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Effects of High School Engineering Courses on Engineering Recruitment and Specific Discipline Selection*

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Engineering needs in the workforce continue to rise. Filling these needs requires recruiting future engineers to colleges and universities. However, this is not an easy task. One area that has been explored in the attempt to reach students for engineering is offering engineering or STEM classes to K-12 students. This research investigated engineering classes offered specifically at the high school level. These courses and factors related to them were analyzed for relationships with engineering recruitment and discipline selection. 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 with the percentage of graduates from that high school who entered the largest engineering school in the state. A nationwide sample of current undergraduate engineering students was used to study the influence of high school engineering participation on engineering discipline selection. Analysis found significant relationships between the availability of high school engineering courses and engineering school 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.

Keywords: engineering recruitment, K-12 engineering, pre-engineering, high school engineering, engineering major

1. Introduction

The need for professionals in the science, technology, engineering, and math (STEM) fields grows each year. The National Society of Professional Engineers found in 2021 that the number of engineers must grow by 15% to meet increasing demand and account for losses [1]. Universities have the difficult task of introducing enough new engineers to the workforce and corporations are searching for new engineering talent.

Increasing recruitment into engineering is the logical first barrier to fighting the engineer shortage in the United States [2]. Engineering programs targeting K-12 students have grown in popularity as a path for increasing recruitment. This research investigates engineering programs at the high school level. Existing research into the minimum age at which detail-oriented engineering concepts can be successfully introduced found that 13-year-old students were more engaged and found more enjoyment in detail-oriented aspects of engineering projects than 12-year-old students [3]. Junior high students' ages range anywhere from 11–14 years old. With such significant differences between 12 – and 13-year-olds, the research was steered toward high school students.

Research has been conducted into engineering curriculum at the high school level; however, there are a number of gaps. The existing research is largely focused on Project Lead the Way (PLTW). Project Lead the Way is the largest of the K-12 engineering programs [4]. Other K-12 engineering programs exist in the United States. These programs include Engineering by Design, Engineering4USA, EPICS High, and Project ExCITE. Additional existing research into K-12 engineering courses relies on stand-alone engineering programs in specific schools or districts. This study accounted for all high school engineering programs, both formal and stand-alone.

The goal of this research was to answer the following research questions related to the effect of high school engineering availability and participation on engineering school recruitment and discipline selection.

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

2. Background and Literature

The costs and barriers associated with implementing high school engineering curriculum often leads

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universities and companies to become involved in the implementation and funding [5]. Since high school engineering course participation is not always a curriculum requirement, there is no way to ensure participation in the program by all or even particular students. This study researched the impact of the availability of such classes on engineering recruitment. Establishing a relationship on the basis of availability without looking at actual participation provides better understanding of the true benefit of these classes from the perspective of investing engineering colleges and companies. This data could also be utilized by educators fighting for engineering programs in their schools.

Once a student decides on engineering as a major, they must then decide on which engineering discipline to pursue. Different engineering disciplines are more closely aligned with different interests and skill sets. Students who enjoy electrical concepts may not enjoy statics or vice versa. Students finding the right fit in their engineering discipline is important for ensuring those students persist into the workforce as engineers.

2.1 Identity Formation

Identity formation involves a recurring process of building and morphing one's own identity. Formation of an identity requires exploration of different life paths and careers. Building on Marcia's identity formation model, Crocetti et al. asserted that commitment, in-depth exploration, and reconsideration of the previous commitment are key components of identity formation [6]. Marcia's 1966 model used the categories of exploration and commitment. Exploration is the process of seeking and testing possibilities. Exploration leads to self-perceptions. These perceptions can lead to commitment. Commitment requires making decisions about one's identity. The Circumplex of Identity Formation Modes (CIFM) marries these models [7].

The modes of the CIFM include socialization, exploration, defiance, and petrification. The mode of particular interest to this research is exploration. This research is interested in factors related to identity formation, but specifically in the formation of an engineering identity.

2.2 Engineering Identity and Formation

Engineering identity is a role identity. A role identity is the perceptions of an individual related to that role in culture and society [8]. High school is a time of identity formation. Patrick, Prybutok, and Borrego used three factors of engineering identity. Those factors are interest, performance or competence, and recognition. Their framework utilizes two of the most cited frameworks related to identity and STEM fields. The framework of Carlone and Johnson defined identity in the co-mingling of performance, competence, and recognition. Hazari et al. then added interest as an additional key factor [9].

High school students are forming their role or career identities. Understanding the formation of a student's engineering identity will lend understanding to why students gravitate toward or move away from engineering [10]. Educational enrichment can influence the formation of a role identity such as engineering identity. Educational enrichment includes in school and extracurricular exposure to the subject [11]. The hope is that high school students in engineering classes are exploring engineering as their future major.

Exploration of a role can influence all of the categories of identity formation. It can establish or build on interest, provide opportunities for recognition, and instill performance and competency beliefs [7]. An engineering class is the ideal setting for a high school student to explore engineering during identity formation [11]

2.3 High School Engineering Availability

A study conducted using data from Indiana high schools researched the likelihood of attending engineering school after high school based on the availability of PLTW in the high school. 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 looked at participation in PLTW for the schools with PLTW available. 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. The study used data for only one graduating class and did not include any programs other than PLTW [12].

The only research into the availability of high school engineering classes rather than participation in those classes used only PLTW and only one graduating class. The lack of information on engineering classes that might have been offered by other schools and the lack of evidence from multiple cohorts left significant gaps in the only availability study found.

2.4 Recruitment of Engineering Students

Multiple studies have found that students who participate in PLTW are more likely to major in STEM [13–17]. One study by Salzman, Mann, and Ohland found that out of 240 Purdue students who participated in PLTW, 53% chose to major in engineering and an additional 35% chose other STEM fields [16]. However, participation in high school engineering is not a prerequisite to engineering school recruitment. A qualitative study conducted at a research university in the southeast interviewed 21 engineering students about their entrance into engineering. Six of the students stated that they were persuaded by friends to pursue engineering. Familiarity with engineering-based tasks pre-college was included in 10 of the student narratives. Only three of the participating students took STEM classes in high school [18].

2.5 *Program of Participation*

Several different K-12 engineering programs exist in the United States. Twenty different programs were active in schools in the United States in 2009. Sorge and Hess noted the lack of research into the different programs [19]. This large number of programs makes it difficult to pick a program to focus on. The overwhelming majority of existing research utilizes the largest of the programs, Project Lead the Way. Most of the studies cited in this research rely only on PLTW creating a gap with respect to students involved in other programs.

2.6 *Depth of Participation*

Few studies account for depth of participation, or number of engineering courses taken, in high school engineering programs. Utley, et al. accounted for depth of participation in their study on PLTW and engineering retention. The researchers found no significant relationship between depth of participation in PLTW and engineering school retention [20]. A study on PLTW and improving minority engineering recruitment also accounted for the number of high school engineering courses taken. The study consisted of over 3000 minority students graduating in 2010. A positive relationship was found between participation in PLTW and recruitment into a STEM major; however, there no significance was found between STEM recruitment and the number of PLTW courses completed [21]. An additional study by Pike and Robbins found that participation in more PLTW classes increased the likelihood of majoring in a STEM field with a dosage effect [14]. A study conducted at Purdue University into perceptions of students on PLTW found significant differences between taking one course or two or more courses. Students who took more PLTW classes agreed more strongly with the positive impacts of PLTW [16].

The majority of existing literature shows significant relationships between PLTW or stand-alone programs and engineering recruitment. The existing literature is primarily focused on a single district, state, or institution. The existing studies also only investigated one engineering program or curriculum at a time. Research into curriculums other than PLTW is severely lacking. No existing studies account for all high school engineering programs. The few existing studies including depth of participation were exclusively PLTW studies. These studies supplied mixed results of taking multiple high school engineering classes.

2.7 *Engineering Discipline Selection*

Choosing a major is a stressful task. For engineering students, this task is a two-tiered process. Once a student has chosen engineering, they must then choose an engineering discipline. Research exists into engineering major selection that associates academic achievement in high school with choice in engineering major [22]. Godwin, Sonnert, and Sadler studied the relationship between engineering discipline interest and out-of-school activities. A significant relationship was found between out-of-school activities students participated in and the engineering disciplines they were interested in [10]. Several studies have focused on students' motivation for their choice in engineering discipline. These studies, conducted across the globe, all concluded that intrinsic motivation is the primary influence on engineering discipline selection. Intrinsic motivation includes students' perceptions, intentions, feelings, and attitudes [23–26].

No existing research was found into high school engineering classes and engineering major 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 [27]. 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 [16].

High school factors and experiences with engineering have been tied to engineering discipline selection. High school engineering curriculum is geared toward specific engineering disciplines. Existing literature laid the groundwork for further investigation into high school engineering's influence on engineering major selection.

3. Methods – RQ1: High School Engineering Availability and Recruitment

3.1 *Design and Data Source*

Historical data and quantitative research methods were for this study. Data was gathered on the availability of engineering courses for Mississippi public high schools. The number of engineering classes offered and year those classes first became available were requested for each high school in the state. The data was obtained from the high schools' principals, counselors, or career and technical directors. Once the study received Institutional Review Board (IRB) approval, a web based Qualtrics questionnaire was sent to each public high school principal in Mississippi. 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. Data was obtained for 104 of the 234 public high schools in Mississippi.

Data was also collected on all incoming Mississippi State Bagley College of Engineering (BCoE) students from Fall 2013 through Spring of 2020. This data was obtained by working with the Office of Institutional Research and Effectiveness. The high school attended for each incoming engineering student was gathered from the university.

3.2 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 offer engineering courses while 29 schools did have engineering courses. By the final year in the study, 48 high schools did not offer engineering courses 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 included 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 high school graduating cohorts. Years with readily available high school graduation data were utilized.

4. Methods – RQ2 and RQ3 – High School Engineering Participation and Engineering Discipline

4.1 Design and Data Source

Quantitative research methods were used to analyze gathered survey data. 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 [28]. 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.

4.2 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.

4.3 Survey Instrument

The Assessing Women and Men in Engineering (AWE) Longitudinal Assessment of Engineering Self-Efficacy Survey was utilized for this study [29]. 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 background questions provided all necessary data for this study.

5. Results

5.1 High School Engineering Availability and Recruitment

The analyzed sample consisted of 104 of the 234

Table 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

Table 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

public high schools in Mississippi. Table 1 shows the number of high schools in the sample that had engineering courses available for each year analyzed in the study.

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.

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 offer engineering courses.

To answer the research question, Mann-Whitney U tests were performed using engineering course availability and percent of graduates entering engineering. These tests were run for each school year. The results are shown in Table 3.

The Mann-Whitney tests found significance in the difference 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 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, $H(4) = 8.66, p = 0.070$. 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, $U = 742.50$, $z = 1.80$, $p = 0.072$.

5.2 High School Engineering Participation and Engineering Discipline

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,

Table 3. Mann Whitney Test Results for Engineering Class Availability and Percent of Graduates Entering Engineering

Percent of Graduates Entering BCoE	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

Table 4. 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
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 0.05 level.

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.

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, $\chi^2(11) = 58.70$, $p < 0.001$. The association strength fell between small and moderate (Cohen, 1988), Cramer's $V = 0.203$. The statistically significant results were further investigated for direction of the association. The column proportion comparisons and standardized residuals for each discipline based on engineering class participation are given in Table 4.

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 $\chi^2(66) = 75.30$, $p = 0.203$. Partial likelihood ratio χ^2 are presented in Table 5.

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, $\chi^2(33) = 58.17$, $p = 0.004$. The association strength fell between small and moderate (Cohen, 1988), Cramer's $V = 0.182$. The column proportion comparisons and standardized residuals were analyzed. The significant results for depth and discipline are given in Table 6.

Table 5. 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 $p < 0.05$ level.

Table 6. 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

Table 7. 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

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, $\chi^2(22) = 46.09$, $p = 0.002$. The association strength fell between small and moderate (Cohen, 1988), Cramer's $V = 0.199$. The column proportion comparisons and standardized residuals were analyzed. The significant results for program of participation and discipline are given in Table 7.

Civil engineering was the only discipline to show significant differences based on program of participation at the $p < 0.05$ 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.

6. Discussion

6.1 High School Engineering Availability and Recruitment

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.

A significant difference in the percentage of students attending the Bagley College of Engineering was found 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 did not make 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.

The 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 [12]. 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 [7]. 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 forming the engineering identity that will lead them to engineering school.

Additional factors related to class availability were analyzed. No significant difference was found in recruitment based on the number of courses available. The program each schools' engineering courses were 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 on 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 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.

6.1.1 Limitations

This study utilized existing historical data sets. A portion of the data was self-report 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.

6.1.2 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.

6.2 High School Engineering Participation and Engineering Discipline

This study 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 8 with their expected yearly job openings for the next decade and the direction of the association that was found with class participation, if any.

These twelve disciplines account for 151,900 yearly engineering job openings [30]. 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

Table 8. Yearly Job Openings for Each Discipline with Direction of Association with Participation [30]

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?

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.

The finding of 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 [16]. 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 [31]. The other 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.

Our third 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 disciplines such as Civil Engineering and Architecture, Computer Science Principles, and Digital Electronics. These are all courses in the PLTW engineering curriculum [31].

Analyzing for 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 [31]. 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 participated in engineering classes in high school 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.

6.2.1 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 considered. 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.

6.2.2 Future Work

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.

7. 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. Significant correlation was found for six different graduating classes, covering schools with differing numbers of courses, different curriculum programs, of 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.

This study also relied on survey responses from current engineering undergraduates from across the country in order to answer the second and third research questions. The responses included students' high school engineering class participation, details surrounding their participation, and their current engineering major. Chi-square analysis was performed to test for association between high school engineering class participation and engineering discipline selection.

A significant association was found 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 explore the role identities of different engineering majors while forming their engineering identity. 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 part of the students' engineering identity and is the specific goal they have been recruited to and are hoping to persist through.

University engineering programs should take an interest in aiding high schools to provide engineering curriculum. These university engineering programs will see the pay out in more interested engineering students. Professional engineering organizations should take a similar interest. Discipline specific organizations whose disciplines have been shown to benefit from existing high school engineering curriculum, such as IEEE and ASME, should take an even stronger interest. Those disciplines who have not seen a significant relationship with high school engineering participation may benefit from developing discipline specific learning objectives and activities that could be implemented in these classes. However, the data ultimately shows that high school engineering courses are steering students toward the engineering disciplines that are in high demand in the workforce.

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