International Journal of Engineering Education Vol. 40, No. 1, pp. 83–96, 2024
Printed in Great Britain

0949-149X/91 $3.00+0.00

Effects of High School Engineering Course Participation on Persistence Attitudes and Engineering Self-Efficacy*

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The demand for engineers continues to grow. Retaining engineering students through to degree completion is a key step in filling more engineering jobs. Retaining engineering students is easier said than done. An area that has grown in popularity in the fight to close the STEM gap is K-12 engineering programs. This research studied high school engineering courses and their effects on undergraduate engineering student persistence attitudes and engineering self-efficacy. A large-scale, national sample was sought by surveying undergraduate engineering students from across the United States. Responses from 1612 undergraduate engineering students provided the sample for this study. The percentage of the survey sample that participated in high school engineering classes was 40.3% which accounted for 649 participants. Overall, no significant relationship was found between high school engineering class participation and students' persistence attitudes or engineering self-efficacy. The only area of self-efficacy showing significance with high school engineering was Engineering Career Success Expectations. High school engineering courses present engineering as a career worth working toward. However, once students are in engineering school, collegiate factors such as GPA and engineering work experience show more clear relationships with persistence and self-efficacy.

Keywords: engineering retention; K-12 engineering; pre-engineering; high school engineering; engineering persistence; engineering self-efficacy

1. Introduction and Literature Review

The National Science Foundation expected a shortage of 70,000 engineers in the United States by 2010 [1]. From May 2009 to May 2015, the number of STEM jobs increased by 10.5% while non-stem jobs only increased 5.2%. Increased demand requires an increase in people entering STEM programs; however, the National Science Board reported that from 1985 to 2005 there was a 15% decline in the number of engineering degrees earned in the United States [2].

One avenue 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" [1]. This study was particularly interested in supporting the engineering pipeline. When discussing the need for more engineers, conversation usually turns to recruiting more engineering students; however, recruitment is only part of the battle. Once students have entered engineering school, they must complete their engineering degree. Understanding how high school engineering participation impacts student persistence in engineering can help to move students through the "pipeline" and into the world as professional 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 [3]. This means that roughly half of students entering engineering school will not complete their degree in engineering.

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 in a variety of areas from sports to academics [4, 5]. Research shows that when athletes are confident in their team, they try harder, push themselves further, are more persistent, and display better performance [6]. 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. 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

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* Accepted 17 September 2023.

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 confidence in their ability to persist and a strong engineering self-efficacy.

1.1 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 [7]. 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 [8]. 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 [7]. 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.

1.2 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 (performance accomplishments), comparing one's performance to the performance of others (vicarious experience), encouragement or discouragement from others (verbal persuasion), and physiological states and reactions (emotional arousal) [9].

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 [10]. One's own previous accomplishments are especially effective at influencing self-efficacy [9]. High school engineering participation has the potential to contribute to several of the sources seen above.

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 [11]. 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 [10, 3]. Engineering self-efficacy relates to students' abilities to navigate challenges in their engineering studies and their beliefs in their ability to complete the curriculum. [12].

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 [10]. Another study conducted on implementation of a engineering curriculum by thirty-six high school teachers found that students' self-efficacy for engineering increased after completing the curriculum [13]. 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 [11].

1.3 Commitment to Persist in Engineering

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 [2]. This study agrees with the findings by Cole, Highland, and Weinland in their study at the same university in earlier years [3]. 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 [14]. 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 [15].

Research is lacking into 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.

1.4 Research Questions

It is 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. This study addresses these gaps. This study also analyzes the persistence attitudes of engineering students toward engineering school and their intended engineering 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' confidence in their abilities to persist. The research answers the following questions to address these gaps:

RQ1: Does high school engineering class participation impact engineering students' persistence attitudes?

RQ2: Is there a correlation between high school engineering class participation and engineering self-efficacy?

2. Methods

2.1 Design and Data Source

After IRB approval, an online Qualtrics survey invitation was emailed to engineering deans and department heads from over 100 engineering schools across the country for distribution to their undergraduate engineering students. At least 300 responses were needed assuming a national engineering student population of about 800,000 based on national graduation rates from 2017–2020 [16]. The study received a usable sample size of 1612 responses.

2.2 Participants

The colleges and universities that received the survey request were public universities and private colleges across the United States. A sample size of 1612 respondents was received representing 37 different states. Minority participation including African Americans, Hispanics, and American Indians made up 19.48% of responses and White Americans made up 65.57% of the sample. The gender representation of the sample included 44.8% female and 52.1% male with the remaining participants preferring not to identify. 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.

2.3 Survey Instrument

The survey instrument used in this study was the AWE (Assessing Women and Men in Engineering) Longitudinal Assessment of Engineering Self-Efficacy Survey. Background questions were added to the instrument. These additions did not impact the instrument subscales. The updated instrument was named, "Engineering Self-Efficacy and Persistence Survey". The instrument included background questions into students' engineering major, grade point average, work experience, and demographic information. The added background questions included whether or not students had participated in high school engineering courses.

This study focused on responses to the confidence in persistence/commitment to persist survey items as dependent variables. The six 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 [17]. Content validity was verified by external expert reviews [18]. 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 [17].

The study also relied on the students' engineering self-efficacy as a 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 [17]. External expert review was utilized to verify content validity [18]. The reliability data for the subscales is given in Table 1. Alpha values of 0.7 to 0.9 are considered acceptable reliability [17].

3. Results

The percentage of the survey sample that participated in high school engineering classes was 40.3% which accounted for 649 participants.

3.1 Persistence Attitudes

The overall persistence attitude scores for the surveyed data set were each calculated as a mean of two or more of the confidence in persistence items. The mean scores for the overall data set are given in Table 2. These scores are also given based on high school engineering class participation and gender.

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 and 4 respectfully.

The lowest mean for each persistence attitude based on classification was seen in first year students. The first-year student mean scores were all below the mean scores of the overall sample but were 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 5.

None of the persistence attitude Mann-Whitney

Table 1. LAESE Self-Efficacy Subscales and Reliability Data [17]

Subscale	Items	Cronbach's Alpha
Engineering career success expectations	Someone like me can succeed in an engineering career	0.84
	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	
Engineering self-efficacy I	I can succeed in an engineering curriculum	0.82
	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	
Engineering self-efficacy II	I can complete the math requirements for most engineering majors	0.82
	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	
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	

Table 2. 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
Female	Mean	4.60	4.71	4.61	4.42	4.73
	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.

Table 3. Persistence Attitude and Classification 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

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.

Table 4. 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

Table 5. 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

3.2 Engineering Self-Efficacy

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 6 gives the mean self-efficacy scores for the overall sample, for participation status, and for each gender.

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 7.

White Americans have the highest average self-efficacy scores across all five categories (overall and each subscale). 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 8 gives the results for each engineering self-efficacy variable.

As seen in Table 8, 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, $r(1610) = 0.042$, $p = 0.047$. High school engineering class participation was not significantly correlated with Overall Engineering Self-Efficacy or any of the other self-efficacy subscales.

3.3 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

Table 6. 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.

Table 7. 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.

association between gender and high school engineering participation. A statistically significant association was found between gender and high school engineering class participation, $\chi^2(1) = 24.61$, $p < 0.001$. The association strength was small (Cohen, 1988), Cramer's V = 0.126. The column proportion comparisons and standardized residuals are given in Table 9.

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

Table 8. 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

*$p < 0.05$.

Table 9. 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.

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, $\chi^2(3) = 0.89, p = 0.831$.

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.

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 10.

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 11.

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.

Table 10. Kruskal-Wallis Test Results for Persistence Attitudes Across Cumulative GPA

	Median					
Persistence Attitudes across GPA	**Below 2.0**	**2.0 – 2.9**	**3.0 – 3.5**	**3.6 – 4.0**	***H(4)***	***p***
Confidence In Persistence with Satisfaction	4.33	4.67	4.83	4.83	62.29	< 0.001
Confidence In Persistence	4.40	4.80	5.00	5.00	59.95	< 0.001
Confidence In Persistence – Discipline Specific	4.00	4.00	5.00	5.00	41.17	< 0.001
Confidence In Persistence – Discipline Specific with Satisfaction	3.83	4.33	4.67	4.67	44.73	< 0.001
Confidence In Persistence – Engineering Specific	4.75	5.00	5.00	5.00	56.24	< 0.001

Table 11. 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	<0.001
Confidence In Persistence	4.82	4.64	221201.00	–9.18	0.000
Confidence In Persistence – Major Specific	4.81	4.48	213118.00	–10.84	0.000
Confidence In Persistence – Major Specific with Satisfaction	4.58	4.32	223077.00	–8.40	0.000
Confidence In Persistence – Engineering Specific	4.79	4.69	258745.00	–5.12	<0.001

Table 12. Kruskal-Wallis Test Results for Classification and Engineering-Self Efficacy Scales

Engineering Self-Efficacy Scales across Classification	**Mean**						
	First-year	**Second-year**	**Third-year**	**Fourth-year**	**Fifth-year+**	***H(4)***	***p***
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

Table 13. 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

Table 14. 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

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 12 contains the results of each Kruskal-Wallis test.

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 13.

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 14 gives the results of the Mann-Whitney tests.

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.

4. Discussion

4.1 Persistence Attitudes

There first research question asks for the relationship between high school engineering class participation and engineering 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 lack of relationship between participation and persistence attitudes is in line with the findings of previous research related to PLTW participation and engineering degree persistence [2, 3]. 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 [2]. 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.

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 student's 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.

4.2 Engineering Self-Efficacy

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 [3, 10, 11].

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 [12, 19–22]. 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 [18, 23, 24].

The second 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 [10, 13]. 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.

Looking more closely at the engineering self-efficacy items helps us to draw meaning from these results. Table 15 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.

High school engineering class participation showed a positive correlation with Engineering Career Success Expectations. As seen in Table 15, 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.

Table 15. Survey Self-Efficacy Items with Bandura Efficacy Expectation Sources [9, 17]

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
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

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 [25] 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 teach 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 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 [11, 19].

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.

4.3 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 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 a 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.

4.4 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.

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.

5. Conclusion

A nationwide survey sample of undergraduate engineering students was used for this research. 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 engage in confidence belief forming engineering experiences.

The 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 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.

While high school engineering courses are effectively presenting engineering as a desirable career choice, their significant benefits are not seen in university retention factors. 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, but not expect these courses to solve engineering retention issues.

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