am already planning to change my major.
   - ☐ Not confident; it is highly likely that I will change my major.
   - ☐ There's about a 50% chance that I'll change my major.
   - ☐ I'm fairly confident that I will keep my current choice as my major.
   - ☐ I'm very confident that I will keep my current choice as my major.

5. At the present time, how confident are you that you will complete any engineering degree (any engineering major)? (Check one)
   - ☐ Not at all confident; I am already planning to change out of engineering.
   - ☐ Not confident; it is highly likely I will not complete an engineering degree.
   - ☐ There's about a 50% chance that I'll complete an engineering degree.
   - ☐ I'm fairly confident that I will complete an engineering degree.
   - ☐ I'm very confident that I will complete an engineering degree.

6. At the present time, how confident are you that you will complete any degree (any major) at this institution? (Check one)
   - ☐ Not at all confident; I am already planning to transfer to another institution or drop out of college.
   - ☐ Not confident; it is highly likely I will not complete any college degree.
   - ☐ There's about a 50% chance that I'll complete a degree at this institution.
   - ☐ I'm fairly confident that I will complete a degree at this institution.
   - ☐ I'm very confident that I will complete a degree at this institution.

Figure 3.2 Confidence in Persistence Survey Items (AWE, 2007)

Independent Variables

Engineering participation was coded at two levels: 1 (participated), 2 (did not participate). *Depth of participation* was coded at four levels: 1 (one class), 2 (two classes), 3 (3 classes), and 4 (4+ classes). *Engineering program* was coded for each program: 1 (PLTW), 2 (Engineering by Design), 3 (Engineering4USA), 4 (EPICS High), 5 (ExCITE), 6 (Stand-alone program/classes), and 7 (Other). An additional code was added for SkillsUSA (8) due to the number of responses.

Dependent Variables

Engineering discipline was coded as follows:

1 Aerospace	10 Engineering Science
2 Agricultural	11 Environmental
3 Architectural	12 Industrial
4 Bioengineering	13 Materials
5 Chemical	14 Mechanical
6 Civil	15 Nuclear
7 Computer Engineering	16 Petroleum
8 Computer Science	17 Undecided
9 Electrical	18 Other
	19 Biomedical

The code for Biomedical was added due to the number of students indicating it as their major in the "Other" category. *Persistence attitudes* were collected as responses to the individual Likert-items. Persistence attitudes were calculated as means of two or more of the commitment to persist items. A discipline specific commitment to persist was calculated as the mean value of the two major specific items (Item 2 and 4 in Figure 3.2). The discipline specific commitment to persist with satisfaction was calculated as the mean value of the two major specific items and the satisfaction item (Item 1, 2, and 4 in Figure 3.2). An engineering commitment to persist was calculated as a mean value of the two engineering specific items (Item 3 and 5 in Figure 3.2). An overall commitment to persist was calculated using the five persistence Likert items (Items 2-6 in Figure 3.2). A commitment to persist along with satisfaction was also calculated by finding the mean of all six items.

Procedure

Once the study received approval from the Institutional Review Board (IRB), the web-based survey was generated using Qualtrics online platform (Qualtrics, Provo, UT). As stated, participants were sought from the nation’s engineering schools via email. The email contained a link to the Qualtrics survey along with:

- Survey instructions and estimated completion time
- A description of the data being gathered
- IRB information
- Confidentiality and anonymity assurance

The survey remained open for two weeks. When the survey closed, 1820 responses were collected. Unfinished surveys were removed to reach a usable sample size of 1612 records.

Analysis

This study utilized Statistical Package for Social Sciences (SPSS) software version 28.0 (IBM Corp., Armonk, NY). Different statistical analysis methods were used for the different research questions in this study.

RQ2: Is there an association between high school engineering class participation and engineering discipline selection?

Participants selected one of eighteen options as their current engineering major. An additional major was added due to its frequency in the Other category. A chi-square test of independence was used to test for association between engineering class participation and engineering discipline. In order to meet necessary expected count assumptions for chi-square analysis, engineering disciplines with a count less than twenty were excluded. This eliminated Agricultural, Architectural, Materials, Engineering Sciences, Petroleum and Undecided. Records with the selection of Other were also eliminated. This resulted in the elimination of 183 records and a usable sample of 1429 for the chi-square test.

RQ3: Does high school engineering class participation impact engineering students' persistence attitudes?

When analyzing the impact of high school engineering class participation on students' persistence attitudes, Mann-Whitney U-Tests were used. These tests were conducted with high school engineering class participation as the independent variable and each of the five persistence attitudes as dependent variables. The persistence attitudes were calculated using the mean scores of the commitment to persist items. These attitudes include engineering commitment to persist, discipline specific commitment to persist, discipline specific commitment to persist with satisfaction, overall commitment to persist, and overall commitment with satisfaction. The persistence attitude scores are considered ordinal variables. These were calculated using two to three 5-point Likert items each. Since these are not true scales and are not at least 7-point Likert items the variables remained ordinal and nonparametric tests were used even after taking the mean (Grace-Martin, 2023). These tests were repeated for each classification of students individually – first-year, second-year, third-year, fourth-year, and fifth-year+. A separate Mann-Whitney U-Test was run for an association between co-op/internship participation and commitment to persist. Additional Kruskal-Wallis tests were performed for GPA and persistence attitudes as well as classification and persistence attitudes.

RQ4: Does the depth of the high school engineering participation or program of participation relate to engineering discipline selection?

A three-way loglinear analysis was used to analyze depth of high school engineering participation, program of participation, and engineering discipline selection. The sample for this analysis only considered those students who did participate in high school engineering classes. In order to meet the necessary assumptions for loglinear regression, program of participation was combined into only three groups (PLTW, Stand-alone program/classes, and Other programs). Engineering disciplines were also limited to 13 groups from the collected 19. The disciplines removed were Agricultural, Architectural, Engineering Science, Materials, Petroleum, and Undecided. These disciplines along with the selection of Other were considered missing. The remaining usable sample size was 583. Individual chi-square tests of independence were used to analyze the relationship between depth of participation and discipline, program of participation and discipline, and depth of participation and program of participation.

RQ5: Does the depth of the high school engineering participation or program of participation impact engineering and discipline specific persistence attitudes?

The analysis performed to test the relationships between depth of high school engineering class participation and persistence attitudes and between program of participation and persistence attitudes was the Kruskal-Wallis test. The sample size for these tests included only the students who participated in high school engineering classes (N = 649). The test was first performed with depth of participation as the independent variable and each of the four persistence attitudes as dependent variables. The persistence attitudes mean scores include engineering commitment to persist, discipline specific commitment to persist, overall commitment to persist, and overall commitment + satisfaction. These tests were run again using program of participation as the independent variable. In order to meet necessary assumptions of the Kruskal and Wallis test, Program of Participation was combined into only three groups (PLTW, Stand-alone program/classes, and Other programs).

Results

All of the analysis conducted is based in engineering participation. The percentage of respondents who participated in high school engineering classes was 40.3% while 59.7% did not participate in high school engineering classes. The participating 40.3% accounted for 649 participants. Of these 649 participating students 27% took one class, 25.6% took 2 classes, 18.6% took three classes, and 28.8% took four or more classes. When looking at the program students participated in, 36.2% participated in Project Lead the Way, 47.8% participated in Stand-alone/School Specific classes, and 16% participated in Other Programs.

Engineering Discipline – Research Questions 2 and 4.

The respondents each selected their current engineering discipline. These responses were categorized using demographic groups. The count and percentages of respondents in each major were found using gender and ethnicity. Table 3.1 gives the count and percentages of each gender in each of the engineering disciplines.

Table 3.1 Engineering Discipline and Gender Descriptive Statistics

Engineering Discipline	Gender		
	Male	Female	Prefer Not to Say
Aerospace			
n	64	28	4
%	66.67	29.17	4.17
Bioengineering			
n	25	69	2
%	26.04	71.88	2.08
Chemical			
n	81	108	4
%	41.97	55.96	2.07
Civil			
n	65	82	2
%	43.62	55.03	1.34
Computer			
n	57	32	4
%	61.29	34.41	4.3
Computer Science			
n	41	36	4
%	50.62	44.44	4.3
Electrical			
n	104	45	3
%	68.42	29.61	1.97
Environmental			
n	9	37	1
%	19.15	78.72	2.13
Industrial			
n	35	35	3
%	47.95	47.95	4.11
Mechanical			
n	229	118	4
%	65.24	33.62	1.14
Biomedical			
n	18	49	4
%	25.35	69.01	5.63

Table 3.1 (continued)

Engineering Discipline	Gender		
	Male	Female	Prefer Not to Say
Other			
n	112	83	10
%	54.63	40.49	4.88
Total			
n	840	722	45
%	52.27	44.93	2.8

Differences in gender percentages greater than 15% are seen in seven of the engineering disciplines. Those disciplines are Aerospace (Male = 66.67, Female = 29.17), Bioengineering (Male = 26.04, Female = 71.88), Computer (Male = 61.29, Female = 34.41), Electrical (Male = 68.42, Female = 29.61), Environmental (Male = 19.15, Female = 78.72), Mechanical (Male = 65.24, Female = 33.62), Biomedical (Male = 25.35, Female = 69.01). The counts and percentages for each ethnicity in each major are given in Table 3.2.

Table 3.2 Engineering Discipline and Ethnicity Descriptive Statistics

	Ethnicity					
	African/Black American	American Indian/Alaskan Native	Latino/Hispanic American	White American	Asian/Pacific American	Other[a]
Engineering Discipline						
Aerospace						
n	1	1	17	59	11	7
%	1.04	1.04	17.71	61.46	11.46	7.29
Bioengineering						
n	3	0	14	57	18	5
%	3.09	0	14.43	58.76	18.56	5.15
Chemical						
n	5	0	15	138	27	9
%	2.58	0	7.73	71.13	13.92	4.64
Civil						
n	5	0	20	105	13	6
%	3.36	0	13.42	70.47	8.72	4.03

Table 3.2 (continued)

		Ethnicity					
		African/Black American	American Indian/Alaskan Native	Latino/Hispanic American	White American	Asian/Pacific American	Other[a]
Engineering Discipline							
Computer							
	n	7	0	6	52	21	7
	%	7.53	0	6.45	55.91	22.58	7.53
Computer Science							
	n	3	0	9	48	14	7
	%	3.7	0	11.11	59.26	17.28	8.64
Electrical							
	n	8	0	18	92	21	16
	%	5.16	0	11.61	59.35	13.55	10.32
Environmental							
	n	2	0	5	33	6	1
	%	4.26	0	10.64	70.21	12.77	2.13
Industrial							
	n	5	0	6	41	12	9
	%	6.85	0	8.22	56.16	16.44	12.33
Mechanical							
	n	10	2	40	251	31	17
	%	2.85	0.57	11.4	71.51	8.83	4.84
Biomedical							
	n	3	0	8	52	6	2
	%	4.23	0	11.27	73.24	8.45	2.82
Other[a]							
	n	10	1	31	129	26	8
	%	4.88	0.49	15.12	62.93	12.68	3.90
Total							
	n	62	4	189	1057	206	94
	%	3.58	0.25	11.72	65.57	12.78	5.83

[a] These categories were considered "Missing" during analysis.

White Americans make up over half of the sample for each engineering major. This ethnicity group makes up 65.57% of the total sample. In order to test for association between high school engineering class participation and engineering discipline, a chi-square test for independence was performed. A statistically significant association was found between high school engineering class participation and engineering discipline, $\chi^2(11) = 58.70$, $p < .001$. The association strength fell between small and moderate (Cohen, 1988), Cramer's V = .203.

Since the results were statistically significant, further investigation was needed into the direction of the association. The column proportion comparisons and standardized residuals for each discipline based on engineering class participation are given in Table 3.3.

Table 3.3 Column Comparisons and Standardized Residuals for Discipline based on Participation

Engineering Discipline		High School Engineering Class Participation	
		Yes	No
Aerospace	Count	**49_a**	**47_b**
	Standardized Residual	1.8	-1.4
Bioengineering	Count	**26_a**	**71_b**
	Standardized Residual	-2.0	1.6
Chemical	Count	**50_a**	**144_b**
	Standardized Residual	-3.1	2.5
Civil	Count	62_a	87_a
	Standardized Residual	0.4	-0.3
Computer	Count	35_a	58_a
	Standardized Residual	-0.3	0.3
Computer Science	Count	**46_a**	**35_b**
	Standardized Residual	2.4	-2.0
Electrical	Count	**73_a**	**82_b**
	Standardized Residual	1.5	-1.2
Environmental	Count	18_a	29_a
	Standardized Residual	-0.2	0.1

Table 3.3 (continued)

Engineering Discipline		High School Engineering Class Participation	
		Yes	No
Industrial	Count	**19_a**	**54_b**
	Standardized Residual	-1.9	1.5
Mechanical	Count	**163_a**	**188_b**
	Standardized Residual	2.0	-1.6
Nuclear	Count	5_a	17_a
	Standardized Residual	-1.3	1.0
Biomedical	Count	22_a	49_a
	Standardized Residual	-1.2	1.0

Note: Different subscripts indicate significantly different proportions between column variables for that major at the .05 level.

The column proportion comparisons show significant differences for Aerospace, Bioengineering, Chemical, Computer Science, Electrical, Industrial, and Mechanical. The standardized residuals give the direction of the significant association for each major based on class participation. For Aerospace, Computer Science, Electrical, and Mechanical engineering disciplines, the proportion of students in those majors who participated in high school engineering classes is significantly higher than those who did not participate. For Bioengineering, Chemical, and Industrial engineering disciplines, the proportion of students in those majors who did not participate in high school engineering classes is significantly higher than those who did participate. All other disciplines did not have significant differences based on class participation.

A three-way loglinear analysis was performed for the associations between depth of participation, program of participation, and engineering discipline. The resulting model included all main effects and all two-way associations, depth*discipline, program*discipline, and program*depth. The model had a likelihood ratio of $\chi^2(66) = 75.30$, $p = .203$. Partial likelihood ratio χ^2 are presented in Table 3.4.

Table 3.4 Partial Associations for Depth, Program, and Discipline Variables

Effect	df	Partial Chi-Square	*p*
Discipline*Depth	33	55.47	0.01
Discipline*Program	22	38.22	0.02
Depth*Program	6	59.34	0.00
Discipline	11	328.11	0.00
Depth	3	10.22	0.02
Program	2	106.17	0.00

Results are considered significant at the $p < .05$ level.

Since the three-way association was not significant but the two-way associations were, individual chi-square analysis was used first for depth and discipline and then for program and discipline. A statistically significant association was found between depth of high school engineering class participation and engineering discipline, $\chi^2(33) = 58.17$, $p = .004$. The association strength fell between small and moderate (Cohen, 1988), Cramer's V = .182. The column proportion comparisons and standardized residuals were analyzed. The significant results for depth and discipline are given in Table 3.5.

Table 3.5 Significant Column Comparisons and Standardized Residuals for Discipline based on Depth of Participation

Engineering Discipline	Depth			
	1 class	2 classes	3 classes	4+ classes
Environmental				
Count	9_{a}	7_{a}	$2_{a, b}$	0_{b}
Standardized Residual	1.8	1.2	-0.8	-2.2
Mechanical				
Count	34_{a}	$42_{a, b}$	$32_{a, b}$	55_{b}
Standardized Residual	-1.7	0.2	0.0	1.5

Mechanical and Environmental engineering were the only two disciplines to show significant differences based on depth of participation. The standardized residuals give the direction of the significant association based on depth of participation. For Mechanical engineering, the proportion of students who participated in at least four high school engineering classes is significantly higher than those who participated in only one class. For Environmental engineering, the proportion of students who participated in one or two high school engineering classes is significantly higher than those who participated in four or more classes.

A statistically significant association was found between program of high school engineering class participation and engineering discipline, $\chi^2(22) = 46.09$, $p = .002$. The association strength fell between small and moderate (Cohen, 1988), Cramer's V = .199. The column proportion comparisons and standardized residuals were analyzed. The significant results for program of participation and discipline are given in Table 3.6.

Table 3.6 Significant Column Comparisons and Standardized Residuals for Discipline based on Program of Participation

Engineering Discipline	Program of Participation		
	Project Lead the Way	Stand-alone/School Specific	Other Programs
Civil			
Count	35_a	17_b	$10_{a,b}$
Standardized Residual	2.5	-2.3	0.2

Civil engineering was the only discipline to show significant differences based on program of participation at the $p < .05$ level. The standardized residuals give the direction of the significant association based on program of participation. The proportion of Civil engineering students who participated in PLTW is significantly higher than those who participated in stand-alone/school specific courses.

Persistence Attitudes – Research Questions 3 and 5

The overall persistence attitude scores for the surveyed data set are each calculated as a mean of different items measured on a one to five scale. The mean scores for the overall data set are given in Table 3.7. These scores are also given based on high school engineering class participation and gender.

Table 3.7 Persistence Attitude Overall Descriptive Statistics including Participation and Gender

Variable		Persistence Attitudes				
		Confidence in Persistence with Satisfaction	Confidence in Persistence	Confidence in Persistence - Discipline Specific	Confidence in Persistence - Discipline Specific with Satisfaction	Confidence in Persistence - Engineering Specific
Overall	Mean	4.59	4.70	4.60	4.41	4.72
	N	1612	1612	1612	1612	1612
	Std. Deviation	0.47	0.47	0.66	0.62	0.54
Class Participation						
Yes	Mean	4.58	4.69	4.57	4.39	4.73
	N	649	649	649	649	649
	Std. Deviation	0.49	0.49	0.69	0.65	0.53
No	Mean	4.60	4.71	4.62	4.43	4.72
	N	963	963	963	963	963
	Std. Deviation	0.46	0.45	0.63	0.60	0.54
Gender						
Male	Mean	4.60	4.71	4.61	4.42	4.73
	N	840	840	840	840	840
	Std. Deviation	0.48	0.47	0.66	0.62	0.54
	Mean	4.60	4.71	4.61	4.42	4.73
Female	N	722	722	722	722	722
	Std. Deviation	0.45	0.44	0.64	0.60	0.53
Total[a]	Mean	4.60	4.71	4.61	4.42	4.73
	N	1562	1562	1562	1562	1562
	Std. Deviation	0.46	0.46	0.65	0.61	0.53

[a] Responses of "Prefer not to Say" to the gender item were eliminated during analysis leaving a different sample sized than the overall.

The lowest mean persistence attitude score for the overall data set is for Confidence in Persistence - Discipline Specific including Satisfaction (*M* = 4.41, *SD* = 0.62). The overall Confidence in Persistence including Satisfaction with Current Major score (*M* = 4.59, *SD* = 0.47) includes all six measured persistence attitude items. Descriptive statistics were also gathered for persistence attitude scores based on ethnicity and student classification. These values are given in Table 3.8 and 3.9 respectfully.

Table 3.8 Persistence Attitude and Ethnicity Descriptive Statistics

Ethnicity		Persistence Attitudes				
		Confidence In Persistence with Satisfaction	Confidence In Persistence	Confidence In Persistence - Major Specific	Confidence In Persistence - Major Specific with Satisfaction	Confidence In Persistence - Engineering Specific
African/ Black American	Mean	4.48	4.61	4.52	4.30	4.65
	N	62	62	62	62	62
	Std. Deviation	0.42	0.44	0.60	0.53	0.50
Latin/ Hispanic American	Mean	4.58	4.68	4.57	4.40	4.71
	N	189	189	189	189	189
	Std. Deviation	0.53	0.53	0.80	0.70	0.59
White American	Mean	4.63	4.73	4.64	4.46	4.74
	N	1057	1057	1057	1057	1057
	Std. Deviation	0.44	0.43	0.60	0.57	0.53
Asian/ Pacific American	Mean	4.50	4.64	4.47	4.25	4.70
	N	206	206	206	206	206
	Std. Deviation	0.47	0.46	0.75	0.70	0.49
Total	Mean	4.60	4.71	4.60	4.42	4.73
	N	1514	1514	1514	1514	1514
	Std. Deviation	0.46	0.45	0.65	0.61	0.53

Table 3.9 Persistence Attitude and Classification Descriptive Statistics

Classification		Persistence Attitudes				
		Confidence In Persistence with Satisfaction	Confidence In Persistence	Confidence In Persistence - Major Specific	Confidence In Persistence - Major Specific with Satisfaction	Confidence In Persistence - Engineering Specific
First-year	Mean	4.44	4.51	4.20	4.16	4.64
	N	339	339	339	339	339
	Std. Deviation	0.53	0.52	0.77	0.71	0.56
Second-year	Mean	4.52	4.62	4.45	4.32	4.68
	N	392	392	392	392	392
	Std. Deviation	0.54	0.53	0.75	0.72	0.58
Third-year	Mean	4.69	4.83	4.75	4.51	4.86
	N	383	383	383	383	383
	Std. Deviation	0.37	0.36	0.51	0.51	0.36
Fourth-year	Mean	4.67	4.80	4.86	4.58	4.72
	N	356	356	356	356	356
	Std. Deviation	0.43	0.41	0.41	0.48	0.58
Fifth-year+	Mean	4.67	4.81	4.90	4.59	4.70
	N	142	142	142	142	142
	Std. Deviation	0.35	0.33	0.27	0.36	0.57
Total	Mean	4.59	4.70	4.60	4.41	4.72
	N	1612	1612	1612	1612	1612
	Std. Deviation	0.47	0.47	0.66	0.62	0.54

We can see that the lowest mean for each persistence attitude was seen in first year students. These first-year students' mean scores were all below the overall means but all still all above 4.0. In order to analyze the relationship between high school engineering class participation and persistence attitudes, Mann-Whitney tests were run for each of the persistence attitude scores with participation in high school engineering classes. The results are shown in Table 3.10.

Table 3.10 Mann-Whitney Test Results for Each Persistence Attitude based on Participation

Persistence Attitudes across Participation	Median				
	Yes	No	*U*	*z*	*p*
Confidence In Persistence with Satisfaction	4.83	4.83	3191212.00	0.75	0.454
Confidence In Persistence	5.00	5.00	319963.00	0.90	0.368
Confidence In Persistence - Major Specific	5.00	5.00	323571.50	1.41	0.158
Confidence In Persistence - Major Specific with Satisfaction	4.67	4.67	320072.50	0.85	0.394
Confidence In Persistence - Engineering Specific	5.00	5.00	313191.00	0.10	0.924

None of the persistence attitude Mann-Whitney tests resulted in a significant difference based on participation in high school engineering classes. The Mann-Whitney tests were repeated using student classification as subgroups. No significant results were found for any of the classification groups (first-year, second-year, third-year, fourth-year, and fifth-year+). The Mann-Whitney tests were also repeated using gender as subgroups. No significant results were found for either the male or female subgroup.

Although there was no significant result for persistence attitudes and participation in high school engineering classes. Deeper factors related to participation were still analyzed. Kruskal-Wallis tests were first used to compare persistence attitudes based on depth of engineering class participation. Results are shown in Table 3.11.

Table 3.11 Kruskal-Wallis Test Results for Each Persistence Attitude based on Depth of Participation

Persistence Attitudes across Depth of Participation	Median				*H(3)*	*p*
	1 Class	2 Classes	3 Classes	4 Classes		
Confidence In Persistence with Satisfaction	4.67	4.83	4.83	4.83	3.22	0.36
Confidence In Persistence	5.00	5.00	5.00	5.00	3.45	0.327
Confidence In Persistence - Discipline Specific	5.00	5.00	5.00	5.00	3.48	0.323
Confidence In Persistence - Discipline Specific with Satisfaction	4.67	4.67	4.67	4.67	3.57	0.312
Confidence In Persistence - Engineering Specific	5.00	5.00	5.00	5.00	4.36	0.255

None of the persistence attitudes showed significant differences based on depth of high school engineering class participation. Kruskal-Wallis tests were then performed on each persistence attitude based on program of engineering class participation. Results are shown in Table 3.12. None of the persistence attitudes showed significant differences based on program of high school engineering class participation.

Table 3.12 Kruskal-Wallis Test Results for Each Persistence Attitude based on Program of Participation

Persistence Attitudes across Program of Participation	Median			*H(2)*	*p*
	PLTW	School Specific	Other Programs		
Confidence In Persistence with Satisfaction	4.83	4.83	4.83	0.41	0.814
Confidence In Persistence	5.00	5.00	5.00	0.40	0.818
Confidence In Persistence - Discipline Specific	4.67	4.67	4.67	0.54	0.764
Confidence In Persistence - Discipline Specific with Satisfaction	5.00	5.00	5.00	0.59	0.745
Confidence In Persistence - Engineering Specific	5.00	5.00	5.00	0.16	0.922

Additional Analysis

Additional descriptive statistics and analyses were conducted to mitigate certain limitations and provide relationship data between additional variables. A chi-square test was performed to analyze the association between gender and high school engineering participation. A statistically significant association was found between gender and high school engineering class participation, $\chi^2(1) = 24.61$, $p < .001$. The association strength was small (Cohen, 1988), Cramer's V = .126. The column proportion comparisons and standardized residuals are given in Table 3.13.

Table 3.13 Column Comparisons and Standardized Residuals for Gender based on Engineering Class Participation

Gender		High School Engineering Class Participation	
		Yes	No
Male	Count	348_a	456_b
	Standardized Residual	2.6	-2.1
Female	Count	241_a	481_b
	Standardized Residual	-2.8	2.3

Note: Different subscripts indicate significantly different proportions between column variables for that gender.

The column proportions show that a larger proportion of males participated in high school engineering classes than did not participate while females had the opposite association. High school engineering class participation was also analyzed with ethnicity using chi-square analysis. No significant association was found between ethnicity and high school engineering class participation, $\chi^2(3) = .89$, $p = .831$.

Two of the four research questions in this study are based on program of high school class participation and depth of participation. A chi-square test was used to analyze the association between depth of engineering class participation and program of participation. A statistically significant association was found between depth of participation and program of participation, $\chi^2(6) = 74.70$, $p < .001$. The strength of association was between small and moderate (Cohen, 1988), Cramer's V = .240. The column proportion comparisons and standard residuals are given in Table 3.14.

Table 3.14 Column Comparisons and Standardized Residuals for Program of Participation based on Depth of Participation

Depth of Participation		Program of Participation		
		PLTW	Stand Alone Class	Other Programs
1 class	Count	33_a	118_b	$24_{a, b}$
	Standardized Residual	-3.8	3.6	-0.5
2 classes	Count	46_a	91_b	$29_{a, b}$
	Standardized Residual	-1.8	1.2	0.8
3 classes	Count	55_a	$55_{a, b}$	11_b
	Standardized Residual	1.7	-0.5	-1.7
4+ classes	Count	102_a	51_b	34_a
	Standardized Residual	4.1	-4.2	1.1

A higher proportion of students taking one or two classes participated in stand-alone/school specific courses rather than PLTW. A higher proportion of students taking three classes participated in PLTW than other recognized programs. Finally, a higher proportion of students participating in four or more classes participated in PLTW or other programs than in stand-alone/school specific course.

Students were asked if they had a family member in the same engineering discipline. The percentage of students without a family member in the same major was 87.2%. Mann-Whitney U tests were conducted to see if there was a difference in persistence attitudes based on having family in the same major. No significant differences were found. A chi-square test was used to test for association between having a family member in the same discipline and choosing that engineering discipline. A statistically significant association was found between family member in the same discipline and engineering discipline, $\chi^2(11) = 25.25$, $p = .008$. The strength of association was small (Cohen, 1988), Cramer's V = .133. The only two majors with significant differences in proportions based on family members were Electrical and Bioengineering. For Electrical, a significantly higher proportion of students had a family member in the same major. For Bioengineering, a significantly lower proportion of students had a family member in the same major.

When asked their reason for taking high school engineering courses, 78.9% of students said it was a personal choice. When looking for student past experiences, the data showed that 83.4% of students were in high school immediately prior to their current institution. Kruskal-Wallis tests were conducted to look for associations between reason for taking high school engineering classes and persistence attitudes and between student past experiences and persistence attitudes. No significant differences were seen in persistence attitudes based on these factors.

Students were also asked to give their cumulative grade point average (GPA) within one of four ranges (below 2.0, 2.0 - 2.9, 3.0 - 3.5, and 3.6 - 4.0). A chi-square test of independence was performed to analyze for association between high school engineering class participation and cumulative GPA. No statistically significant association was found between class participation and cumulative GPA, $\chi^2(4) = 9.00$, $p = .061$. Kruskal-Wallis tests were performed to analyze for significant differences in persistence attitudes based on cumulative GPA. The results for these tests are shown in Table 3.15.

Table 3.15 Kruskal-Wallis Test Results for Persistence Attitudes Across Cumulative GPA

Persistence Attitudes across GPA	Median				*H(4)*	*p*
	Below 2.0	2.0 - 2.9	3.0 - 3.5	3.6 - 4.0		
Confidence In Persistence with Satisfaction	4.33	4.67	4.83	4.83	62.29	< .001
Confidence In Persistence	4.40	4.80	5.00	5.00	59.95	< .001
Confidence In Persistence - Discipline Specific	4.00	4.00	5.00	5.00	41.17	< .001
Confidence In Persistence - Discipline Specific with Satisfaction	3.83	4.33	4.67	4.67	44.73	< .001
Confidence In Persistence - Engineering Specific	4.75	5.00	5.00	5.00	56.24	< .001

All of the Kruskal-Wallis tests returned significant results. Significant differences were found for each persistence attitude based on cumulative GPA. The medians show the direction of the relationship between persistence attitudes and GPA. As GPA increases the median persistence score also increases.

Students were also asked if they had participated in a co-op or internship during their time in engineering school. Mann-Whitney U tests were performed for the relationship between co-op or internship participation and each persistence attitude. These results are given in Table 3.16.

Table 3.16 Mann-Whitney Test Results for Persistence Attitudes Across Co-op/Internship Participation

	Mean				
Persistence Attitudes across Co-op/Internship Participation	Yes	No	*U*	*z*	*p*
Confidence In Persistence with Satisfaction	4.71	4.53	228207.50	-7.74	<.001
Confidence In Persistence	4.82	4.64	221201.00	-9.18	.000
Confidence In Persistence - Major Specific	4.81	4.48	213118.00	-10.84	.000
Confidence In Persistence - Major Specific with Satisfaction	4.58	4.32	223077.00	-8.40	.000
Confidence In Persistence - Engineering Specific	4.79	4.69	258745.00	-5.12	<.001

All of the Mann-Whitney tests returned significant results. Significant differences were found for each persistence attitude based on co-op/internship participation. The means show the direction of the relationship between persistence attitudes and co-op/internship. The mean persistence score increases with co-op/internship participation.

Discussion

Engineering Discipline

The first research question this study aimed to answer looked for an association between high school engineering class participation and engineering discipline. The results found a small to moderate association between these variables. One reason for the strength of the overall association could be that out of the 12 disciplines analyzed only seven showed a significant difference in proportions based on class participation. The analyzed majors are given in Table 3.17 with their expected yearly job openings for the next decade and the direction of the association that was found with class participation, if any.

Table 3.17 Yearly Job Openings for Each Discipline with Direction of Association with Participation (US Bureau of Labor Statistics, 2023)

Engineering Discipline	*N*	Expected Yearly Job Openings	Direction of Association[a]
Computer Science	81	50,900	+
Civil	149	24,200	n/a
Industrial	73	22,400	-
Electrical	155	20,100	+
Mechanical	351	17,900	+
Computer	93	5,300	n/a
Aerospace	96	3,800	+
Environmental	47	3,400	n/a
Chemical	194	2,000	-
Bioengineering	97	1,200	-
Biomedical	71	*	n/a
Nuclear	22	700	n/a

*Combined with Bioengineering.
[a]Direction based on answer of "yes" to Did you participate in high school engineering classes?

These twelve disciplines account for 151,900 yearly engineering job openings (US Bureau of Labor Statistics, 2023). Out of the four disciplines with a positive association, three are in the top five disciplines based on the largest expected yearly job openings. All four are in the top seven of the twelve disciplines based on expected job openings. These disciplines account for 61.03% of the total expected yearly engineering job openings represented by the disciplines in this study. This is good news for high school engineering classes positively influencing the total number of unfilled engineering jobs. These findings suggest that high school engineering courses are helping students explore and form task value beliefs about the majority of engineering disciplines in highest demand. The three disciplines with an association in the negative direction with engineering class participation made up only 15.67% of yearly engineering job openings, and Industrial engineering alone accounted for 14.75% of these openings. While high school engineering class curriculum does not have the capacity to teach every engineering major, these findings may suggest at least introducing Industrial engineering since a significant number of participating students are choosing other engineering disciplines that seem to be more central to the curriculum.

Our finding Mechanical, Electrical, Aerospace, and Computer Science positively associated with participation in high school engineering classes is consistent with the findings from a study that examined the most popular engineering majors for PLTW participants at Purdue University. The study conducted at Purdue found that Mechanical, Electrical and Computer, Civil, and Aerospace were the most popular majors among PLTW participants. Electrical and Computer engineering were combined, and Computer Science was not included in the Purdue study. The Purdue research team identified these majors as those most closely aligned with PLTW curriculum (Salzman, 2012). The Purdue study only included PLTW high school engineering courses, yet the only outlier between our findings and the Purdue study's most popular PLTW majors is the lack of association with Civil engineering. PLTW's engineering curriculum offers a course titled Civil Engineering and Architecture (PLTW, 2023). While it is impossible to know exactly what is being taught in stand-alone/school-specific courses, these courses may align with the commonalities between the other programs studied. These programs, along with the first classes in the PLTW engineering curriculum, teach about engineering and design thinking. The lack of a significant relationship between participation and Civil engineering leads us to believe that the other national programs and stand-alone classes studied do not include as heavy of an emphasis on Civil engineering.

A second research question studied the association between program of participation and depth of discipline with choice of engineering discipline. When researching these deeper factors related to participation, only the students who participated in high school engineering classes were considered. The large majority of existing research is focused on impacts from PLTW; however, PLTW did not make up the largest percentage of participants in our study. Out of the 649 participating students, 36.4% participated in PLTW while 48.5% participated in stand-alone/school specific classes. Other recognized programs made up the remaining 15.1%. These programs included Engineering by Design, EPICS High, Engineering4USA, ExCITE, and SkillsUSA. These findings support that PLTW is by far the most widely popular national high school engineering program, but it is not the only opportunity for engineering in high school.

A significant relationship was found between the depth of engineering participation and program of participation. Students who took one or two high school engineering courses were more likely to have participated in Stand-alone/School Specific courses than PLTW. Students who participated in four or more classes were more likely to have taken classes in PLTW or other nationally recognized programs than school specific courses. Over 66% of students participating in PLTW took three or more classes. Alternatively, over 66% of students participating in stand-alone/school specific curriculum took one or two classes. This suggests that recognized programs, especially PLTW, have developed deeper curriculums than school specific course curriculums. This deeper curriculum has the ability to devote entire classes to engineering discipline studies such as Civil Engineering and Architecture, Computer Science

Principles, and Digital Electronics. These are all courses in the PLTW engineering curriculum (PLTW, 2023).

Analyzing the association between engineering discipline and program of participation led to a moderately small association. The strength of association may be due to the fact that only one discipline had significant differences based on participation. Interestingly, this major was Civil engineering. A significantly higher number of students who participated in high school engineering classes and majored in Civil engineering had participated in PLTW. As discussed, Civil was the only discipline recognized in the previous Purdue study on PLTW that did not produce a significant relationship with participation in this study. PLTW offers a specific course on Civil engineering. PLTW also offers courses centered on electrical engineering and computer science topics, but these courses must also be covered in stand-alone/school specific courses (PLTW, 2023). Both of these other disciplines (Computer Science and Electrical) had significant association with high school engineering course participation overall. Civil engineering on the other hand has a significant association specifically with PLTW participation.

Depth of participation, or number of high school engineering classes taken, had a small association with engineering discipline. The only two majors to show significant differences in proportions based on depth of participation were Mechanical and Environmental. Mechanical engineering students who had participated in high school engineering classes were more likely to have taken four classes than one class. This could be due to those students' commitment to majoring in engineering or due to the mechanical engineering topics in the curriculum. As discussed above, deeper participation is also associated with PLTW participation. When evaluating the PLTW engineering curriculum, the majority of the units in the first three engineering courses are centered in Mechanical engineering topics. These topics include statics, kinematics, force, motion, fluid flow, mechanisms, materials, structure, and mechanical systems. Each of the three courses contains a minimum of one unit that is entirely Mechanical concepts. Participating Environmental engineering students were more likely to have taken one or two classes than four classes. However, these Environmental engineering students accounted for only 18 of the participating students while Mechanical students accounted for 163.

A potential modifier specific to engineering and discipline selection is having family members that majored in a specific engineering discipline. A student who grew up doing science fair projects on structural support because their father was a civil engineer may have been more likely to choose civil engineering for reasons that have nothing to do with their high school engineering classes. However, the large majority of students surveyed, 87.2% did not have a family member in the same discipline. The only potential modifying relationship found between having family in the same major and engineering discipline was for Electrical engineering. A higher proportion of Electrical engineering students had an immediate family member also in Electrical engineering. The small percentage of students affected by familial engineering major and lack of relationship with most of the engineering majors leads us not to be concerned with the overall modifying effects of having a family member in the same discipline.

The choice of engineering major contributes to students' expectancy value. This choice sets the specific motivated goal/action that students are working toward. They have formed task beliefs about the discipline that have led them to deciding it is worth pursuing. This goal becomes the basis of students' persistence and self-efficacy. Students are not simply working toward an engineering degree. They are working toward a Mechanical engineering degree, or an Electrical engineering degree, or a Chemical engineering degree, etc. This engineering discipline becomes the goal that students have task and competence beliefs about.

Persistence Attitudes

There are two research questions related to engineering persistence attitudes. The first asks for the relationship between high school engineering class participation and persistence attitudes. The second asks for the effects of depth of class participation and program of participation on persistence attitudes. No significant relationship was found between participation and any of the persistence attitudes. This includes overall, engineering, and discipline specific persistence attitudes. The same held true when looking at depth of student participation in high school engineering classes and program of participation. The lack of relationship between participation and persistence attitudes and depth of participation and persistence attitudes is in line with the findings of previous research related to PLTW participation and engineering degree persistence (Utley et al., 2019; Cole, Highland, and Weinland, 2013). Utley did find that students who participated in PLTW were retained at a higher level from first to second year than those who did not participate (2019). The data for our study was analyzed using classification as subgroups and no significant relationship was found at any level for class participation and persistence attitudes.

The lack of relationship may be explained by the high persistence attitude scores for the overall data set. The lowest mean in any category was 4.41 out of 5.00. These high persistence attitude scores give hope for closing the retention gap but could be indicative of the type of students who respond to voluntary engineering surveys. The two lowest persistence attitudes included satisfaction with current discipline in the scoring. When looking at frequencies for each of the commitment to persist items, the "satisfaction with current discipline" responses indicated 19.2% of students were neutral or lower. The other items all had less than 6% of students falling in these categories. This suggests that while students are confident in their ability to persist in their engineering major, they may not be satisfied with their major. Relating these findings to our theoretical framework of Expectancy-Value Model, we see that student scores are higher in confidence belief categories than the satisfaction or task beliefs. Further research into the specific effect of high school engineering classes and engineering satisfaction could provide more insight into the task beliefs necessary for engineering persistence.

Additional collected data was analyzed for its significance related to engineering persistence. Students were asked to give their reason for participating in high school engineering classes. The large majority, 78.9%, of students participated by their own choice. Students' past life experiences were also accounted for. Over 83% of students were in high school just before starting in their current institutions. This leaves less than 17% to be potentially impacted by previous jobs, military training, or additional degrees. Both reason for participation and past experience were analyzed and showed no association with persistence attitudes.

Cumulative grade point average and co-op/internship participation were both found to be positively associated with all of the engineering persistence attitudes. Students with a higher GPA are more satisfied with and confident in their persistence abilities. The cumulative GPA of the overall data set was high with 83% of students reporting a GPA of 3.0 or above (48.9% with 3.6 or above). Students who participated in a co-op or internship had higher persistence attitudes than students who did not. Students who participated in a co-op or internship accounted for 35.1% of the students. These personal accomplishments are helping students to form confidence value beliefs. By performing well in classes, students' confidence in their abilities is strengthened. When students co-op or intern, they participate in real world engineering design and problem solving. We see from the significant relationship with persistence attitudes that these engineering experiences help improve students' confidence beliefs and also their task beliefs about the engineering job they are studying to obtain.

Limitations

This study relied on self-report data and voluntary participation. No data was gathered on engineering experiences or knowledge attained outside of engineering class participation. Students' STEM extracurriculars and hobbies remained extraneous. It was also impossible to separate whether students participated in high school engineering courses due to existing plans to pursue engineering or participated prior to major selection. There was no way to account for the standard of course implementation and teaching experienced by each student which could have an influence. While analysis used students' current engineering majors, there was no way to know if this was the major students started in immediately following high school.

A large number of the current engineering students were in either high school or early college during the COVID-19 pandemic. The lack of face-to-face instruction at the college level could have created either easier or more difficult learning environments for students. The possible impact of those semesters was not taken into account. At the high school level, students may have been unable to get true engineering class experience. The hope is that these impacts were only felt for one or two semesters and had negligible impact on the factors being studied, but this limitation should be taken into consideration.

Future Work

Outside factors influencing persistence such as financial hardship, family responsibilities, and illness were not accounted for in this research. A large-scale, nationwide study like this one that looks into retention through graduation and takes into account students' reasons for leaving engineering could help better understand the gap in what appears to be a student base with high persistence attitudes but a retention rate that does not reflect those attitudes.

Additionally, surveying high school students from multiple states, participating in different high school engineering programs with differing depths of participation would provide more concrete evidence to the true effects of the high school engineering classes. Pre- and post-participation surveys would account for students specific discipline choices before and after participation in the courses.

Conclusion

This study relied on survey responses from current engineering undergraduates from across the country. The responses included students' high school engineering class participation, current engineering major, and items related to their commitment to persist in engineering and their current engineering major. The commitment to persist items were grouped into five persistence attitudes and scored. Chi-square analysis was performed to test for association between high school engineering class participation and engineering discipline selection. Mann-Whitney tests were run to test for significance between high school engineering class participation and each persistence attitude.

We did find a significant association between a student's choice in engineering discipline and their participation in high school engineering courses. Participation in these classes was found to positively associate with disciplines that make up over 60% of the yearly engineering jobs represented in this study. These findings show that high school engineering courses are helping students to form task value beliefs that help make up their engineering expectancy value. These task beliefs lead to more students choosing highly sought engineering disciplines which can help with the recruitment side of closing the engineering gap.

Alternatively, student persistence attitudes did not show significant associations with high school engineering courses. Overall, the surveyed sample showed high persistence attitude scores with the lowest scores coming from satisfaction with their major. When analyzing additional factors, we found that GPA and co-op/internship participation had a significant positive association with persistence attitudes. This leads us to believe that universities should focus on encouraging co-op and internship experiences and perhaps start introducing project-based-learning elements early in the curriculum to help students receive confidence belief forming engineering experiences.

CHAPTER IV

STUDY 3: HIGH SCHOOL ENGINEERING CLASS PARTICIPATION'S INFLUENCE ON ENGINEERING SELF-EFFICACY

We have all heard the phrases, "confidence is key" and "believe in yourself". These sayings have become popular for a reason. Belief in one's own ability is a known factor in attempting and achieving goals. This is true for a variety of topics from sports to academics (Nicholson et al., 2013; Elms et al., 2022). Research shows that when athletes are confident in their team, they try harder, push themselves further, are more persistent, and display better performance (Fransen et al., 2017). These are all qualities that we want in engineering students.

In the case of engineering studies, success means persisting in school and entering a career as an engineer. We have discussed the importance of recruitment and retention of engineering students in the previous chapters. Students moving through the "pipeline" to an engineering career will be faced with challenges and adversity. No one claims that engineering school is easy. Persisting on the hard days when the test grade was not ideal, or the problem seems too complex is integral to engineering success both in education and career. In order to triumph through the difficult parts of engineering school, students must believe in their own abilities and believe that the end goal is worth the hard work. They must have a strong engineering self-efficacy.

Literature Review

This literature review explores the theoretical framework of self-efficacy which guided this study. The independent variables for this study were high school engineering participation, depth of participation, and program of participation. Literature surrounding these variables was discussed in Chapter 3. The dependent variable for this study was engineering self-efficacy. Existing literature on engineering self-efficacy and high school engineering is discussed below.

Engineering Self-Efficacy

Self-efficacy as a concept was first proposed by Bandura in 1977 and stems from social cognitive theory. Self-efficacy is a person's belief that he or she has the ability to successfully complete the actions necessary to produce a desired outcome. Self-efficacy can have an impact on both choice of activities and success in those endeavors. Expectations from one's self-efficacy can impact the amount of effort and the length of persistence in a chosen activity. In academic research, self-efficacy is usually associated with academic motivation. Efficacy beliefs are formed through four informational sources. These sources are personal performance and achievements, comparing one's performance to the performance of others (vicarious experience), encouragement or discouragement from others, and physiological states and reactions (emotional arousal). These sources can be seen in Figure 4.1 (Bandura, 1977).

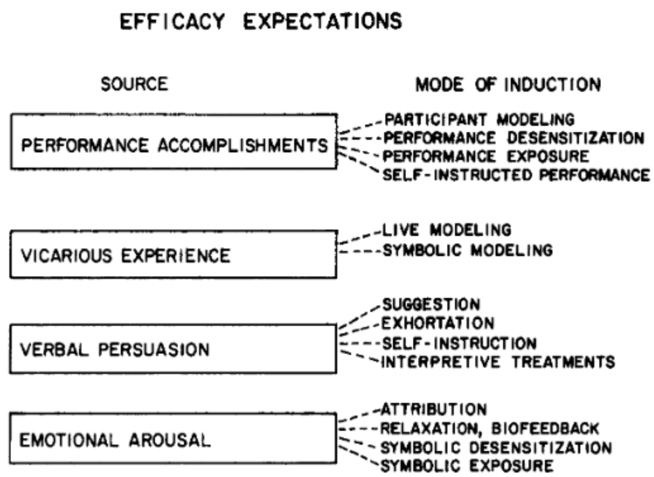

Figure 4.1 Sources of Efficacy Information and Modes of Inducing Treatment by Bandura (1977)

The consequences of self-efficacy beliefs are approach or avoidance, performance, and persistence. Self-efficacy formation can be a self-fulfilling prophecy. High self-efficacy can lead to better performance which leads to positive recognition and comparison of one's performance to the performance of others (Fantz et al., 2011). One's own previous accomplishments are especially effective at influencing self-efficacy (Bandura, 1977). High school engineering participation has the potential to contribute to several of the sources seen above.

Self-Efficacy Studies

Bandura found that academic self-efficacy can determine a student's goals, motivation, and performance. Research has shown that academic self-efficacy has a positive relationship with persistence and grades (Starobin et al., 2014). This relationship has also been found to hold true with respect to engineering self-efficacy. Engineering self-efficacy has been found to relate to students' career selection and engineering persistence (Fantz et al., 2011; Cole et al., 2013). Engineering self-efficacy relates to students' abilities to navigate challenges in their engineering studies and their beliefs in their ability to complete the curriculum. (Concannon and Barrow, 2012).

High school engineering classes and engineering knowledge have been studied in relation to engineering self-efficacy. In *Pre-collegiate Factors Influencing the Self-Efficacy of Engineering Students*, researchers analyzed the relationship between pre-collegiate engineering experiences and self-efficacy in first-year college engineering students. The findings of this self-efficacy study showed that students who participated in semester long engineering and technology classes in high school or middle school had significantly higher self-efficacy scores than students who had not participated in engineering classes (Fantz et al., 2011). Another study conducted on implementation of an engineering curriculum by thirty-six high school teachers found that students' self-efficacy for engineering increased after completing the curriculum (Hirsch et al., 2005). Conversely, Starobin and colleagues compared the self-efficacy of community college students who had participated in PLTW with students who had not participated in PLTW. The data showed that PLTW students had a significantly lower self-efficacy rating than non-PLTW students. One possible explanation given by the researchers is that the PLTW students were suffering from comparing themselves to high-ability peers (Starobin et al., 2014).

In summary, it was evident from research that self-efficacy is key to student success. What was unclear was the role that high school engineering played in student self-efficacy. Mixed results existed in the previous literature surrounding these variables. The existing studies were small, pertaining to one program or class and with participants from one institution or set of high schools. No factors other than participating or not participating had been included in the studies.

Present Study

This study surveyed a large population of undergraduate engineering students, from engineering schools across the country, on their engineering self-efficacy. All high school engineering classes, both stand-alone and part of nationally recognized programs, were included. Participation, depth of participation, and program of participation were analyzed to better understand the effects of high school engineering participation on students' engineering self-efficacy. Since self-efficacy plays such an important role in achievement and persistence, it is important to understand how high school engineering fits into this concept.

Research Questions

This study addressed gaps in the literature by answering the following research questions:

> **RQ6:** Is there a correlation between high school engineering class participation and engineering self-efficacy?
>
> **RQ7:** Does the depth of high school engineering participation or program of participation impact engineering self-efficacy?

Though there is some mismatch in results the majority of studies showed a positive relationship between pre-college engineering courses and self-efficacy. Extending that idea, it makes sense that an increase in knowledge and experience with a subject would improve confidence beliefs. We hypothesized that high school engineering participation would have a significant positive impact on engineering self-efficacy. However, no hypothesis was formed for question 7.

Methods

Design

Quantitative research methods were used to analyze gathered survey data for both research questions.

Definitions. *Depth of participation* was defined as the number of semester-long engineering classes a student completes during high school. A yearlong course was considered two classes. *Engineering program* referred to a nationally recognized engineering program that the classes are a part of such as Project Lead the Way, Engineering by Design, EPICS, etc.

Data Source

An online survey link was sent via email to over 700 engineering deans and department heads across the country for distribution to all engineering undergraduate students. The survey was to remain open until at least 300 student responses are received with usable data. A 90% confidence level, standard deviation of 0.5, and 5% error were used to calculate a necessary sample size of 270. The desired number of responses was increased to ensure an appropriate sample is attained. The study received a usable sample size of 1612 responses.

Participants

The survey was distributed to 100+ higher education engineering programs for distribution to their engineering students. Undergraduate engineering students across all engineering disciplines were targeted. This provided a large population of engineering students. The higher education institutions included public universities, private colleges, and HBCUs. The goal was for all regions of the United States to be represented. Responses were received from 1612 participants from 37 states. There were 840 (52.1%) male respondents and 722 (44.8%)

female respondents while 45 respondents preferred not to give their gender. Minority participation (African/Black American, American Indian/Alaskan Native, and Latino/Hispanic) made up 19.48% of the respondents. Other represented ethnicities included Asian and Pacific American with 14.02% of responses and White American representing 65.57% of participants. Some participants selected “Other” or chose not to select an ethnicity. The classification breakdown of respondents was 339 (21%) first-year, 392 (24.3%) second-year, 383 (23.8%) third-year, 356 (22.1%) fourth-year, and 142 (8.8%) fifth-year or above.

Instrument

The Assessing Women and Men in Engineering (AWE) Longitudinal Assessment of Engineering Self-Efficacy Survey was utilized. Background questions were added to the survey to ascertain students’ participation in engineering classes in high school. No additions impacted the self-efficacy scales.

The survey included background items for students’ engineering major, year in school, and demographic information. Background items were added to ask students about their participation in high school engineering classes, program affiliation of the classes (e.g., PLTW), and their depth of participation (number of classes taken) along with other background information. All background items are multiple choice. The updated instrument is included in Appendix B.

This study focused on the students’ engineering self-efficacy as the dependent variable. The self-efficacy items were 7-point Likert items with an additional “don’t know” option. These 24 items make up four self-efficacy subscales. The instrument was validated via testing with both male and female students (AWE, 2007). External expert review was utilized to verify content validity (Marra et al., 2009). The reliability data for the subscales is given in Table 4.1. Alpha values of 0.7 to 0.9 are considered acceptable reliability (AWE, 2007).

Table 4.1 LAESE Self-Efficacy Subscales and Reliability Data (AWE, 2007)

Subscale	Items	Cronbach's Alpha
Engineering career success expectations	Someone like me can succeed in an engineering career A degree in engineering will allow me to obtain a well paying job I expect to be treated fairly on the job. A degree in engineering will give me the kind of lifestyle I want I expect to feel “part of the group” on my job if I enter engineering A degree in engineering will allow me to get a job where I can use my talents and creativity A degree in engineering will allow me to obtain a job that I like	0.84
Engineering self-efficacy I	I can succeed in an engineering curriculum I can succeed in an engineering curriculum while not having to give up participation in my outside interests I will succeed (earn an A or B) in my physics courses I will succeed (earn an A or B) in my math courses I will succeed (earn an A or B) in my engineering courses	0.82
Engineering self-efficacy II	I can complete the math requirements for most engineering majors I can excel in an engineering major during the current academic year I can complete any engineering degree at this institution I can complete the physics requirements for most engineering majors I can persist in an engineering major during the next year I can complete the chemistry requirements for most engineering majors	0.82

Table 4.1 (continued)

Subscale	Items	Cronbach's Alpha
Coping self-efficacy	I can cope with not doing well on a test	0.78
	I can make friends with people from different backgrounds and/or values	
	I can cope with friends' disapproval of chosen major	
	I can cope with being the only person of my race/ethnicity in my class	
	I can approach a faculty or staff member to get assistance	
	I can adjust to a new campus environment	

Independent Variables

High school engineering class participation was coded at two levels: 1 (participated), 2 (did not participate). *Depth of participation* was coded at four levels: 1 (one class), 2 (two classes), 3 (3 classes), and 4 (4+ classes). *Engineering program* was coded for each program: 1 (PLTW), 2 (Engineering by Design), 3 (Engineering4USA), 4 (EPICS High), 5 (ExCITE), 6 (Stand-alone program/classes), and 7 (Other). An additional code was added for SkillsUSA (8) due to the number of responses in the Other category.

Dependent Variable

Engineering self-efficacy was analyzed as a mean value for the twenty-four 7-point Likert items. A mean value was found and analyzed for each subscale: Engineering Career Success Expectations, Engineering Self-Efficacy I, Engineering Self-Efficacy 2, and Coping Self-Efficacy.

Procedure

Once the study received approval from the Institutional Review Board (IRB), the web-based survey was generated using Qualtrics online platform (Qualtrics, Provo, UT). As stated, participants were sought from the nation's engineering schools via email. The email contained a link to the Qualtrics survey along with:

- Survey instructions and estimated completion time
- A description of the data being gathered
- IRB information
- Confidentiality and anonymity assurance

The survey remained open for two weeks. When the survey closed, 1820 responses were collected. Unfinished surveys were removed to reach a usable sample size of 1612 records.

Analysis

This study utilized Statistical Package for Social Sciences (SPSS) software version 28.0 (IBM Corp., Armonk, NY). Different statistical tests were used for the different research questions in this study.

RQ6: Is there correlation between high school engineering class participation and engineering self-efficacy?

Pearson correlation was performed to analyze the relationship between high school engineering class participation and engineering self-efficacy. The data was transformed to meet required assumptions for use of Pearson correlation. These correlations were performed with overall engineering self-efficacy and each of the self-efficacy subscales as the dependent variable. The self-efficacy scales are Engineering Career Success Expectations, Engineering Self-Efficacy I, Engineering Self-Efficacy II, and Coping Self-Efficacy. Since these subscales are true Likert scales rather than just Likert items and were measured on a 7-point scale, we treat the means as continuous (Grace-Martin, 2023). These Pearson correlations were repeated with the data grouped by classification.

RQ7: Does the depth of high school engineering participation or program of participation impact engineering self-efficacy?

Kruskal-Wallis tests were utilized to test the association between depth of high school engineering participation and engineering self-efficacy and program of high school engineering participation and engineering self-efficacy. The sample size for these tests included only the students who participated in high school engineering classes (N = 649). The test was first performed with depth of participation as the independent variable and each of the self-efficacy scales as the dependent variable. These tests were run again using program of participation as the independent variable. In order to meet necessary assumptions of the Kruskal and Wallis test, Program of Participation was combined into only three groups (PLTW, Stand-alone program/classes, and Other programs).

Results

This research is based in high school engineering course participation. The percentage of respondents who participated in high school engineering classes was 40.3% while 59.7% did not participate in high school engineering classes. The participating 40.3% accounted for 649 participants. Of these 649 participating students 27% took one class, 25.6% took 2 classes, 18.6% took three classes, and 28.8% took four or more classes. When looking at the program students participated in, 36.2% participated in Project Lead the Way, 47.8% participated in Stand-alone/School Specific classes, and 16% participated in Other Programs.

The student responses to the twenty-four self-efficacy items were used to calculate each student's self-efficacy scores for each subscale as well as their overall engineering self-efficacy. The average overall engineering self-efficacy score for the sample was 5.66 out of 7. The descriptive statistics for the population based on mean self-efficacy scores are given in the following tables. Table 4.2 gives the mean self-efficacy scores for the overall sample, for participation status, and for each gender.

Table 4.2 Engineering Self-Efficacy Overall Descriptive Statistics including Participation and Gender

Variable		Self-Efficacy Scales				
		Overall Engineering Self-Efficacy	Engineering Success Career Expectations	Engineering Self-Efficacy I	Engineering Self-Efficacy II	Coping Self-Efficacy
Overall	Mean	5.68	5.72	5.45	5.89	5.69
	N	1612	1612	1612	1612	1612
	Std. Deviation	0.70	0.85	1.10	0.86	0.85
Class Participation						
Yes	Mean	5.66	5.76	5.46	5.85	5.68
	N	649	649	649	649	649
	Std. Deviation	0.76	0.85	1.15	0.93	0.89
No	Mean	5.66	5.69	5.44	5.91	5.71
	N	963	963	963	963	963
	Std. Deviation	0.66	0.86	1.06	0.81	0.83
Gender						
Male	Mean	5.73	5.83	5.54	5.94	5.80
	N	840	840	840	840	840
	Std. Deviation	0.69	0.82	1.09	0.84	0.83
Female	Mean	5.59	5.63	5.35	5.83	5.59
	N	722	722	722	722	722
	Std. Deviation	0.70	0.85	1.10	0.86	0.84
Total[a]	Mean	5.67	5.74	5.45	5.89	5.70
	N	1562	1562	1562	1562	1562
	Std. Deviation	0.70	0.84	1.10	0.85	0.84

[a] Responses of "Prefer not to Say" to the gender item were eliminated during analysis leaving a different sample sized than the overall.

The highest average scores are in Engineering Self-Efficacy II while the lowest are in Engineering Self-Efficacy I. The table shows that the mean self-efficacy scores for females are lower than males in all categories. The average self-efficacy scores for each ethnicity were also calculated. These values are given in Table 4.3.

Table 4.3 Engineering Self-Efficacy and Ethnicity Descriptive Statistics

Ethnicity		Self-Efficacy Scales				
		Overall Engineering Self-Efficacy	Engineering Career Success Expectations	Engineering Self-Efficacy I	Engineering Self-Efficacy II	Coping Self-Efficacy
African/Black American	Mean	5.65	5.67	5.31	5.86	5.77
	N	62	62	62	62	62
	Std. Deviation	0.69	0.86	1.11	0.75	0.78
Latin/Hispanic American	Mean	5.61	5.75	5.28	5.87	5.61
	N	189	189	189	189	189
	Std. Deviation	0.73	0.89	1.13	0.83	0.92
White American	Mean	5.72	5.78	5.51	5.95	5.78
	N	1057	1057	1057	1057	1057
	Std. Deviation	0.65	0.81	1.07	0.82	0.77
Asian/Pacific American	Mean	5.42	5.47	5.29	5.58	5.39
	N	206	206	206	206	206
	Std. Deviation	0.82	0.88	1.15	1.02	1.06
Total[a]	Mean	5.66	5.73	5.44	5.89	5.70
	N	1514	1514	1514	1514	1514
	Std. Deviation	0.70	0.84	1.09	0.86	0.85

[a] Responses of "Other" were eliminated for analysis. Responses of American Indian/Alaskan Native were also eliminated due to the low count and analysis requirements.

White Americans have the highest average self-efficacy scores across all five categories (overall and each subscale). The average self-efficacy scores for each classification were also calculated. These values are given in Table 4.4.

Table 4.4 Engineering Self-Efficacy and Classification Descriptive Statistics

Classification		Self-Efficacy Scales				
		Overall Engineering Self-Efficacy	Engineering Career Success Expectations	Engineering Self-Efficacy I	Engineering Self-Efficacy II	Coping Self-Efficacy
First-year	Mean	5.77	5.87	5.55	5.91	5.75
	N	339	339	339	339	339
	Std. Deviation	0.65	0.75	1.01	0.85	0.82
Second-year	Mean	5.62	5.68	5.44	5.83	5.62
	N	392	392	392	392	392
	Std. Deviation	0.69	0.84	1.16	0.86	0.83
Third-year	Mean	5.63	5.73	5.35	5.89	5.67
	N	383	383	383	383	383
	Std. Deviation	0.67	0.80	1.08	0.86	0.82
Fourth-year	Mean	5.66	5.66	5.56	5.95	5.73
	N	356	356	356	356	356
	Std. Deviation	0.78	0.95	1.09	0.89	0.93
Fifth-year+	Mean	5.55	5.60	5.22	5.82	5.72
	N	142	142	142	142	142
	Std. Deviation	0.73	0.97	1.18	0.81	0.86

First-year students had the highest average overall engineering self-efficacy scores while fifth+ and then second-year students had the lowest. In order to establish the correlation between high school engineering class participation and engineering self-efficacy, participation was tested against each of the self-efficacy scales using Pearson correlation. Table 4.5 gives the results for each engineering self-efficacy variable.

Table 4.5 Pearson Correlation Results for Participation with each Self-Efficacy Scale

Variable	Self-Efficacy Scales				
	Overall Engineering Self-Efficacy	Engineering Career Success Expectations	Engineering Self-Efficacy I	Engineering Self-Efficacy II	Coping Self-Efficacy
High School Engineering Class Participation	0.014	0.042*	0.019	-0.028	-0.01

*$p < .05$

As seen in Table 4.5, engineering class participation only provided a significant correlation with one self-efficacy subscale. There was a statistically significant, small positive correlation between high school engineering class participation and Engineering Career Success Expectations, $r(1610) = .042$, $p = .047$. High school engineering class participation was not significantly correlated with Overall Engineering Self-Efficacy or any of the other self-efficacy subscales. These Pearson Correlations were repeated with data grouped by classification. The significant results are given in Table 4.6.

Table 4.6 Significant Pearson Correlation Results for Participation with each Self-Efficacy Scale by Classification Subgroup

Classification	Self-Efficacy Scales				
	Overall Engineering Self-Efficacy	Engineering Career Success Expectations	Engineering Self-Efficacy I	Engineering Self-Efficacy II	Coping Self-Efficacy
Third-year	.104*	.161**			

*$p < .05$, **$p < .01$

The only classification with significant results for the correlation between high school engineering class participation and self-efficacy scales was third year. There was a statistically significant, small positive correlation between third-year students who participated in high school engineering classes and Overall Engineering Self-Efficacy, $r(647) = .104$, $p = .041$. There was also a statistically significant, small positive correlation between third-year students who participated in high school engineering classes and Engineering Career Success Expectations, $r(647) = .161$, $p = .002$. No other classifications had significant results.

The surveyed sample was next analyzed to look for associations between additional factors of participation and engineering self-efficacy. These additional factors include depth of participation and program of participation. The Kruskal-Wallis tests performed to look for association between depth of high school engineering class participation and the engineering self-efficacy scales returned no significant results. Table 4.7 gives the results of the Kruskal-Wallis tests.

Table 4.7 Kruskal-Wallis Test Results for Depth of Participation and Engineering-Self Efficacy Scales

Engineering Self-Efficacy Scales across Depth of Participation	Mean					
	1 class	2 classes	3 classes	4+ classes	*H(3)*	*p*
Overall Engineering Self-Efficacy	5.57	5.59	5.74	5.75	5.74	0.125
Engineering Career Success Expectations	5.70	5.69	5.81	5.76	3.79	0.285
Engineering Self-Efficacy I	5.29	5.43	5.59	5.56	4.72	0.193
Engineering Self-Efficacy II	5.75	5.78	5.95	5.93	5.65	0.13
Coping Self-Efficacy	5.60	5.55	5.76	5.81	4.71	0.195

Similarly, the Kruskal-Wallis tests performed to look for association between program of high school engineering class participation and the engineering self-efficacy scales returned no significant results. These results are given in Table 4.8.

Table 4.8 Kruskal-Wallis Test Results for Program of Participation and Engineering-Self Efficacy Scales

Engineering Self-Efficacy Scales across Program of Participation	Mean			*H(2)*	*P*
	PLTW	Stand-alone Classes	Other Programs		
Overall Engineering Self-Efficacy	5.69	5.61	5.66	1.32	0.516
Engineering Career Success Expectations	5.79	5.70	5.71	1.38	0.503
Engineering Self-Efficacy I	5.51	5.43	5.44	0.88	0.644
Engineering Self-Efficacy II	5.91	5.77	5.92	3.81	0.149
Coping Self-Efficacy	5.65	5.66	5.72	0.72	0.698

The primary focus of this study was engineering self-efficacy. The engineering self-efficacy scales measured by our sample were further analyzed to look for associations with student classification. The self-efficacy scales were analyzed for association with student classification. Kruskal-Wallis tests were performed with each engineering self-efficacy scale as the dependent variable. Table 4.9 contains the results of each Kruskal-Wallis test.

Table 4.9 Kruskal-Wallis Test Results for Classification and Engineering-Self Efficacy Scales

Engineering Self-Efficacy Scales across Classification	Mean					*H(4)*	*p*
	First-year	Second-year	Third-year	Fourth-year	Fifth-year+		
Overall Engineering Self-Efficacy	5.79	5.62	5.63	5.67	5.54	17.49	0.002
Engineering Career Success Expectations	5.88	5.68	5.73	5.70	5.60	13.15	0.011
Engineering Self-Efficacy I	5.57	5.46	5.37	5.60	5.27	16.71	0.022
Engineering Self-Efficacy II	5.92	5.83	5.90	5.97	5.82	8.21	0.084
Coping Self-Efficacy	5.78	5.63	5.67	5.77	5.72	9.05	0.06

The Kruskal-Wallis tests found significant associations between classification and Overall Engineering Self-Efficacy, Engineering Career Success Expectations, and Engineering Self-Efficacy I. Further analysis of the means shows Overall Engineering Self-Efficacy is highest for first-year students (M = 5.79). Engineering Career Expectation mean scores are highest for first year students and decrease for each following classification year. First-year students also have the highest Engineering Self-Efficacy I average scores followed by fourth year students. Kruskal-Wallis tests were also used to analyze GPA and the engineering self-efficacy scales. The results are shown in Table 4.10.

Table 4.10 Kruskal-Wallis Test Results for GPA and Engineering-Self Efficacy Scales

Engineering Self-Efficacy Scales across GPA	Mean					
	Below 2.0	2.0 - 2.9	3.0 - 3.5	3.6 - 4.0	*H(4)*	*P*
Overall Engineering Self-Efficacy	5.50	5.37	5.55	5.83	102.53	0.000
Engineering Career Success Expectations	5.92	5.61	5.70	5.77	8.14	0.087
Engineering Self-Efficacy I	4.67	4.61	5.18	5.91	310.93	0.000
Engineering Self-Efficacy II	5.56	5.53	5.74	6.10	112.84	0.000
Coping Self-Efficacy	5.54	5.73	5.73	5.67	3.94	0.414

Significant differences were found based on GPA for three of the scales, Overall Engineering Self-Efficacy, Engineering Self-Efficacy I, and Engineering Self-Efficacy II. The highest average score for each scale corresponded with the highest grade point averages. Mann-Whitney U tests were performed for the association between co-op/internship participation and engineering self-efficacy scales. Table 4.11 gives the results of the Mann-Whitney tests.

Table 4.11 Mann-Whitney Test Results for Co-op/Internship Participation and Engineering-Self Efficacy Scales

Engineering Self-Efficacy Scales across Co-op/Internship Participation	Mean			
	Yes	No	*U*	*p*
Overall Engineering Self-Efficacy	5.69	5.64	280574.50	0.088
Engineering Career Success Expectations	5.78	5.69	277434.50	0.04
Engineering Self-Efficacy I	5.54	5.40	271102.00	0.006
Engineering Self-Efficacy II	5.96	5.85	271384.50	0.006
Coping Self-Efficacy	5.71	5.68	288178.00	0.396

Students who participated in co-ops or internships scored higher on average in all of the self-efficacy scales. Significant differences between students who did and did not participate in co-ops or internships were found for Engineering Career Success Expectations, Engineering Self-Efficacy I, and Engineering Self-Efficacy II.

Discussion

The average Overall Engineering Self-Efficacy score for the surveyed sample was 5.68 out of the maximum of 7. The mean scores for the four self-efficacy subscales fell between 5.45 and 5.89 for the overall sample. These values indicate a positive engineering self-efficacy for the surveyed sample across all subscales. This positive self-efficacy gives us reason to hope that the majority of the surveyed students will persist through their engineering degree programs and enter the engineering work force (Starobin et al., 2014, Fantz et al., 2011; Cole et al., 2013).

Breaking down the surveyed population we see that males have higher average self-efficacy scores than females across all five of the measured engineering self-efficacy scales. A large body of existing literature supports the finding of males having higher engineering and career-related self-efficacy than females (Concannon and Barrow, 2012; Vogt et al., 2007; Jones et al., 2010; Voyer and Voyer, 2014, Henderson et al., 2022). When investigating the mean engineering self-efficacy scores for the sample based on ethnicity, White Americans have the highest mean self-efficacy scores across all of the measured scales. White Americans also make up 65.57% of the surveyed engineering undergraduates. This percentage of participants supports the lack of minority representation in engineering identified by previous research (Wilson, 2000; Chubin, May, and Babco, 2005; Marra et al., 2009)

The first research question of this study asked about the correlation between high school engineering class participation and engineering self-efficacy. Existing literature has shown positive associations between pre-college engineering classes and higher self-efficacy (Fantz et al., 2011; Hirsch et al., 2005) The current research used Pearson correlations to analyze the sample to attempt to answer this research question for each of the engineering self-efficacy mean scales. The only engineering self-efficacy scale with a significant correlation to high school engineering class performance was Engineering Career Success Expectations. High school engineering class participation had a small, positive correlation with this subscale. The remaining measured self-efficacy scales did not have a significant correlation with high school engineering class participation. Additionally, no significant differences in mean self-efficacy scores were seen based on depth of high school engineering participation or program of participation.

Looking more closely at the engineering self-efficacy items helps us to draw meaning from these results. Table 4.12 gives each of the survey self-efficacy items with the Bandura efficacy expectation source they are most closely linked to. These items are also broken down by subscale.

Table 4.12 Survey Self-Efficacy Items with Bandura Efficacy Expectation Sources (AWE, 2007; Bandura, 1977)

Subscale	Item	Efficacy Expectation
Engineering Career Success Expectations	Someone like me can succeed in an engineering career	Vicarious Experience
	A degree in engineering will allow me to obtain a well paying job	Vicarious Experience
	I expect to be treated fairly on the job.	Emotional Arousal
	A degree in engineering will give me the kind of lifestyle I want	Vicarious Experience
	I expect to feel "part of the group" on my job if I enter engineering	Emotional Arousal
	A degree in engineering will allow me to get a job where I can use my talents and creativity	Vicarious Experience
	A degree in engineering will allow me to obtain a job that I like	Vicarious Experience
Engineering Self-Efficacy I	I can succeed in an engineering curriculum	Performance Accomplishments
	I can succeed in an engineering curriculum while not having to give up participation in my outside interests	Performance Accomplishments
	I will succeed (earn an A or B) in my physics courses	Performance Accomplishments
	I will succeed (earn an A or B) in my math courses	Performance Accomplishments
	I will succeed (earn an A or B) in my engineering courses	Performance Accomplishments

Table 4.12 (continued)

Subscale	Item	Efficacy Expectation
Engineering Self-Efficacy II	I can complete the math requirements for most engineering majors	Performance Accomplishments
	I can excel in an engineering major during the current academic year	Performance Accomplishments
	I can complete any engineering degree at this institution	Performance Accomplishments
	I can complete the physics requirements for most engineering majors	Performance Accomplishments
	I can persist in an engineering major during the next year	Performance Accomplishments
	I can complete the chemistry requirements for most engineering majors	Performance Accomplishments
Coping Self-Efficacy	I can cope with not doing well on a test	Emotional Arousal
	I can make friends with people from different backgrounds and/or values	Emotional Arousal
	I can cope with friends' disapproval of chosen major	Verbal Persuasion
	I can cope with being the only person of my race/ethnicity in my class	Emotional Arousal
	I can approach a faculty or staff member to get assistance	Emotional Arousal
	I can adjust to a new campus environment	Emotional Arousal

High school engineering class participation showed a positive correlation with Engineering Career Success Expectations. As seen in Table 4.12, the majority of the items (5 out of 7) in this subscale most closely align with the vicarious experience self-efficacy source. These items ask students about their beliefs surrounding the career that an engineering degree will help them obtain. The only question surrounding their personal ability to succeed asks if a person "like" them can succeed in engineering.

The positive correlation of high school engineering courses with this subscale suggests that these courses are helping students to form beliefs about the type of career and lifestyle they can have with an engineering degree. It is likely that these courses discuss earning potential for engineering graduates and expose students to engineers that are currently practicing in the workforce. Project Lead the Way for example often partners with universities and corporations to provide classroom and project mentors as part of their curriculum (PLTW, 2022). Exposing students to these vicarious experiences helps them to envision their future careers and build their Engineering Career Success Expectations. This career expectations centered self-efficacy is vital to motivating students toward their goal of earning an engineering degree. Students' belief in themselves to complete an activity is a large part of self-efficacy, but the desirability of the activity is also important. High school engineering courses are teaching students about engineering and helping them to form beliefs about their future engineering careers. While this study showed that high school engineering courses have a positive correlation with these outcome expectations, no correlation was found with the other self-efficacy scales.

The other scales are based in the expectation sources of performance accomplishments and emotional arousal. Emotional arousal is mostly seen in Coping Self-Efficacy. These items center on handling and overcoming difficult situations. These situations are not engineering specific so it makes sense that high school engineering courses would not be significantly correlated with these coping beliefs. The Engineering Self-Efficacy I and II subscales contain items related to students' belief in their ability to succeed in different aspects of engineering. The expectation source most likely to influence these beliefs is personal accomplishments. The lack of correlation between these scales and high school engineering classes leads us to believe that although students are learning about engineering, significant personal ability beliefs are not forming. This means that these classes are not providing opportunities for personal engineering accomplishments that are significantly affecting self-efficacy formation. The curriculum in these engineering courses will vary from program to program and course to course. However, the high school courses are more surface level, hands-on, and informative than the majority of theory-based engineering university courses. This curriculum mismatch could be a further explanation as to the lack of significant ability beliefs formed in these high school engineering courses that are translating to university engineering self-efficacy.

A surveyed variable that did show significant association with performance accomplishment scales was GPA. The average measures of Overall Engineering Self-Efficacy, Engineering Self-Efficacy I, and Engineering Self-Efficacy II showed a significant difference based on grade point average. Since grades are a measure of students' performance, it is not surprising that GPA showed significance with the scales that are based on performance accomplishments. The average scores for both Engineering Self-Efficacy I and Engineering Self-Efficacy II are highest for the highest GPA range of 3.6 – 4.0 followed by the range of 3.0 – 3.5. These associations support the strong, positive relationship between engineering self-efficacy and grades that is found in existing literature (Starobin, 2014; Vogt et al., 2007).

Co-op and internship experience also had a significant association with a few of the self-efficacy scales. The scales that showed significant differences based on these engineering work experiences were Engineering Career Success Expectations, Engineering Self-Efficacy I, and Engineering Self-Efficacy II. These real-world job experiences provide personal and vicarious experiences for students to form positive beliefs about their future engineering careers. They are also provided with opportunities to succeed in engineering tasks on a daily basis. These personal accomplishments in an engineering work environment act as a significant source for the formation of efficacy beliefs.

Limitations

This study also relied on self-report data and voluntary participation. No data was gathered on engineering experiences or knowledge attained outside of high school engineering course participation. Extracurricular activities, and hobbies were not assessed. There was no way to account for the standard of engineering curriculum implementation and teaching experienced by each student which could have had influence on class participation and self-efficacy formation.

Many of the current undergraduate engineering students were in either high school or early college during the COVID-19 pandemic. The lack of face-to-face instruction at the college level could have created either easier or more difficult learning environments for students. The possible impact of those semesters was not considered in this study. At the high school level, students may have been unable to get hands-on engineering class experience. The hope is that these changes were only felt for one or two semesters and had negligible impact on the factors being studied, but this limitation should be taken into consideration.

Future Work

The design of this study involved surveying university students about past high school engineering class participation. Studying high school students who are participating in high school engineering classes could provide further insights. Surveying students on their engineering self-efficacy pre and post engineering class participation would give a more definitive measure of the impact of the high school engineering class on the students' engineering self-efficacy. This engineering self-efficacy would be unaffected by university experiences.

An in-depth study into high school engineering and self-efficacy that involves understanding the curriculum, topics, and assessments presented in the engineering courses could help to guide course curriculum recommendations. This would provide better understanding of the experiences and opportunities afforded to students in these courses and how those map to engineering self-efficacy sources. Conducting this study with a large-scale, nationwide sample from different high school engineering curriculums would provide valuable insights into whether or not there are any curriculum models that impact engineering self-efficacy of graduating high schoolers.

Conclusion

This study relied on survey responses from current engineering undergraduate students across the United States. These survey responses included twenty-four self-efficacy items broken down into four self-efficacy subscales. The self-efficacy subscales were analyzed for correlation with high school engineering class participation using Pearson correlation. A separate Pearson correlation was performed for each self-efficacy subscale. Kruskal-Wallis tests were run to look for significance between additional participation factors and self-efficacy. These factors included depth of engineering class participation and program of participation. A significant correlation was found between high school engineering participation and the self-efficacy subscale of Engineering Career Success Expectations. This was the only subscale that showed a correlation with high school engineering courses. Depth of participation in these courses and program of participation for the courses showed no significance with any of the self-efficacy scales.

Engineering co-op or internship experience and GPA both showed significance with the performance-based engineering self-efficacy subscales.

The overall surveyed sample had positive engineering self-efficacy scores overall and across all the subscales. Participation in high school engineering courses provides learning and experiences necessary to establish more positive expectations around a career in engineering but does not lead to a higher overall engineering self-efficacy than those students who did not participate. Contributing to Engineering Career Success Expectations is a valuable part of students' overall self-efficacy. However, educators would have to make changes to the current high school engineering offerings in order to provide students with the personal experiences necessary to form a more positive overall engineering self-efficacy. These courses are short and typically cover a broad range of engineering topics. Without having the ability to dig deep into certain engineering topics and provide students with opportunities to perform and accomplish within their desired engineering field, this task seems nearly impossible for high school engineering courses.

CHAPTER V

CONCLUSION

Moving students through the "pipeline" and into engineering careers consists of recruiting students to engineering and retaining students through to the workforce. Are high school engineering classes the answer to the engineering gap? Not on their own, but they are contributing.

The first study in this research considered the recruitment of engineering students based on the availability of engineering courses in their high schools. By analyzing percentages of students entering the largest engineering school in the state, significance was found between the availability of high school engineering classes and recruitment of students into engineering school. The significance between engineering class availability and engineering school entrance was found for six different graduating classes. This analysis covered schools of different sizes, in different areas of the state, with differing numbers of engineering courses, and different engineering curriculum programs.

The second study focused on two different topics, engineering discipline selection and engineering persistence attitudes. Survey responses from undergraduate engineering students across the nation provided the data for this study. The responses were analyzed for an association between high school engineering class participation and engineering discipline selection. The findings showed that engineering class participation in high school is positively associated with selecting one of seven engineering disciplines. These seven disciplines contribute to the majority of the expected yearly engineering job openings over the next ten years. No significance was found between high school engineering course participation and engineering persistence attitudes. The survey sample showed high persistence attitude scores. Performance factors such as college GPA and engineering co-op/internship participation were shown to have positive association with persistence attitudes.

Engineering self-efficacy was the area of interest of the third study. Students' engineering self-efficacy was analyzed for relationship with engineering class participation in high school. The only engineering self-efficacy subscale to show significance with high school engineering classes was Engineering Career Success Expectations. This subscale related to students' views of engineering as a future career. High school engineering classes provided students with experiences that helped them form views about engineering careers. High school engineering courses did not show significance with the other engineering self-efficacy subscales related to personal abilities and coping. Depth of participation in high school engineering and program of participation did not show significance with engineering self-efficacy.

Are high school engineering classes worth the cost of implementation? Evidence from these studies suggests that high school engineering courses have a positive impact on closing the engineering gap from a recruitment standpoint. Recruitment is the first step to having more engineers in the workforce. This research also suggests that these courses help students to choose their engineering discipline. Selection of an engineering discipline sets the goal that students are working toward. They are not simply working toward an engineering degree but toward a specific engineering degree.

Exploration into engineering and specific disciplines is the beginning of a student's engineering identity formation. These courses help to get students into engineering school and into disciplines with the greatest need. While these classes are beneficial to recruitment, they did not show any significance toward persistence and self-efficacy. Areas that relate to performance-based belief formation such as success in the classroom and engineering work experience would be a more beneficial place to start toward improving students' engineering self-efficacy and persistence attitudes. Educators should embrace the role that high school engineering courses are playing in teaching students about engineering as a career and presenting it as a desirable goal.

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APPENDIX A

MISSISSIPPI HIGH SCHOOL ENGINEERING CLASS AVAILABILITY QUESTIONNAIRE

High School Engineering Class Availability

Please answer the following questions on the availability of engineering courses and activities for your high school students. Thank you so much for your time!

1. What is the name of your high school?

2. Does your school offer high school engineering/STEM specific courses?
If NO, skip to question 7.
If YES, please complete ALL remaining questions.

- ◯ Yes
- ◯ No

3. If yes, are your courses part of one of the following pre-engineering programs?

- ◯ Project Lead the Way
- ◯ Engineering by Design
- ◯ Engineering4USA
- ◯ EPICS High
- ◯ ExCITE
- ◯ School specific stand alone class
- ◯ Other (please specify)

4. How many engineering courses does your school offer?

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4+

5. When did your school first start offering engineering classes?

◯ 2012 or earlier

◯ 2013

◯ 2014

◯ 2015

◯ 2016

◯ 2017

◯ 2018

◯ 2019 or later

6. Are there grade classification, academic achievement, or other requirements for participation (how are students selected)?

7. Does your school offer engineering/STEM related extracurricular activities (e.g. Robotics, engineering clubs, etc.)

◯ Yes

◯ No

APPENDIX B

MODIFIED LONGITUDINAL ASSESSMENT OF ENGINEERING SELF-EFFICACY SURVEY

ENGINEERING STUDENT SELF-EFFICACY AND PERSISTENCE SURVEY

University/College currently attending: ___________________________________ (e.g. Penn State)

Your major or intended major as of today (Check one):

- ☐ Aerospace
- ☐ Agricultural
- ☐ Architectural
- ☐ Bioengineering
- ☐ Chemical
- ☐ Civil
- ☐ Computer Engineering
- ☐ Computer Science
- ☐ Electrical
- ☐ Engineering Science
- ☐ Environmental
- ☐ Industrial
- ☐ Materials
- ☐ Mechanical
- ☐ Nuclear
- ☐ Petroleum
- ☐ Undecided
- ☐ Other____________________________

Gender:

- ☐ Male
- ☐ Female

Ethnicity / Citizenship: (Check a maximum of two)

- ☐ 1. African/Black American
- ☐ 2. American Indian/Alaskan Native
- ☐ 3. Asian & Pacific American
- ☐ 4. Latino/Hispanic American
- ☐ 5. White American
- ☐ 6. Foreign National on student visa
- ☐ 7. Foreign National/U.S. Resident (green card)
- ☐ 8. Other: _______________________________

As of today, I am a: (Choose one)

- ☐ First-year Student
- ☐ Second-year Student
- ☐ Third-year Student
- ☐ Fourth-year Student
- ☐ Fifth-year Student and above

Where were you immediately before starting at this institution? (Check one).

- ☐ High School
- ☐ 4-year college
- ☐ Vocational/technical school
- ☐ Other:_____________________
- ☐ 2-year college
- ☐ Military
- ☐ Working a full-time job

1. What was your cumulative college GPA at the end of the most recent academic semester/term?

☐ Below 2.0
☐ 2.0 – 2.9
☐ 3.0 – 3.5
☐ 3.6 – 4.0

IF FIRST SEMESTER STUDENT SKIP THIS QUESTION, CONTINUE TO QUESTION 2

2. Did you participate in any engineering classes in high school?

☐ Yes ☐ No

IF YES ANSWER QUESTIONS 3 THROUGH 5, IF NO PROCEED TO QUESTION 6.

3. How many semester long engineering courses did you take in high school?

☐ 1 Class
☐ 2 Classes
☐ 3 Classes
☐ 4+ Classes

4. What program were your high school engineering classes a part of?

☐ Project Lead the Way
☐ Engineering by Design
☐ Engineering4USA
☐ EPICS High
☐ ExCITE
☐ Stand-alone program/classes
☐ Other/Unknown
If other please list: _______________

5. Why did you take high school engineering courses?

☐ Personal choice
☐ Suggested by friends
☐ Suggested by teacher or counselor
☐ Suggested by parents
☐ Required by parents
☐ Required by school
☐ Other

6. Have you participated in an engineering co-op or internship during your time in college?

☐ Yes ☐ No

7. Do you have any immediate family members (parent or siblings) with a degree in your chosen engineering major?

☐ Yes ☐ No

8. At the present time, how satisfied are you with your decision about your specific engineering major? (Circle a number from the scale below)

Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
0	1	2	3	4

9. At the present time, how confident are you that you will keep your chosen engineering major through college? (Check one from the items below)
   - ☐ Not at all confident; I am already planning to change my major
   - ☐ Not very confident; it is highly likely that I will change my major
   - ☐ There's about a 50% chance that I'll change my major
   - ☐ I'm fairly confident that I will keep my current choice as my major
   - ☐ I'm very confident that I will keep my current choice as my major

10. At the present time, how confident are you that you will be enrolled in <u>any major in the college or school of engineering in the next academic year</u>? (Check one)
    - ☐ Not at all confident; I am already planning to change out of engineering.
    - ☐ Not confident; it is likely that I will not be in engineering then.
    - ☐ There's about a 50% chance that I'll still be in engineering.
    - ☐ I'm fairly confident that I will still be in engineering then.
    - ☐ I'm very confident that I will still be in engineering then.

11. At the present time, how confident are you that you will <u>graduate with</u> <u>your current engineering major</u>? (Check one)
    - ☐ Not at all confident; I am already planning to change my major.
    - ☐ Not confident; it is highly likely that I will change my major.
    - ☐ There's about a 50% chance that I'll change my major.
    - ☐ I'm fairly confident that I will keep my current choice as my major.
    - ☐ I'm very confident that I will keep my current choice as my major.

12. At the present time, how confident are you that you will complete <u>any</u> engineering degree (any engineering major)? (Check one)
    - ☐ Not at all confident; I am already planning to change out of engineering.
    - ☐ Not confident; it is highly likely I will not complete an engineering degree.
    - ☐ There's about a 50% chance that I'll complete an engineering degree.
    - ☐ I'm fairly confident that I will complete an engineering degree.
    - ☐ I'm very confident that I will complete an engineering degree.

13. At the present time, how confident are you that you will complete <u>any</u> degree (any major) at this institution? (Check one)
    - ☐ Not at all confident; I am already planning to transfer to another institution or drop out of college.
    - ☐ Not confident; it is highly likely I will not complete any college degree.
    - ☐ There's about a 50% chance that I'll complete a degree at this institution.
    - ☐ I'm fairly confident that I will complete a degree at this institution.
    - ☐ I'm very confident that I will complete a degree at this institution

14. What sources of information did you use when considering which engineering major to pursue? (Check all that apply)

☐ Employers
☐ High School Teachers or Counselors
☐ High School Engineering Classes
☐ Other (please specify) ___________________________
☐ Other family members
☐ Parents
☐ Did not consult with any sources

Directions: For each statement below indicate whether you **Strongly Disagree, Disagree, Slightly Disagree, Neither Disagree nor Agree, Slightly Agree, Agree, Strongly Agree,** or **Don't Know** by circling the appropriate number or symbol.

I am confident that …	Strongly Disagree	Disagree	Slightly Agree	Neither Disagree nor Agree	Slightly Agree	Agree	Strongly Agree	Don't Know
I can succeed in an engineering curriculum	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
Someone like me can succeed in an engineering career.	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
I can succeed in an engineering curriculum while <u>not</u> having to give up participation in my outside interests (e.g. extracurricular activities, family, sports) .	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
I will succeed (earn an A or B) in my physics courses.	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
I will succeed (earn an A or B) in my math courses	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
I will succeed (earn an A or B) in my engineering courses	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
I can complete the math requirements for most engineering majors	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
Doing well at math will enhance my career/job opportunities	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
A degree in engineering will allow me to obtain a well-paying job	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
I can do well in an engineering major during the current academic year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
I will be treated fairly on the job. That is, I expect to be given the same opportunities for pay raises and promotions as my fellow workers if I enter engineering.	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
I can complete any engineering degree at this institution	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
I can cope with doing poorly (or not as good as I had hoped) on a test in one of my engineering classes.	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
A degree in engineering will give me the kind of lifestyle I want	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
I can make friends with people from different backgrounds and/or values. . . .	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
Doing well at math will increase my sense of self-worth	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
I will feel "part of the group" on my job if I enter engineering	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
I can complete the physics requirements for most engineering majors	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
Taking math courses will help me to keep my career options open	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
I can cope with friends' disapproval of my chosen major	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**

A degree in engineering will allow me to get a job where I can use my talents and creativity	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
I can cope with being the only person of my race/ethnicity in a class	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
I can persist in engineering during the current academic year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
I can approach a faculty or staff member to get assistance with academic problems	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
I can adjust to a new campus environment	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
A degree in engineering will allow me to obtain a job that I like	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**
I can complete the chemistry requirements for most engineering majors	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**?**

Thank You!