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Effect of Project Lead the Way Participation on Retention in Engineering Degree Programs

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Keywords

pre-engineering, PLTW, retention, pre-college, engineering education

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Abstract

A key goal of pre-college engineering programs is to increase the number and retention of students pursuing engineering degrees. The researchers conducted a transcript analysis in order to compare the retention of entering engineering majors at a university based on whether or not they participated in Project Lead the Way (PLTW) in high school. PLTW Engineering is a high school pre-engineering curriculum that offers a series of courses to increase student awareness and scaffold an understanding of engineering design. The findings from this study offer little support regarding the impact of students' PLTW participation on engineering degree completion. However, findings do suggest some support for the impact of PLTW participation on retention from freshmen to sophomore year, particularly among minority freshmen.

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Introduction

Advancements in technology have caused a shift in the knowledge and skills needed by those entering the workforce, which has resulted in a sustained growth in science and engineering careers for several years. The U.S. Department of Commerce's Economics and Statistics Administration (2011) projected that science, technology, engineering, and mathematics (STEM) occupations would grow faster than non-STEM occupations between 2008 and 2018. Between May 2009 and May 2015, STEM occupations grew by 10.5%, compared to just 5.2% growth for non-STEM occupations, and saw an addition of over 800,000 jobs (Fayer, Lacey, & Watson, 2017). Moving forward, the same report predicted that the "architectural, engineering, and related services industry is projected to grow by 8% from 2014 to 2024" (Fayer, Lacey, & Watson, 2017, p. 21). Additionally, Tai (2012) has suggested that with a significant number of baby boomers approaching retirement age, the greater need for STEM graduates could significantly influence the country's economy and global competitiveness.

Historically, universities have not been able to produce enough skilled STEM graduates to meet the ever-increasing demand of the job market. Between 1985 and 2005, the number of degrees earned in engineering declined by nearly 15% (from 77,572 in 1985 to 66,133 in 2005) (National Science Board, 2008). In 2012, the President's Council of Advisors on Science and Technology (PCAST) predicted that the United States would need to produce one million more STEM majors than the current rate would produce, which represented a 34% annual increase. More recently, Yoder (2017) indicated that undergraduate enrollment in engineering programs reached a 10-year high during 2017 with nearly 620,000 full-time engineering students; this was a 3% increase from 2016 enrollment, and a 54% increase compared to 2008.

While increasing the number of people entering STEM fields presents a challenge, another concern is the lack of diversity among current STEM professionals and those in the STEM pipeline. The National Research Council (2011) points to the need to expand the number of STEM college students and to broaden the participation of women and minorities in the STEM workforce. Researchers report that less than 25% of the total STEM workforce are women (Yoder, 2017) and that "women hold a disproportionately low share of STEM undergraduate degrees, particularly in engineering" (Beede et al., 2011, p. 1). More recently, Yoder (2017) found that women earned only 23% of engineering degrees in 2017.

Although the predominant message in the research literature indicates that women have lower rates of retention in engineering than their male counterparts (e.g., Adelman, 1998; Astin & Astin, 1992; Brainard & Carlin, 1998; National Science Board, 2008), other studies indicate that women and men have similar rates of retention (e.g., Hartman & Hartman, 2006; Ohland et al., 2008, 2011). Regardless of whether gender plays a role in rates of student attrition, males continue to make up the majority of overall students enrolled in engineering programs. Researchers indicate that reasons for the underrepresentation of women in engineering may include the culture of engineering departments (Jones, Ruff, & Paretti, 2013), stereotype threat (Beasley & Fischer, 2012), and a lack of strong female role models (White & Massiha, 2016).

Underrepresented minority students are also reported to have higher rates of attrition from engineering programs (National Science Board, 2008). Of the bachelor degrees awarded in science and engineering, 11.5% were awarded to Hispanics, 0.5% to Native Americans, and 8.3% to African Americans (National Science Foundation & National Center for Science and Engineering Statistics, 2017) while representing 16.3%, 0.9%, and 12.6% of the U.S. population, respectively (Humes, Jones, & Ramirez, 2011).

To address the demand for more future engineering majors, many P–12 schools are implementing pre-college engineering programs. For example, Project Lead the Way (PLTW) grew from being in just 30 schools in 1998 (Blais & Adelson, 1998) to more than 10,000 schools in all 50 states in 2018 (Project Lead the Way, 2018a). The goal of these programs is to increase the number and preparedness of high school students planning to pursue an engineering degree (Blais & Adelson, 1998). Research on the effectiveness of secondary pre-engineering programs and their influence on student retention in undergraduate engineering is limited. Thus, the purpose of this study was to explore the retention of engineering majors at a large Midwestern land-grant university based on whether or not they participated in PLTW during high school. The researchers conducted a transcript analysis to compare the retention of entering engineering majors at the university based on their participation in PLTW. This study allowed us to explore the following research questions:

1. Are undergraduate majors who declare a major in a field of engineering retained at a higher rate to complete a degree in engineering if they participated in PLTW in high school?
2. Are undergraduate majors who declare a major in a field of engineering retained at a higher rate from their first to second year in college if they participated in PLTW in high school?

Background Literature

Pre-college Engineering Programs

In an effort to stimulate students' interests in engineering fields, there has been a growth of pre-college engineering programs (Phelps, Camburn, & Min, 2018). To highlight the importance of including these programs in P–12 schools, the National Academy of Engineering (2009, pp. 49–50) identified key benefits of pre-college engineering education that include:

- improved learning and achievement in science and mathematics;
- increased awareness of engineering and the work of engineers;
- understanding of and the ability to engage in engineering design;
- interest in pursuing engineering as a career; and
- increased technological literacy.

Further, the incorporation of engineering practices within the Next Generation Science Standards (NGSS Lead States, 2013) increases the need for students to have a better understanding of engineering during their P–12 education. In elementary school, students may be exposed to the Engineering is Elementary curriculum that is designed to help elementary students discover engineering design and engineering careers (Cunningham, 2017). Recently, PLTW deployed PLTW Launch to introduce K–5 students to engineering and engineering careers. In middle school, students may have access to PLTW Gateway, which is designed to provide students in Grades 6–8 with engineering activities in computer science, engineering, and biomedical science, in addition to showing pathways for further study in high school. In addition to PLTW, another student-centered curriculum, Engineer Your World, is also prevalent. This curriculum is for students in Grades 9–12 and provides a similar hands-on curriculum with authentic activities related to engineering (University of Texas, 2017).

Despite the growing number of pre-college engineering programs, little empirical research exists on the effects of participating in these programs on students who pursue engineering degrees in college. In a study of first-year engineering students enrolled at Colorado State University, Fantz, Siller, and DeMiranda (2011) found that students who participated in formal pre-college engineering classes or pursued engineering-related hobbies (e.g., robotics, model rockets, video game development) were associated with a positive significant difference in engineering self-efficacy. Tai (2012) synthesized results from 33 PLTW studies and evaluations. Of these studies, only six were peer reviewed and very few examined the effect of PLTW participation on student achievement and motivation in science and engineering. Of the studies Tai examined, those that examined the effects of PLTW on student achievement and efficacy are limited and further investigation is warranted. However, it is important to note that researchers internally connected to programs have conducted the majority of the research on these programs, including PLTW. Thus, there is also a need for research from individuals not connected to the programs of study.

Project Lead the Way

PLTW Engineering is a high school pre-engineering curriculum that offers a series of courses to increase student awareness and scaffold an understanding of engineering design (Project Lead the Way, 2018b). Students start with two foundation courses: introduction to engineering design and principles of engineering. Then students can choose among courses that focus on different areas of engineering, including aerospace, civil, digital electronics, and environmental. Additionally, students that move through the whole program in high school complete a capstone course during their final year that focuses on a design challenge.

Grimsley found (as cited in Taylor, Foster, & Ratcliff, 2006) that engineering majors who participated in PLTW programs during high school were more likely to indicate that they planned to complete their engineering degrees than those who did not participate in PLTW. Contrasting Grimsley's work, Hess, Sorge, and Feldhaus (2016) examined 31 publications from the research literature and analyzed empirical data related to PLTW. Their analyses indicated that strengths of PLTW included generating student interest in STEM (with an emphasis on engineering), inspiring students to pursue STEM degrees, and providing teachers with professional development and support. However, they also found minimal evidence linking PLTW participation with improving students' abilities in mathematics and science, and pointed out the financial costs for schools to participate and issues with course scheduling and space requirements. They concluded that the literature varied widely, and that more investigation is needed into each of the strengths and weaknesses of PLTW.

One concern that continues to arise is the accessibility of PLTW opportunities to all students regardless of gender, location, SES level, or ethnicity. Early (2017) found that, of the students ($n = 141$) who attended a STEM academy in an urban area, the overwhelming majority were white males (83%). Comparing the ethnicities of the participants to the ethnicities of the participating students' high schools and that of the state, this STEM academy seemed to have more white students than was average for the state and for four out of the five feeder schools.

Retention in College

Retention is an institutional measure used to track whether students remain enrolled at an institution or within a program from year to year (Drake, 2017). Student retention in STEM is a concern, as less than half of the 3 million students who enter college pursuing a STEM degree graduate with a STEM major (Chen & Weko, 2009; Daempfle, 2002; PCAST, 2012). The 2012 PCAST report predicted a deficit in the U.S. STEM workforce and made a call for institutions of higher education to retain more college students in STEM majors. According to the American College and Testing Program (2017) report on retention and completion, only 64.5% of first-year students who attend four-year public institutions return for a second year. The pipeline continues to lose students, with only 37% of first-year STEM majors earning a degree or certificate within six years; for those who complete their STEM degree, only 56% obtain employment in a STEM occupation after graduation (Carnevale, Smith, & Melton, 2011). While there is evidence that the numbers of students initially enrolled and retained in engineering programs have both slightly improved (American Society for Engineering Education, 2016), there is still a need to explore whether increased student participation in high school pre-engineering programs is affecting retention.

In addition to recruiting and retaining students in engineering, there is a call to increase the diversification of students in engineering. Although women make up nearly half of the U.S. workforce and earn more than half of bachelor degrees awarded, they are not well represented in engineering and other physical sciences. According to the National Science Board (2018), only 29% of the bachelor degrees awarded to women in 2015 were in science and engineering, as compared to 40% for men. Additionally, this study reported that only 2% of the women's degrees were in an engineering field, as compared to 10% for men. A closer look at those degrees awarded during 2015 in science and engineering revealed that only 6% of the engineering degrees were awarded to females, while 24% were awarded to males. Clearly, there is a gender gap when examining degree earners. Examination of degree earners by race and ethnicity also indicates a lack of diversity among underrepresented groups. In 2015, the majority of engineering students were awarded to White (16.5%) and Asian (18%) students. By contrast, the percentages of engineering degrees awarded to other groups were as follows: Black/African Americans, 7%; Hispanics/Latinos, 13%;

and American Indian/Alaska Native,11%. Although there is not a lot of fluctuation between some groups, it is clear that minority groups (including women) are less represented within engineering degrees.

Methods

This study employed archival research methods to perform a transcript analysis to examine differences among participants who did or did not participate in PLTW in high school. Researchers obtained a list of all students and their college-wide IDs that had declared a major in an area of engineering starting in the Fall 2010 or Fall 2015 semesters from the advising office in the College of Engineering; this list of students was used to delimit the population of students under study. We used two sources of data for this study, namely data from the student information system and students' high school transcripts. The student information system provided us with information about each student including gender, race, starting degree program, graduating term and degree upon completion, and level of financial need. For this study, high school transcripts provided researchers with two key pieces of information: (1) whether the student participated in a PLTW Engineering program in high school and (2) which PLTW courses students completed.

Data from the high school transcript analysis were used to place students into one of two groups: PLTW and No-PLTW. These groups were used to examine differences in retention in engineering among all students in the study against different variables including gender, ethnicity, financial need, and depth of PLTW participation. Table 1 provides an overview of the number of students in each group from the different semesters under study. A student was omitted from the sample if either a high school transcript was not available (Fall 2010: $n = 17$; Fall 2015: $n = 19$) or the student was an international student (Fall 2010: $n = 39$; Fall 2015: $n = 29$).

Table 1
Demographic information for entering first year students who declared a major in engineering by semester.

Group	Fall 2010 *n*	Fall 2015 *N*
PLTW	103	199
No-PLTW	645	728
Total "*N*" for analysis	748	927

Researchers used a chi square test of independence to explore potential differences in undergraduate majors who declared a major in a field of engineering based on their participation in PLTW. In each case where the chi square test was used, all assumptions were met, including the need for 80% of the cells to have a cell value of five or greater. When assumptions for chi square were not met, the Fisher–Freeman–Halton (Freeman & Halton, 1951) extension of the Fisher exact test for contingency tables greater than a two by two was used. The Fisher–Freeman–Halton probability values were calculated using an online calculator (see http://vassarstats.net/fisher2x3.html).

Findings

Research Question 1: Retention to Completion

To examine retention to degree completion of students who declared engineering as a major upon entering college, a chi square test of independence was used. Table 2 displays the number of students who withdrew from the university, completed a degree in engineering, or completed a non-engineering degree as a function of PLTW participation. A chi square test of independence indicated that there was not enough evidence to suggest an association of PLTW participation and retention (X^2 (2, $n = 748$) = 1.695, $p = 0.428$). In other words, the proportion of PLTW students who completed an engineering degree is not significantly different from the proportion of No-PLTW students who completed a degree. There appears to be no association between whether a student entered college having participated in at least one PLTW course and their retention in an engineering program.

Next, we examined Fall 2010 first-year students' retention to degree completion while controlling for gender, race, level of financial need, and depth of PLTW participation. Researchers used a chi square test of independence to determine whether there was any association between students' retention in engineering and PLTW participation when controlling for gender (see Table 3). Results indicated that there was no significant association among males (X^2 (2, $n = 613$) = 2.133, $p = 0.344$) or females (X^2 (2, $n = 135$) = 0.009, $p = 0.996$). Thus, when controlling for gender the proportion of PLTW students retained into their

Table 2
Retention of first-year 2010 engineering majors by PLTW participation.

Group	Withdrew from university *n* (%)	Completed engineering degree *n* (%)	Completed degree other than engineering *n* (%)	Total *n* (%)
No-PLTW	244 (32.6)	272 (36.4)	129 (17.2)	645 (86.2)
PLTW	42 (5.6)	46 (6.1)	15 (2.0)	103 (13.8)
Total	286 (38.2)	318 (42.5)	144 (19.3)	748 (100.0)

Table 3
Retention of first-year 2010 engineering majors by PLTW participation and gender, race, and financial need.

Controlling variable		Withdrew from university *n* (%)	Completed engineering degree *n* (%)	Completed degree other than engineering *n* (%)	Total *n* (%)
Gender					
Male	No-PLTW	210 (34.3)	222 (36.2)	95 (15.5)	527 (86.0)
	PLTW	37 (6.0)	39 (6.4)	10 (1.6)	86 (14.0)
	Total	247 (40.3)	261 (42.6)	105 (17.1)	613 (100.0)
Female	No-PLTW	34 (25.2)	50 (37.0)	34 (25.2)	118 (87.4)
	PLTW	5 (3.7)	7 (5.2)	5 (3.7)	17 (12.6)
	Total	39 (28.9)	57 (42.2)	39 (28.9)	135 (100.0)
Race					
White	No-PLTW	188 (30.7)	232 (37.9)	112 (18.3)	532 (86.9)
	PLTW	31 (5.1)	38 (6.2)	11 (1.8)	80 (13.1)
	Total	219 (35.8)	270 (44.1)	123 (20.1)	612 (100.0)
Native American	No-PLTW	24 (37.5)	20 (31.3)	7 (10.9)	51 (79.7)
	PLTW	8 (12.5)	3 (4.7)	2 (3.1)	13 (20.3)
	Total	32 (50.0)	23 (35.9)	9 (14.1)	64 (100.0)
Black/African American	No-PLTW	15 (51.7)	8 (27.6)	2 (6.9)	25 (86.2)
	PLTW	0 (0.0)	3 (10.3)	1 (3.4)	4 (13.8)
	Total	15 (51.7)	11 (37.9)	3 (10.3)	29 (100.0)
Hispanic	No-PLTW	8 (44.4)	4 (22.2)	3 (16.7)	15 (83.3)
	PLTW	2 (11.1)	1 (5.6)	0 (0.0)	3 (16.7)
	Total	10 (55.6)	5 (27.8)	3 (16.7)	18 (100.0)
Asian American	No-PLTW	9 (36.0)	8 (32.0)	5 (20.0)	22 (88.0)
	PLTW	1 (4.0)	1 (4.0)	1 (4.0)	3 (12.0)
	Total	10 (40.0)	9 (36.0)	6 (24.0)	25 (100.0)
Financial need[a]					
0	No-PLTW	36 (25.0)	51 (35.4)	26 (18.1)	113 (78.5)
	PLTW	13 (9.0)	12 (8.3)	6 (4.2)	31 (21.5)
	Total	49 (34.0)	63 (43.8)	32 (22.2)	144 (100.0)
1	No-PLTW	31 (27.9)	49 (44.1)	20 (18.0)	100 (90.1)
	PLTW	3 (2.7)	6 (5.4)	2 (1.8)	11 (9.9)
	Total	34 (30.6)	55 (49.5)	22 (19.8)	111 (100.0)
2	No-PLTW	13 (29.5)	13 (29.5)	11 (25.0)	37 (84.1)
	PLTW	1 (2.3)	3 (6.8)	3 (6.8)	7 (15.9)
	Total	14 (31.8)	16 (36.4)	14 (31.8)	44 (100.0)
3	No-PLTW	19 (40.4)	15 (31.9)	4 (8.5)	38 (80.9)
	PLTW	6 (12.8)	2 (4.3)	1 (2.1)	9 (19.1)
	Total	25 (53.2)	17 (36.2)	5 (10.6)	47 (100.0)
4	No-PLTW	18 (38.3)	16 (34.0)	9 (19.1)	43 (91.5)
	PLTW	2 (4.3)	2 (4.3)	0 (0.0)	4 (8.5)
	Total	20 (42.6)	18 (38.3)	9 (19.1)	47 (100.0)
5	No-PLTW	68 (43.0)	50 (31.6)	23 (14.6)	141 (89.2)
	PLTW	9 (5.7)	7 (4.4)	1 (0.6)	17 (10.8)
	Total	77 (48.7)	57 (36.1)	24 (15.2)	158 (100.0)
No FAFSA score	No-PLTW	59 (34.1)	78 (45.1)	36 (20.8)	173 (87.8)
	PLTW	8 (33.3)	14 (58.3)	2 (8.3)	24 (12.2)
	Total	67 (34.0)	92 (46.7)	38 (19.3)	197 (100.0)

[a]Financial need was measured using the Free Application for Federal Student Aid (FAFSA).

second year is not significantly different from the proportion of No-PLTW students who were also retained.

Controlling for student race, researchers used a chi square test of independence to determine any association between student retention in engineering and PLTW participation (see Table 3) for the categories of White and Native American. Due to small cell sizes, the Fisher–Freeman–Halton test was used for all other categories. The chi square test indicated no significant association among students classified as White (X^2 (2, n = 612) = 2.310, p = 0.315) or Native American (X^2 (2, n = 64) = 1.205, p = 0.547). Additionally, the Fisher–Freeman–Halton test indicated no significant association among African American (p = 1.000), Hispanic (p = 1.000), or Asian American (p = 1.000) students' retention. Researchers further aggregated these subgroups to check for difference between majority (White and Asian American) and minority groups (all others); again, no differences were found between the majority (X^2 (2, n = 635) = 1.928, p = 0.381) and minority groups (X^2 (2, n = 113) = 0.022, p = 0.989). Thus, when controlling for student race the proportion of PLTW students who were retained is not significantly different from the proportion of No-PLTW students who were retained.

Researchers used a chi square test of independence to examine for any relationship between retention in engineering and PLTW participation while controlling for financial need (see Table 3). Scores from the Free Application for Federal Student Aid (FAFSA) were used to determine student financial need. Scores range from five (highest need) to zero (no need). Some students did not have a FAFSA score and these students were placed into a separate group: No FAFSA score. The chi square test of independence for the scores of zero, five, and no FAFSA indicated no relationship between retention in engineering and PLTW participation while controlling for financial need (0: no need (X^2 (2, n = 144) = 1.102, p = 0.577); 5: high need (X^2 (2, n = 205) = 2.246, p = 0.325); or No FAFSA score (X^2 (2, n = 197) = 2.496, p = 0.287)). The Fisher–Freeman–Halton test indicated no association while controlling for levels of needs one (p = 1.000), two (p = 1.672), three (p = 1.576), and four (p = 1.827). Thus, results indicated no relationship between retention in engineering and PLTW participation while controlling for financial need.

Researchers used a Fisher–Freeman–Halton test to examine for difference in retention in engineering as related to PLTW participation and depth of PLTW (see Table 4). Depth of PLTW participation was measured as the number of PLTW courses that a student had completed in high school. As such, this analysis only examined the students who had participated in PLTW during high school (n = 103). Of those that took PLTW courses in high school, nearly two-thirds had taken two or fewer PLTW courses (n = 64, or 62%). Only seven students (6.7%) took a sequence of six PLTW courses, which included the capstone course: engineering design and development. The Fisher–Freeman–Halton test indicated no association (p = 0.074) with regard to the number of PLTW courses that students completed in high school and whether they completed an engineering degree.

Research Question 2: First to Second Year Retention

Researchers explored students' retention from their first to second year in college by analyzing college transcripts from the Fall 2015 semester to determine whether they (a) continued as an engineering major; (b) switched to a degree other than engineering; or (c) withdrew from the university, as a function of PLTW participation (see Table 5). A chi square test of independence indicated that there was a significant difference among the groups (X^2 (2, n = 927) = 10.030, p = 0.007). Post hoc analysis using an adjusted residual revealed that the proportion of PLTW students retained (n = 159) into their second year in engineering was at a higher rate than expected (n = 141.3). In contrast to this finding, the proportion of No-PLTW students (n = 499) retained into their second year in college as an engineering major was at a lower rate than expected (n = 516.7).

To test for further differences that may exist, we examined level of retention while controlling for gender, race, and financial need. Researchers used a chi square test of independence to explore any relationship between retention in engineering and PLTW participation while controlling for gender (see Table 6). A chi square test of independence indicated no significant difference for females (X^2 (2, n = 196) = 0.667, p = 0.716); however, for males there was a significant difference (X^2 (2, n = 731) = 9.543, p = 0.008). From a post hoc analysis using

Table 4
Retention of first-year 2010 engineering majors by PLTW participation and depth of participation.

Number of PLTW courses	Withdrew from university *n* (%)	Completed engineering degree *n* (%)	Completed degree other than engineering *n* (%)	Total *n* (%)
1	9 (34.6)	10 (38.5)	7 (26.9)	26 (25.2)
2	11 (28.9)	23 (60.5)	4 (10.5)	38 (36.9)
3	4 (30.8)	8 (61.5)	1 (7.7)	13 (12.6)
4	10 (83.3)	12 (16.7)	0 (0.0)	12 (11.7)
5	4 (57.1)	2 (28.6)	1 (14.3)	7 (6.8)
6	4 (57.1)	1 (14.3)	2 (28.6)	7 (6.8)
Total	42 (40.8)	46 (44.7)	15 (14.6)	103 (100.0)

Table 5
Retention of first-year 2015 engineering majors into their second year by PLTW participation.

Group	Withdrew from university *n* (%)	Persisted in an engineering degree *n* (%)	Persisted in degree other than engineering *n* (%)	Total *n* (%)
No-PLTW	120 (16.5)	499 (68.5)	109 (15.0)	728 (78.5)
PLTW	19 (9.5)	159 (79.9)	21 (10.6)	199 (21.5)
Total	139 (15.0)	658 (71.0)	130 (14.0)	927 (100.0)

adjusted residuals, it was found that the percentage of males (69.4%) who did not participate in PLTW but persisted in an engineering degree into their second year was significantly lower than the overall expected average percentage (71%) for the sample of 927 students as a whole. In comparison, the percentage of males (81.5%) who did participate in PLTW and persisted in an engineering degree into their second year was significantly higher than the overall expected average percentage (71%) for the sample of 927 students as a whole.

Next, researchers controlled for the race of students (see Table 6). A chi square test of independence indicated that there was no significant difference among students classified as White (X^2 (2, n = 639) = 2.980, p = 0.225). Additionally, the Fisher–Freeman–Halton test indicated no significant difference among students classified as Native American (p = 0.130), African American (p = 0.843), Hispanic (p = 0.205), or Asian American (p = 1.000). However, there was a significant difference among students identifying as multiracial (X^2 (2, n = 96) = 6.200, p = 0.045). Post hoc analysis for the multiracial group, however, did not reveal any significant differences in the proportion of students who persisted based on their PLTW participation. These results suggest that race does not affect the association of first to second year retention and PLTW participation.

Researchers further aggregated these subgroups to check for difference between majority (White and Asian American) and minority groups (all others). Results revealed that no differences were found (X^2 (2, n = 674) = 3.193, p = 0.203) among the majority group; however, there was a significant difference in minority groups (X^2 (2, n = 253) = 10.026, p = 0.007). For the minority groups the proportion of No-PLTW students (n = 49) that withdrew from college prior to starting their second year was significantly different from the expected number (n = 41.7). For the minority PLTW students there was a significant difference in the proportion of students who withdrew from college prior to starting their second year (n = 3) versus the expected number (n = 10.3). Additionally, minority PLTW students had a higher level of retention to remain as an engineering major (n = 42) during their second year in comparison to the expected count (n = 33). Findings indicate that minority students who participated in PLTW tended to persist at a higher proportion than expected, while minority students who had not participated in a PLTW course had a lower-than-expected retention rate. Additionally, minority PLTW students withdrew from their first to second year at significantly lower rate than expected.

Researchers used a chi square test of independence to examine for difference in first to second year retention in engineering as related to PLTW participation while controlling for financial need (see Table 6), using a Fisher–Freeman–Halton extension when all assumptions were not met. A chi square test of independence indicated no significant difference among students classified, based on FAFSA rating levels, as 0: no need (X^2 (2, n = 283) = 0.649, p = 0.723), level 1 need (X^2 (2, n = 156) = 3.550, p = 0.169), or 5: high need (X^2 (2, n = 200) = 5.115, p = 0.077). Additionally, results of the Fisher–Freeman–Halton test indicated no significant difference among students classified with a FAFSA rating of two (p = 0.247), three (p = 1.000), four (p = 0.352), or no rating available (p = 0.567). These results suggest that financial need does not influence the association between a students' PLTW participation and their retention from first to second year.

Researchers used a Fisher–Freeman–Halton test to examine for differences in retention in engineering as related to PLTW participation while controlling for depth of PLTW participation (see Table 7). Depth of PLTW participation was equal to the number of PLTW courses that a student had completed in high school. As such, this analysis only examined the students who had participated in PLTW during high school (n = 199). Of those that took PLTW courses in high school, slightly more than one-third had two or fewer PLTW courses (n = 74, or 37%). Thirty-six students (19%) took a sequence of six or seven PLTW courses; all but one of these students completed the engineering design capstone course. Researchers found no association (p = 0.424) which accounted for depth of students' PLTW participation and their retention from first to second year in college.

Discussion

With regard to the students who entered the university as first-years during the Fall 2010 semester, no differences were found in levels of engineering degree completion regardless of whether or not the student participated in PLTW during high school. While these findings are consistent with findings by Cole, High, and Weinland (2013), who explored whether PLTW participation contributed to retention in engineering in a five-year span, the number of PLTW participants was small at the time. Additionally, this

Table 6
Retention of first-year 2015 engineering majors by PLTW participation and gender, race, and financial need.

Controlling variable		Withdrew from university *n* (%)	Stayed in an engineering degree *n* (%)	Stayed in degree other than engineering *n* (%)	Total *n* (%)
Gender					
Male	No-PLTW	95 (13.0)	391 (53.5)	77 (10.5)	563 (77.0)
	PLTW	16 (2.2)	137 (18.7)	15 (2.1)	168 (23.0)
	Total	111 (15.2)	528 (72.2)	92 (12.6)	731 (100.0)
Female	No-PLTW	25 (12.8)	108 (55.1)	32 (16.3)	165 (84.2)
	PLTW	3 (1.5)	22 (11.2)	6 (3.1)	31 (15.8)
	Total	28 (14.3)	130 (66.3)	38 (19.4)	196 (100.0)
Race					
White	No-PLTW	64 (10.0)	353 (55.2)	79 (12.4)	496 (77.6)
	PLTW	15 (2.3)	112 (17.5)	16 (2.5)	143 (22.4)
	Total	79 (12.4)	465 (72.8)	95 (14.9)	639 (100.0)
Native American	No-PLTW	10 (27.8)	18 (50.0)	1 (2.8)	29 (80.6)
	PLTW	0 (0.0)	7 (19.4)	0 (0.0)	7 (19.4)
	Total	10 (27.8)	25 (69.4)	1 (2.8)	36 (100.0)
Black/African American	No-PLTW	6 (22.2)	10 (37.0)	2 (7.4)	18 (66.7)
	PLTW	2 (7.4)	6 (22.2)	1 (3.7)	9 (33.3)
	Total	8 (29.6)	16 (59.3)	3 (11.1)	27 (100.0)
Hispanic	No-PLTW	20 (21.3)	51 (54.3)	7 (7.4)	78 (83.0)
	PLTW	1 (1.1)	13 (13.8)	2 (2.1)	16 (17.0)
	Total	21 (22.3)	64 (68.1)	9 (9.6)	94 (100.0)
Asian American	No-PLTW	7 (20.0)	21 (60.0)	1 (2.9)	29 (82.9)
	PLTW	1 (2.9)	5 (14.3)	0 (0.0)	6 (17.1)
	Total	8 (22.9)	26 (74.3)	1 (2.9)	35 (100.0)
Multiracial	No-PLTW	13 (13.5)	46 (47.9)	19 (19.8)	78 (81.3)
	PLTW	0 (0.0)	16 (16.7)	2 (2.1)	18 (18.8)
	Total	13 (13.5)	62 (64.6)	21 (21.9)	96 (100.0)
Financial need[a]					
0: no need	No-PLTW	22 (7.8)	162 (57.2)	30 (10.6)	214 (75.6)
	PLTW	5 (1.8)	55 (19.4)	9 (3.2)	69 (24.4)
	Total	27 (9.5)	217 (76.7)	39 (13.8)	283 (100.0)
1	No-PLTW	22 (14.1)	77 (49.4)	20 (12.8)	119 (76.3)
	PLTW	4 (2.6)	30 (19.2)	3 (1.9)	37 (23.7)
	Total	26 (16.7)	107 (68.6)	23 (14.7)	156 (100.0)
2	No-PLTW	7 (14.6)	23 (47.9)	8 (16.7)	38 (79.2)
	PLTW	1 (2.1)	9 (18.8)	0 (0.0)	10 (20.8)
	Total	8 (16.7)	32 (66.7)	8 (16.7)	48 (100.0)
3	No-PLTW	3 (7.3)	23 (56.1)	4 (9.8)	30 (73.2)
	PLTW	1 (2.4)	9 (22.0)	1 (2.4)	11 (26.8)
	Total	4 (9.8)	32 (78.0)	5 (12.2)	41 (100.0)
4	No-PLTW	6 (10.0)	33 (55.0)	7 (11.7)	46 (76.7)
	PLTW	2 (3.3)	12 (20.0)	0 (0.0)	14 (23.3)
	Total	8 (13.3)	45 (75.0)	7 (11.7)	60 (100.0)
5: high need	No-PLTW	43 (21.5)	96 (48.0)	21 (10.5)	160 (80.0)
	PLTW	4 (2.0)	29 (14.5)	7 (3.5)	40 (20.0)
	Total	47 (23.5)	125 (62.5)	28 (14.0)	200 (100.0)
No FAFSA score	No-PLTW	17 (12.2)	85 (61.2)	19 (13.7)	121 (87.1)
	PLTW	2 (1.4)	15 (10.8)	1 (0.7)	18 (12.9)
	Total	19 (13.7)	100 (71.9)	20 (14.4)	139 (100.0)

[a]Financial need was measured using the Free Application for Federal Student Aid (FAFSA).

Table 7
Examination of the retention of first-year 2010 engineering majors who participated in PLTW by depth of participation in PLTW.

Number of PLTW courses	Withdrew from university *n* (%)	Persisted in an engineering degree *n* (%)	Persisted in degree other than engineering *n* (%)	Total *n* (%)
1	5 (12.5)	28 (70.0)	7 (17.5)	40 (20.1)
2	5 (14.7)	26 (76.5)	3 (8.8)	34 (17.1)
3	1 (5.0)	17 (85.0)	2 (10.0)	20 (10.1)
4	5 (11.9)	32 (76.2)	5 (11.9)	42 (21.1)
5	0 (0.0)	23 (88.5)	3 (11.5)	26 (13.1)
6	3 (8.6)	31 (88.6)	1 (2.9)	35 (17.6)
7	0 (0.0)	1 (100.0)	0 (0.0)	1 (0.5)
Total	19 (9.5)	159 (79.9)	21 (10.6)	199 (100.0)

study adds to this previous research by disaggregating the participant pool to control for differences across gender, ethnicity, financial need, and the number of PLTW courses taken in high school. Results indicated no relationships between retention in engineering and PLTW participation when controlling for each factor, except for the number of PLTW courses taken in high school. A post hoc analysis determined that those students who took four PLTW courses had a stronger association of withdrawing from college. As noted earlier, students withdraw from higher education institutions for a variety of reasons, and it would be ideal to learn from students in this study their reason for not only withdrawing from college but also their rationale for changing degrees. These findings suggest that retention in engineering degree programs is not dependent upon whether the students participated in the pre-engineering program PLTW. Thus, the question remains: do pre-college engineering programs promote a higher rate of degree completion?

When examining the retention of first-year (Fall 2015) students into their second year, findings suggested that PLTW students were retained into their second year at a higher rate than were No-PLTW students. While controlling for gender, findings suggested that the PLTW males persisted into their second year at a higher rate than No-PLTW males. When controlling for race, no relationship between retention and PLTW participation was found. However, when looking at race from a majority/minority category split, it was found that minority students who participated in PLTW were retained into their second year at a rate higher than expected, while minority students who had not participated in a PLTW course actually had a lower-than-expected retention rate. Additionally, minority PLTW students withdrew from their first to second year at a significantly lower rate than expected. Future research through interviews and/or surveys with students would allow researchers to delve into this phenomenon. Is it because they were already familiar with engineering concepts? Is it for another reason entirely? Or did it just happen to be the case for this particular group of students?

A goal of PLTW is to introduce a diverse array of students to engineering and to recruit them into STEM fields. This research suggests that white males are still the predominate audience for the program. If minority students persist at a higher rate following participation in PLTW, how can a more diverse PLTW population of students be recruited? As Early (2017) suggested, do admission requirements and marketing materials bias recruitment toward a white male student population? In Early's study, the majority of students had to leave their home school and spend a half day at a career technology center. Does this influence the number of students participating in PLTW and particularly the number of minority students? Would moving PLTW into home schools rather than being housed in technology centers recruit a more diverse group of students?

Limitations and Implications for Future Research

Examination of research literature on PLTW revealed that much of this research has been conducted by those affiliated with the implementation of the program and thus is not external in nature; this may result in a level of bias. Additionally, little research has been done on the influence of pre-college engineering programs on retention in engineering degrees. What about other pre-college engineering programs and their influence? Research studies that compare various pre-college engineering programs and their influence are needed, including looking at the cost of the programs as a mitigating factor. With PLTW's curriculum being a costly program (i.e., teacher training and materials for implementation) for schools to implement, how does this compare to other pre-engineering programs' costs and their influence on retention? Further, does fidelity of implementation of the curriculum play a role in the retention of engineering majors?

As with any study, this study also has its limitations. First, this study was limited to two groups of students at one institution who entered as engineering majors during two particular semesters (i.e., Fall 2010 and Fall 2015). A deeper and broader study of more engineering majors is needed to determine any connection between retention in engineering degrees and participation in PLTW.

As this study was completed by analyzing transcripts, other factors, such as non-academics ones, were not considered. For instance, no attempts were made to capture the reason why students might have left the institution or changed to a non-engineering major. Further, evaluation of high school transcripts only took into account PLTW course completion and not the rigor and quality of the course. As with any replicated program, questions and considerations of program fidelity of implementation come into play. This study cannot address fidelity of implementation. Given the nature of this study, researchers were not able to address how students were recruited in PTLW. Further, this study was not able to address affective measures of grit (Duckworth, Peterson, Matthews, & Kelly 2007), mindset (Dweck, 2006), and program–student fit. However, we recommend that future studies examine the effect of pre-engineering programs on student retention in combination with these other measures. Further, the researchers recommend that more longitudinal studies of all students leaving high school PLTW programs should be conducted by external researchers to determine the effectiveness of PLTW to recruit and retain students into engineering.

The findings from this study offer little support of the impact of students' PLTW participation on engineering degree completion. In contrast, findings do suggest some support for the impact of PLTW participation on retention from students' first to second year, particularly among minority first-years. However, more research is needed to study a broader range of students, allowing a more comprehensive understanding of the influence of PLTW on the ability of students to be retained in engineering.

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