Final Report of the Impact of Project Lead the Way on Missouri High School Students

A report to the KC STEM Alliance

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Executive Summary

This report examines the potential impact of Project Lead the Way (PLTW) on two cohorts of Missouri students who began high school in 2013 and 2014 (145,619 students). These students were tracked through high school and into post-secondary education and training programs up to and including academic year 2019-2020. PLTW is a K-12 problem-based curriculum designed to increase science, technology, engineering and mathematics (STEM) interest, skills, and workforce readiness. The program was offered in approximately 17 percent of Missouri high schools during the study's time period. Thirteen percent of all cohort members enrolled in at least one PLTW course. Students who took PLTW courses outperformed those who did not on all high school and college outcomes examined, and these positive outcomes persisted even after controlling for school and student characteristics, including students' achievement prior to high school. Differences between students who did and did not take PLTW courses were substantially larger for those who took two or more PLTW courses compared to those taking only a single PLTW course. The estimated difference was at least twice as large for those taking two or more PLTW courses for all but three outcomes (high school graduation, enrollment in dual credit courses in high school, remedial course taking in college).

Summary of findings

Rollout of PLTW in the state

- PLTW has grown rapidly, first offered in 10 Missouri districts in 2005, and offered in 384 schools in 163 districts across the state in 2020
- Growth in high school implementation has been accompanied by an expansion of the PLTW curriculum from classes in one pathway (Engineering only) to three pathways (Engineering, Biomedical Science and Computer Science)

Participating schools and students

- High schools offering PLTW courses are more likely to be in suburban communities (51 percent) with enrollments of 500 or more students (89 percent)
- Within PLTW schools, PLTW credit earners are more likely to be White, less likely to be African American, and less likely to be from a lower income family
- There are more male than female PLTW credit earners and students' choice of PLTW pathways differ by gender. Females strongly outnumber males in Biomedical Science and males greatly outnumber females in Computer Science and Engineering
- PLTW credit earners had higher 8th grade achievement in math, science and English/Language Arts than non-participants

Potential PLTW impact among all cohort members

- PLTW course takers were more likely to take dual credit courses in high school, to graduate from high school, to enroll in college, and to declare a STEM major upon initial enrollment in college.
- All race and gender subgroups have likely benefitted from PLTW. However, there is variability in the magnitude of PLTW benefits by race and gender subgroups. A number of subgroup results are noteworthy.
    - Black and Hispanic males seemed to have benefited more from taking multiple PLTW courses than White males on the following outcomes: dual credit enrollment in high school, high school graduation, and enrollment in postsecondary education.
    - However, taking 2 or more PLTW courses made a smaller difference for Black and Hispanic males' STEM program enrollment in college compared to White males.

Potential PLTW impact among those attending Missouri public colleges and universities

We examined detailed post-secondary data for cohort members who enrolled in Missouri public two or four year institutions following graduation to estimate differences in retention, completion, and choice of major for PLTW course takers.

- PLTW participants attending Missouri public colleges and universities are more likely to enroll in bachelor's degree programs, bypass remedial courses, enroll in STEM degree programs, and to complete or be making progress towards a bachelor's degree and a STEM degree
- Students attending college in Missouri public institutions in all race and gender subgroups likely benefitted from PLTW. However, there is variability in the magnitude of PLTW benefits by race and gender subgroups. A number of subgroup results are noteworthy.
    - Among females, we found that the increase in STEM enrollment associated with taking 2 or more PLTW courses was smaller for Black and Hispanic students than for White students. A similar result was found for Black females in progress towards completing a STEM degree.
    - Black and Hispanic males taking two or more PLTW courses also appear to have benefitted less from PLTW than White males in terms of progress towards bachelor's degrees and STEM degree completion

We caution that this study reports only correlational evidence. Another limitation is that when the two cohorts of students were in high school, only a relatively small number of Missouri high schools offered PLTW, and in these schools, only a small fraction of students took advantage of this opportunity. Since then, the program has grown substantially. It is possible that later, and larger, cohorts of PLTW participants may have experiences that differ from the earlier PLTW students analyzed in the study.

Nonetheless, our results provide suggestive evidence that more widespread implementation of the program is likely to help more Missouri high school students make the transition to postsecondary education and pursue STEM degrees. The next phase of the study will use more data and a more rigorous study design to better estimate PLTW's causal impact, and to better understand who benefits from the program, and under what conditions.

The report is organized into three sections. Section 1 provides context for the study by presenting PLTW program expansion in Missouri since 2005 and by describing the characteristics of schools offering the program and characteristics of students who participated in the program. Section 2 focuses on the outcomes of all cohort members, examining how PLTW course enrollment is related to the following outcomes: enrollment in high school dual credit courses, high school graduation, enrollment in postsecondary education, and declaration of a STEM major in college. Section 3 presents parallel analyses for the subset of cohort members who attended Missouri public colleges. These 44,170 students constitute 30 percent of the entire cohort and nearly 70 percent of the more than 63,000 cohort members who went on to college directly after finishing high school. Using Missouri public college data, we examine: remedial course enrollment, bachelor's degree enrollment, STEM program enrollment, progress towards completing a bachelor's degree and progress towards completing a STEM degree.

Introduction

Project Lead the Way (PLTW) is a curriculum designed to increase students' interest, skills, and readiness for careers in science, technology, engineering and/or mathematics (STEM). The curriculum uses hands-on activities, projects, and problems to help students connect classroom learning with real world applications (Project Lead The Way 2021b). Started in 1997 with an initial high school engineering pathway program, PLTW's curricular offerings have grown to five programs that span the P-12 continuum: Launch (P-5), Gateway (6-8), Engineering (9-12), Computer Science (9-12) and Biomedical Science (9-12). In 2020, PLTW was available in over 12,200 schools across the United States (PLTW, 2021a).

In 2005, Missouri launched the PLTW program in 10 districts and 16 schools. Program implementation and enrollments have grown steadily with PLTW courses offered in 384 schools in 163 districts by the end of the 2019-20 school year. The increased availability and popularity of the PLTW curriculum reflects a growing awareness in Missouri and across the nation that students pursuing STEM careers need robust STEM learning experiences in high school.

The three high school pathway programs—Engineering, Computer Science, and Biomedical Science—are designed to build knowledge and skills through scaffolded learning experiences. Introductory courses are intended to develop an understanding of and enthusiasm for the field. Advanced courses are designed to extend learning through deeper and more specialized content. Schools may choose from a variety of specialized courses. The Engineering and Biomedical Science pathways end with a capstone course which requires students to take their own idea from design through development.

PLTW's curriculum contains detailed daily lesson plans, an implementation guide, and online resources. All PLTW teachers are required to complete a two-week professional development program before they teach a PLTW course. Professional development is led by national trainers and experienced PLTW teachers (master teachers) and covers both course content and application of that content, with a heavy emphasis on the pedagogical approach of project-based learning.

To date, there have been about a half dozen studies that have investigated PLTW. A brief summary of this research can be found in Appendix A. This study extends the research base on PLTW in several ways. First, we distinguish three different levels of PLTW participation: enrolling in no PLTW courses, one PLTW course, and two or more PLTW courses. This enables us to determine if more PLTW participation is associated with better outcomes. Second, we examine how PLTW participation is related to postsecondary outcomes, a relatively new area of exploration. By linking high school transcript data with data from the National Student Clearinghouse (NSC) and Missouri Department of Higher Education and Workforce Development (DHEWD) we are able to

generate estimates of student success after high school for PLTW participants. Finally, using two cohorts of first-time freshmen attending all Missouri public high schools, our study provides a unique opportunity to assess the outcomes of PLTW for a large, diverse set of students and schools. Our analytic population includes 145,619 students, 13% of which enrolled in at least one PLTW course. With this robust population, we are able to examine outcome differences between PLTW participants and non-participants by gender and race/ethnicity. This will tell us whether specific subgroups of PLTW participants had better outcomes than their counterparts who did not participate in PLTW.

Three questions guided our investigation:

- How do the high school outcomes of PLTW participants differ from those of non-participants?
- How do the postsecondary outcomes of PLTW participants differ from those of non-participants?
- What are the differential benefits of PLTW participation for different demographic groups?

The next section describes the data used for the study. To contextualize our findings, we discuss the rollout of the PLTW program in Missouri from 2005 to 2020. Following that, we present the results of analyses using administrative student data from 2 cohorts of first-time 9th-grade students.

Data

School-level and student-level data used for this study were obtained from the Missouri Department of Elementary and Secondary Education (DESE). The school-level data contained total enrollment and enrollments by demographic characteristics (gender, race, and lunch status) for all schools in the state and records that identified course offerings and corresponding enrollments for the 2005 through 2020 academic years. These data were used to examine the rollout of PLTW courses across the state. School-level data were supplemented by the U.S. Department of Education's Common Core of Data (CCD) for information on the locale of schools (urban, suburban, town and rural) and they were used for the analysis of student program participation and their subsequent outcomes.

Student-level data contained records of students who first enrolled in 9th grade in a Missouri public school in the 2012-2013 school year (AY2013) or the 2013-2014 school year (AY2014). Specifically, the data included:

- School enrollment records,
- Student course enrollments and completions,
- High school graduation status,
- Student demographics (for example, gender, free/reduced lunch status, race/ethnicity),

- 8th-grade Missouri Assessment Program (MAP) scores in math and English Language Arts,
- End Of Course exam scores,
- ACT scores,
- Post-high school status from a graduate follow-up survey reported by school districts,
- College enrollments and majors in the year following high school graduation from the National Student Clearinghouse[1], and
- College enrollments, performance, and completions by major for up to 4 years following high school graduation from DHEWD.

Demographic and pre-high school academic characteristics of 9th-grade cohort students were aggregated to the school level to describe the composition of each school's incoming 9th-grade students. Student course enrollment and completion data were used to measure student PLTW program participation levels and credits earned. The analytic population consisted of the 145,619 first-time 9th-grade students in AY2013 and AY2014 attending 537 high schools.[2]

[1] Every fall, DESE collects data from the NSC on the college enrollment of Missouri high school graduates from the prior school year.

[2] The original student data from DESE included all ninth-grade students, including those who appeared as ninth graders in the records from the previous school year. To define, "first-time" ninth-grade students we removed 3,382 such students from the original data given by DESE.

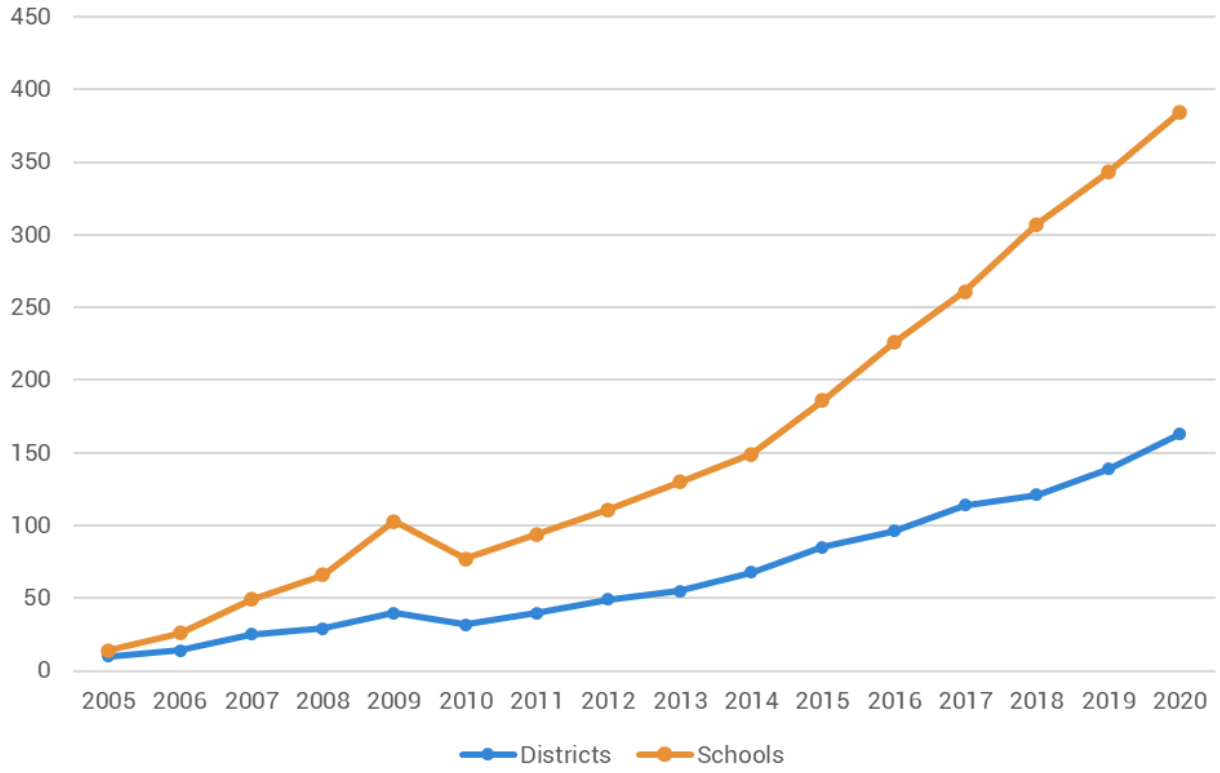
Section 1: PLTW Rollout and Participating Schools and Students

The rollout of PLTW in Missouri

Between 2005 and 2020, implementation of the PLTW program in Missouri grew substantially (Figure 1). This period saw large increases in districts that adopted the program and in students served, particularly after the 2008 recession. The engineering program was the first program to be introduced in the state with 10 districts offering the program in 2005. With the exception of the 2009-2010 period, the number of schools and districts adopting the program has increased every year.

Figure 1

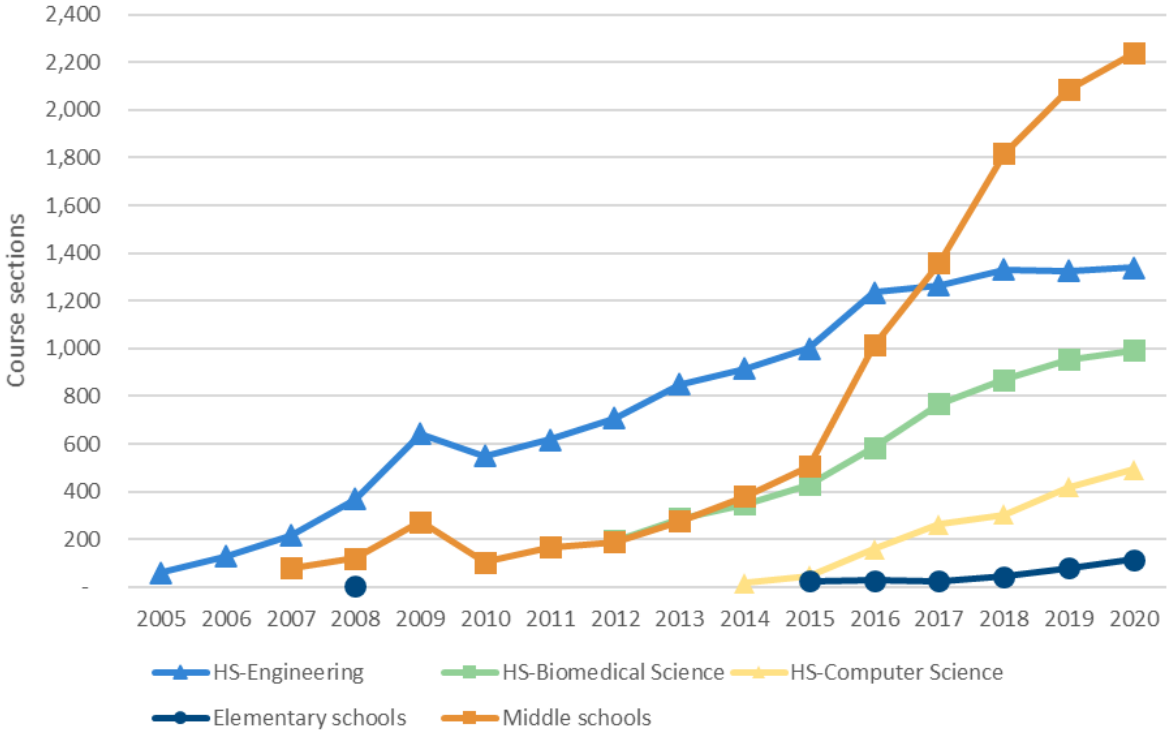
Growth in the number of districts and schools implementing PLTW, 2005-2020



As shown in Figure 2, growth in the number of schools offering the program was accompanied by a major expansion of the PLTW curriculum in the state. The PLTW curriculum implemented in Missouri grew from classes in one topic area in high schools (Engineering) to classes in five topic areas referred to as pathways: *Launch* in elementary schools, *Gateway* in middle schools, and Engineering, Computer Science, and Biomedical Science in high schools. In 2020, PLTW was offered in 384 schools in 163 districts across the state. As Figure 2 illustrates, all three high school pathways and the two introductory courses for pre high school students have demonstrated growth in course offerings since their inception although the timing and degree of expansion differed somewhat by pathways.

Figure 2

Growth in PLTW course offerings by school level and Pathway



High School Expansion: Engineering, the oldest pathway program, has grown from 60 sections in 2005 to 1,338 sections in 2020. Although still the most frequently offered high school program, its growth has slowed in the past five years. The introduction of the Computer Science and Biomedical Science programs may explain some of this slowdown. Biomedical Science, adopted in Missouri in 2012, has grown from 212 sections in 2012 to 991 sections in 2020. Computer Science, adopted in 2015, has grown from 16 sections in 2015 to 493 sections in 2020.

Middle School Expansion: Gateway, the middle school PLTW program grew steadily between 2007 and 2020 accelerating rapidly between 2015 and 2020. During this period, the number of course sections increased by 343 percent. By comparison, the high school PLTW course sections grew by 156 percent over this same time period.[3]

Elementary School Expansion: In the elementary schools, the PLTW Launch curriculum is not delivered through a specific course but through units, lessons, and projects. DESE tracks course delivery by the number of classrooms with PLTW-trained teachers.

[3] The middle school classes generally are offered to students as a 9-week course which generates multiple class sections per teacher per year.

Thus, growth in PLTW at the elementary level reflects classrooms rather than sections offering PLTW Launch. In 2008, six classrooms offered PLTW Launch but all instances disappeared from the data in the following year. The program was dormant until 2015 when 24 elementary classrooms adopted PLTW. Since 2015, Launch has grown from 24 classrooms to 116 classrooms. Although its footprint in Missouri is small compared to the middle and high school programs, it growth has been steady over the past six years.

Characteristics of students and high schools studied

We turn now to an analysis of two cohorts of first time freshmen who began high school in AY2013 and AY2014. Table 1 displays the characteristics of all high schools attended by members of the two 9th grade cohorts (left two columns), schools offering PLTW[4] (middle two columns), and schools that did not offer PLTW (right two columns). Of the 537 high schools, 92 had PLTW courses available to their students and 445 did not. We found that schools that provided PLTW courses were more likely to be in suburban settings with mid to large student enrollments size. In comparison, rural and small schools were much less likely to make PLTW courses available to their students.

Table 1

Characteristics of schools enrolling study cohort members

	All High Schools		School provided PLTW		School did not provide PLTW	
	N	Pct.	N	Pct.	N	Pct.
Sector						
Traditional public high school	524	98%	91	99%	433	97%
Public charter high school	13	2%	1	1%	12	3%
Total	537	100%	92	100%	445	100%
Location						
City	57	11%	18	20%	39	9%
Suburb	78	15%	47	51%	31	7%
Town	96	18%	11	12%	85	19%
Rural	306	57%	16	17%	290	65%
Total	537	100%	92	100%	445	100%
Size						
Fewer than 500 students	368	69%	11	12%	377	81%
500 to 1,199 students	97	18%	29	32%	68	15%
1,200 or more students	72	13%	52	57%	20	4%
Total	537	100%	92	100%	465	100%

Figure 3 shows the racial/ethnic composition of our ninth-grade cohorts. The first two bars on the left represent, respectively, all schools attended by cohort members (all

[4] Schools are defined as offering PLTW programs if at least 1 student took a PLTW course.

schools) and schools that did not offer PLTW (non-PLTW schools). The remaining bars show the race/ethnic compositions of schools that offered PLTW (PLTW schools). The first bar within PLTW schools represents the race/ethnicity of all students attending such schools, and these students were then categorized by their PLTW participation status (i.e., PLTW non-participants and PLTW credit earners). PLTW credit earners were further broken down by the three PLTW Pathways.

We found that PLTW schools enrolled moderately more African American students and fewer White students compared to the state as a whole, and non-PLTW schools. However, within PLTW schools, PLTW credit earners were slightly less likely to be African American and slightly more likely to be White. This pattern was most pronounced in the Computer Science pathway in which credit earners were considerably more likely to be White and considerably less likely to be African American, compared to all students in PLTW schools.

Figure 3

PLTW participation by race/ethnicity

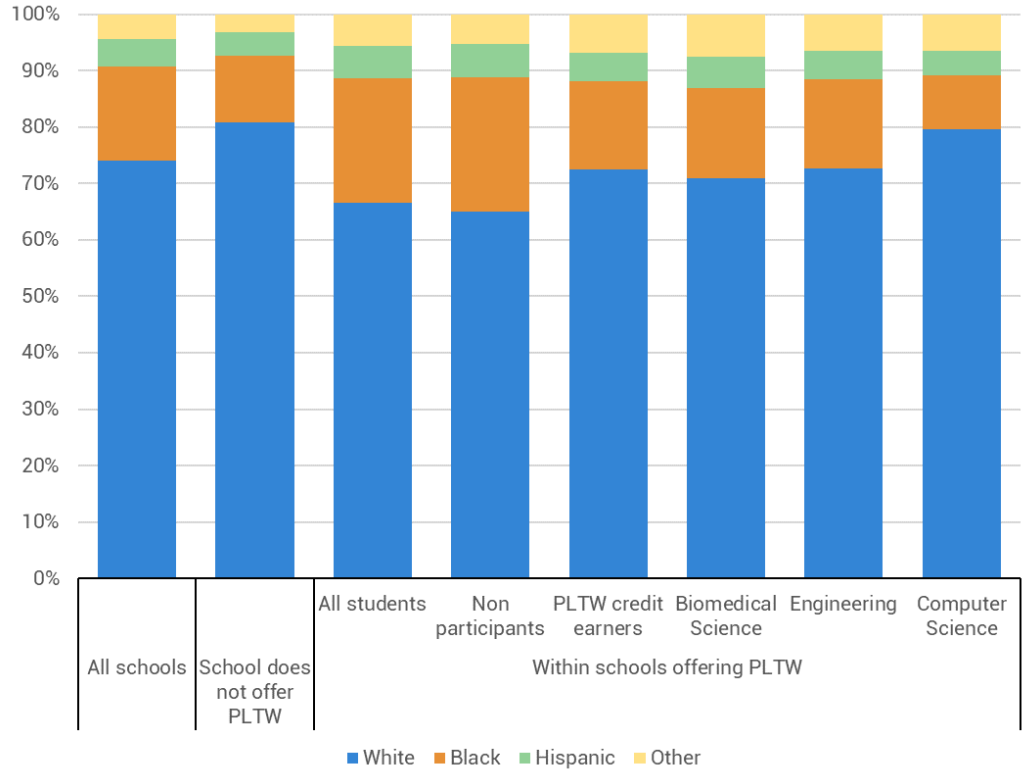


Figure 4 shows the gender distribution of students in the study. Overall, males and females are equally represented in schools that did and did not implement PLTW. However, credit earners were less likely to be female, and the choice of the PLTW pathway differed greatly by gender. Females strongly outnumbered males in the Biomedical Science pathway and males greatly outnumbered females in Computer Science and Engineering.

Figure 4

PLTW participation by gender

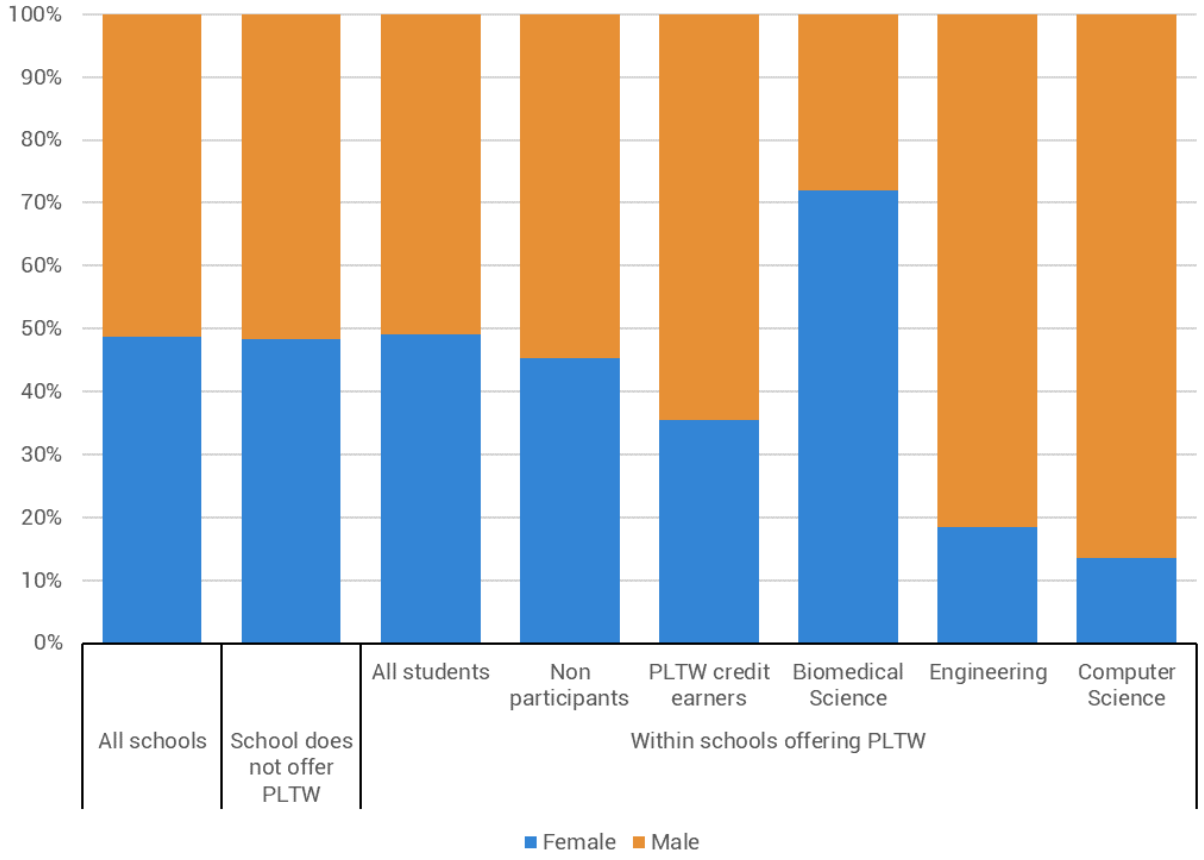
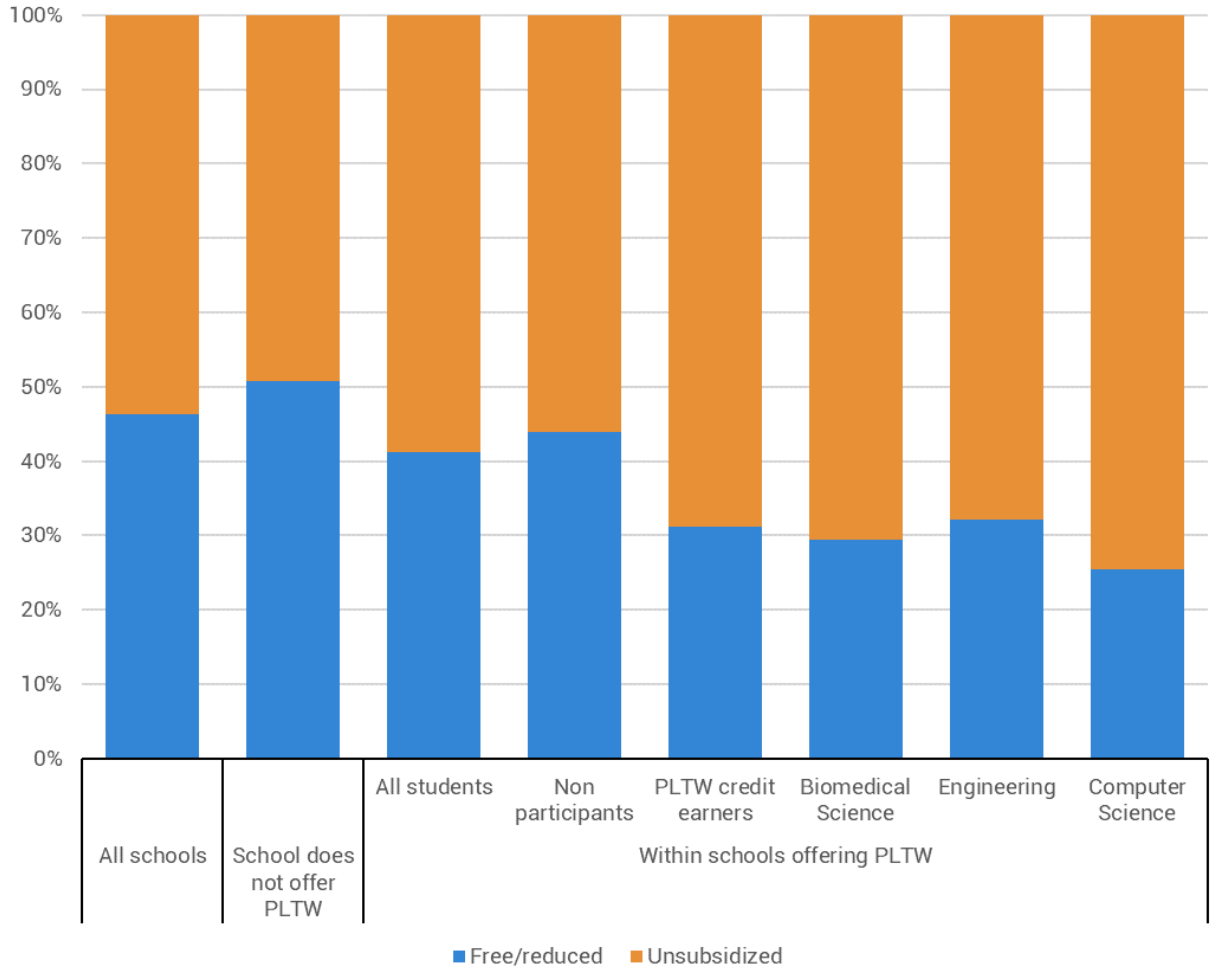


Figure 5 shows the distribution of students' free/reduced price lunch (FRL) status. We found that schools offering PLTW served slightly fewer FRL students than schools not offering the program. In PLTW schools, FRL students were moderately less likely to earn PLTW credit overall and within each pathway.

Figure 5

PLTW participation by free/reduced price lunch status



We next examined academic proficiency levels of cohort members prior to high school using 8th-grade Missouri Assessment Program (MAP) assessment in three subject areas—mathematics, science and English/Language Arts (figures 6, 7, and 8). We found that the average 8th-grade math proficiency was similar between students in schools offering PLTW and students in schools not offering the program. But within PLTW schools, PLTW credit earners had higher 8th-grade math proficiency than non-participants. We saw similar patterns in students' science and English/Language Arts achievement.

Figure 6

PLTW participation by 8th grade MAP math achievement

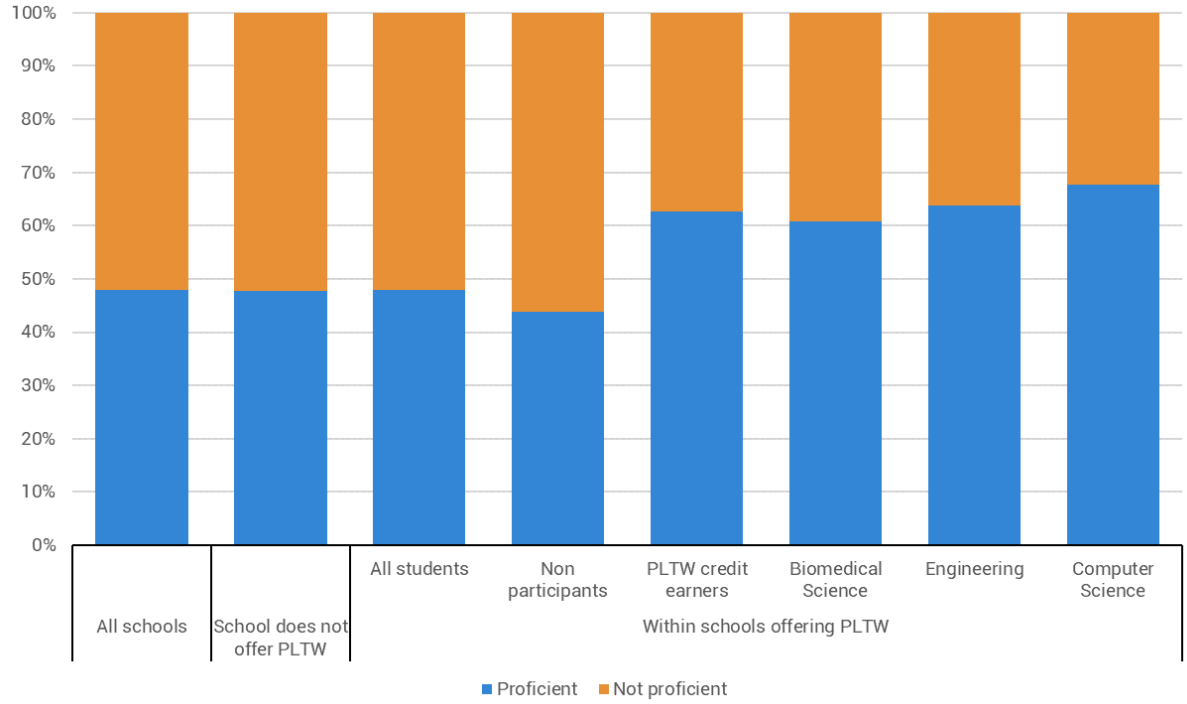


Figure 7

PLTW participation by 8th grade MAP science achievement

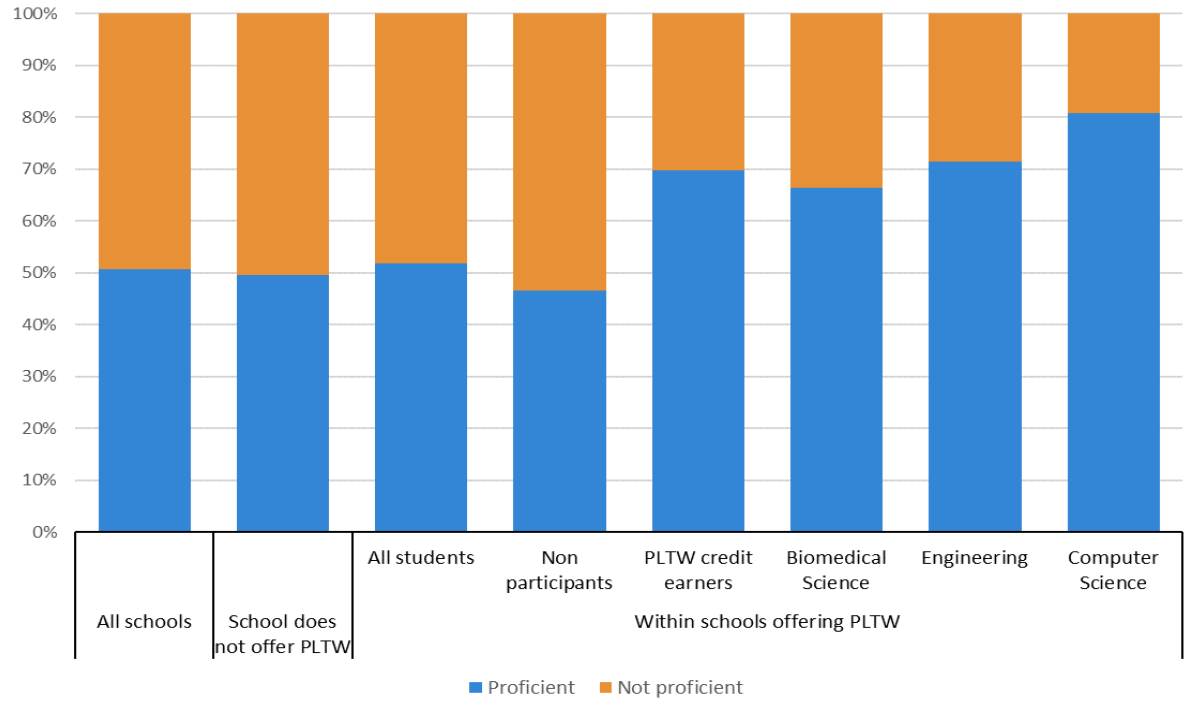
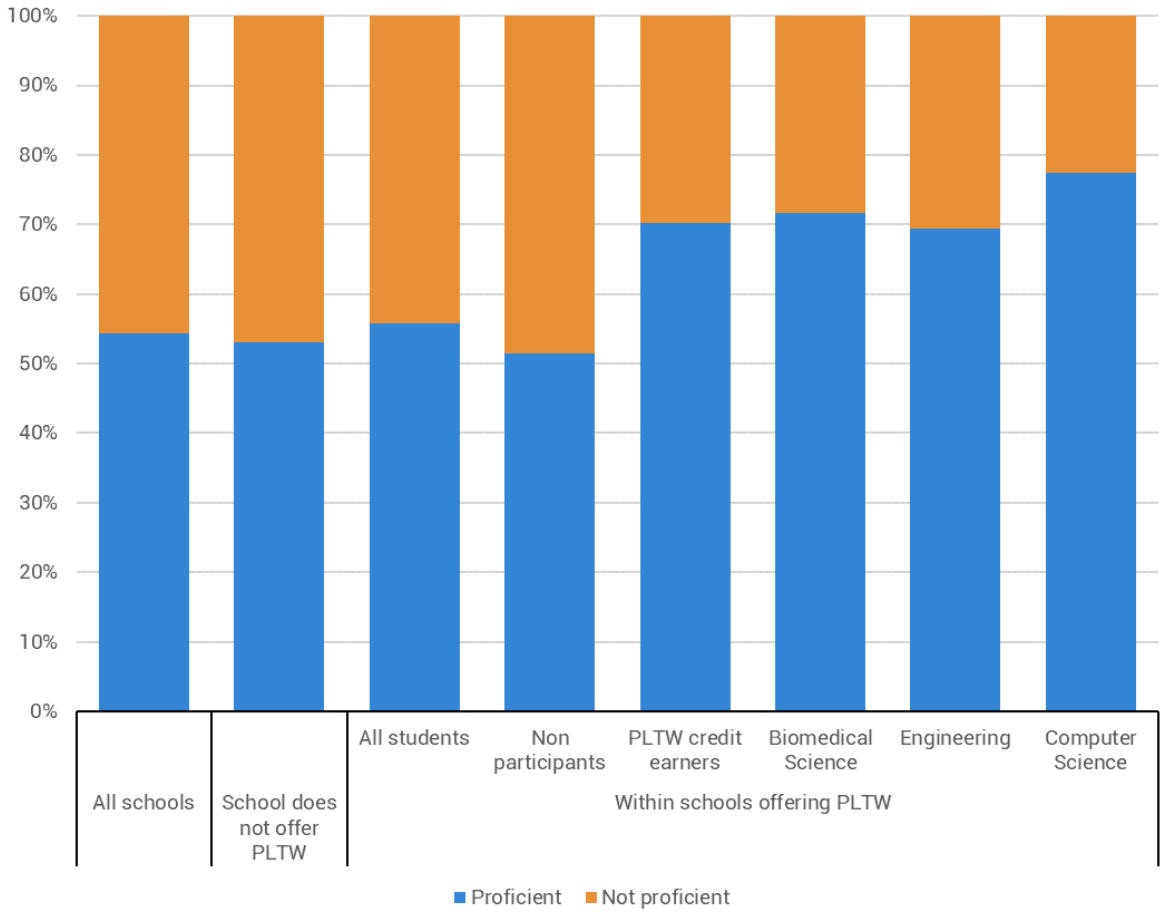


Figure 8

PLTW participation by 8th grade MAP English/language arts achievement



Section 2: High School and Postsecondary Outcomes for all Cohort Members

We now turn to an analysis of how high school and postsecondary outcomes differ by PLTW participation status for all members of the 2013/2014 first time 9th grade cohorts. We begin by examining how schools that do and do not implement PLTW differ on the following high school outcomes: 1) STEM and college credit accumulation during high school, 2) ACT scores, 3) career-technical education (CTE) course enrollment, and 4) high school graduation. A second set of analyses used regression models to examine how students' chances of high school graduation and their enrollment in dual credit courses differed by PLTW participation levels.

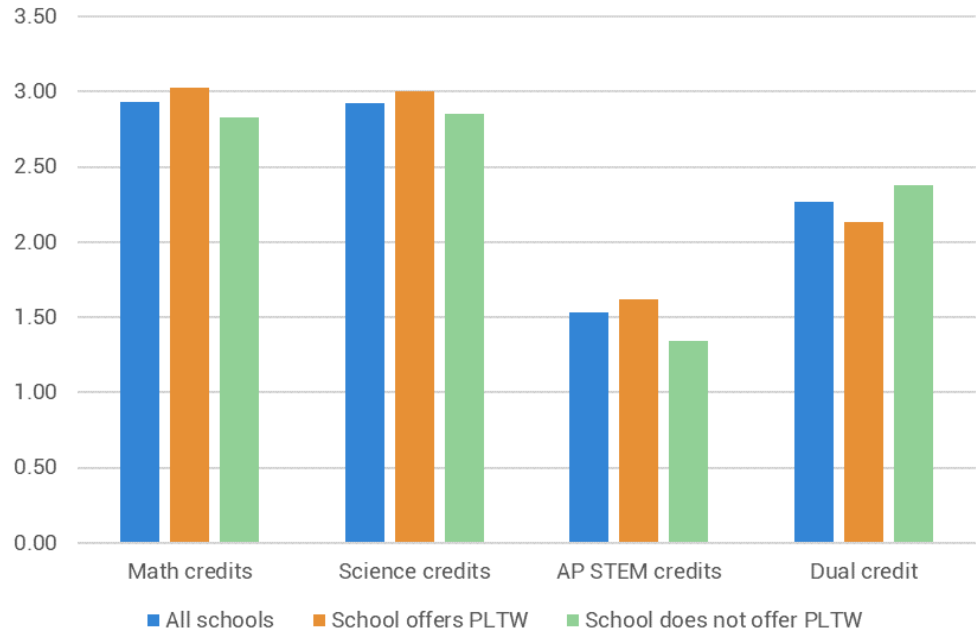
High school outcomes for all cohort members

Credit accumulation

Overall, the average number of credits cohort members accumulated did not differ substantially between schools offering PLTW and schools that did not offer PLTW. Figure 9 shows that on average, students in PLTW schools earned slightly more math, science, and AP STEM credits than students in non-PLTW schools. The pattern was reversed for average credit accumulation in dual credit courses. For that outcome, students in non-PLTW schools earned slightly more dual credits than students in PLTW schools.

Figure 9

Average credit accumulation by school participation in PLTW

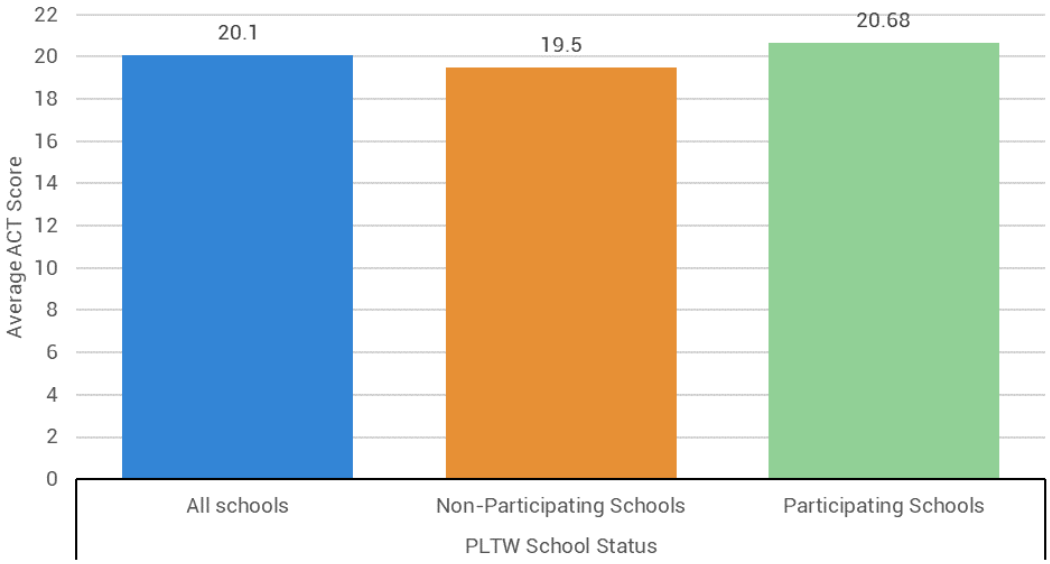


ACT scores

Schools with and without PLTW had similar average ACT scores. Figure 10 shows that students in PLTW schools had slightly higher average ACT scores than those in non-PLTW schools (1.2 points higher).

Figure 10

ACT scores by school participation in PLTW

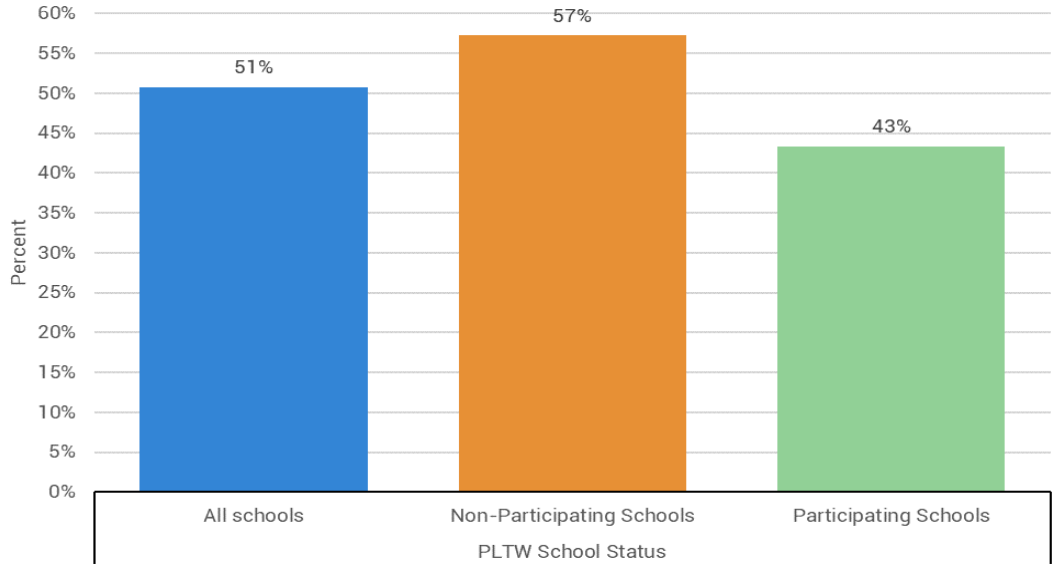


CTE enrollment

Schools that implemented PLTW had considerably lower rates of CTE course enrollment than schools that did not. Figure 11 documents that while over half of cohort students (57 percent) in non-PLTW schools enrolled in CTE courses only 43 percent of students in PLTW schools enrolled in CTE courses.

Figure 11

CTE course enrollment rates by school participation in PLTW

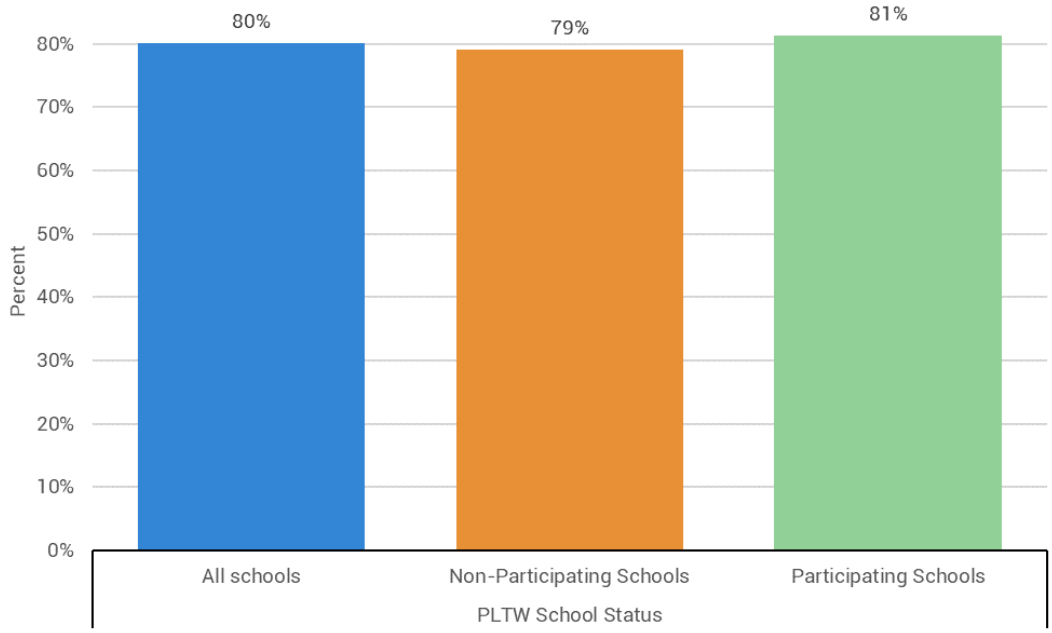


High school graduation

Schools that implemented PLTW had a higher average rate of high school graduation than schools that did not implement PLTW. Figure 12 shows that the graduation rates of PLTW and non PLTW schools are 81 percent and 79 percent respectively.

Figure 12

High school graduation rates by school participation in PLTW



Summary of how PLTW and non-PLTW schools differ on high school outcomes

On average, cohort students in PLTW schools earned more science, math, and AP STEM credits, attained higher ACT scores, and graduated from high school at slightly higher rates than students in non-PLTW schools. Conversely, cohort students in non-PLTW schools earned slightly more dual credits and enrolled in more CTE courses. The modest differences between PLTW and non-PLTW schools may be a reflection of differences in the demographics of the two sets of schools, or other curricular opportunities available in these schools. As previously discussed, non-PLTW schools are more likely to be located in rural settings with less than 500 students in their buildings. In smaller schools, there are generally fewer advanced STEM course or AP offerings. It may be the case that non-PLTW schools provide alternative CTE courses.

Regression analysis of high school outcomes

Regression analyses were conducted to examine how students' PLTW course enrollment is associated with two high school outcomes—enrollment in dual credit courses and high school graduation. All regression analyses estimate differences in outcomes between students who did and did not take PLTW courses. To understand whether greater participation yields more positive outcomes, we distinguish two levels of PLTW participation—taking 1 PLTW course and taking 2 or more PLTW courses. For each outcome, the first analysis estimates the total differences by participation levels, and the second analysis controls for student and school characteristics. Finally, we present the results by gender and race/ethnicity subgroups. Unconditional models are likely to overestimate the benefit of PLTW course taking as they do not consider student or school characteristics associated with PLTW course enrollment. For example, academically stronger students and non-FRL students tend to take more PLTW courses as seen in earlier results of this report. To take this into account, conditional models control for both student and school characteristics that are related to PLTW participation as well as the outcome. These conditional models compare the average outcomes among students who are similar in student and school characteristics. Appendix B contains a list of variables include in analyses and Appendix C describes statistical models.

High school graduation

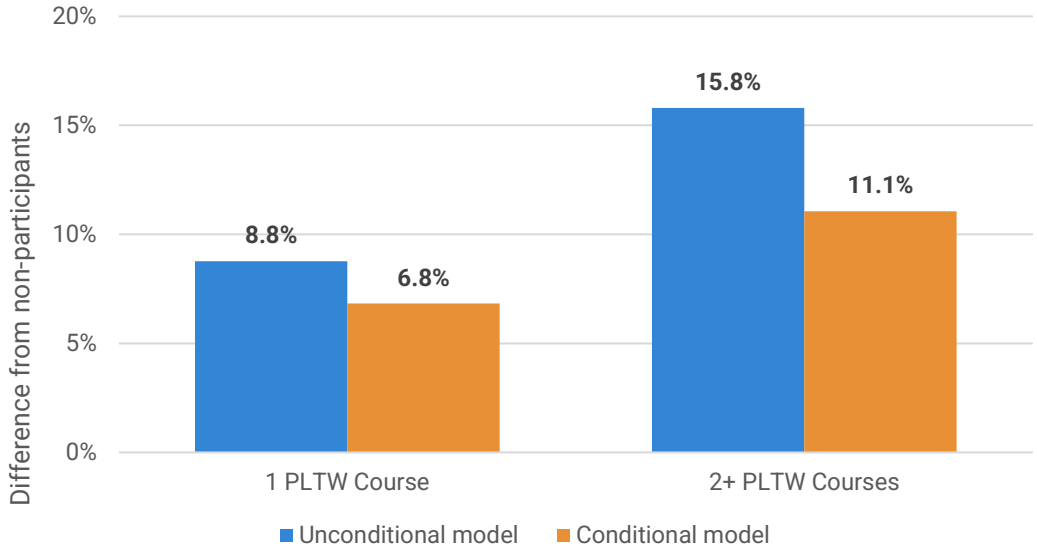
Figure 13 shows unconditional and conditional differences (blue and orange bars, respectively) in the high school graduation rates for students who took one PLTW course (the left side) and those who took 2 or more courses (the right side). In the remainder of the report we colloquially refer to these estimated differences as "benefits", "advantages" and "boosts" associated with PLTW participation.

We find that PLTW participants are much more likely to graduate from high school. According to the unconditional models, high school graduation rates are nearly 9

percentage points higher for students taking 1 PLTW course than students who did not take any PLTW courses, and 16 percentage points higher for those taking 2+ PLTW courses. However, these estimates are smaller (7% and 11%, respectively) when we take into account students' 8th-grade achievement and demographics, and school demographics and average achievement levels.

Figure 13

Differences in high school graduation rates for PLTW participants versus non-participants



Note: Estimates in bold font are statistically significantly different from zero at the $p < .05$ level.

The next analysis breaks down the conditional results by race/ethnicity and gender groups[5]. Figures 14 and 15 present results for females and males, respectively. Within each gender, estimates are provided for each race/ethnicity (White, Black, Hispanic and Other). For example, Figure 14 shows that White females who took 1 PLTW course graduated from high school at a rate that is 5.4 percent higher than White females who did not take any PLTW courses.

[5] We use race / ethnicity categories defined by DESE, which includes White, Black, and Hispanic. The Other value includes the Asian / Pacific Islanders, Native Americans, multi-racial and any other group.

Figure 14

Regression adjusted differences in high school graduation rates for female PLTW participants versus female non-participants by race/ethnicity

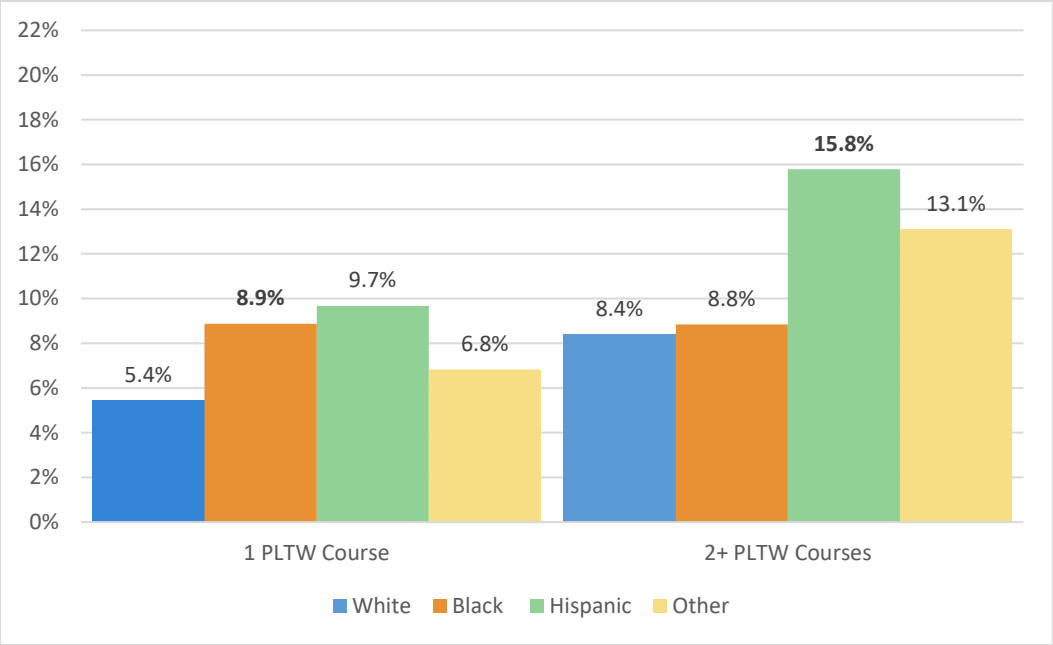
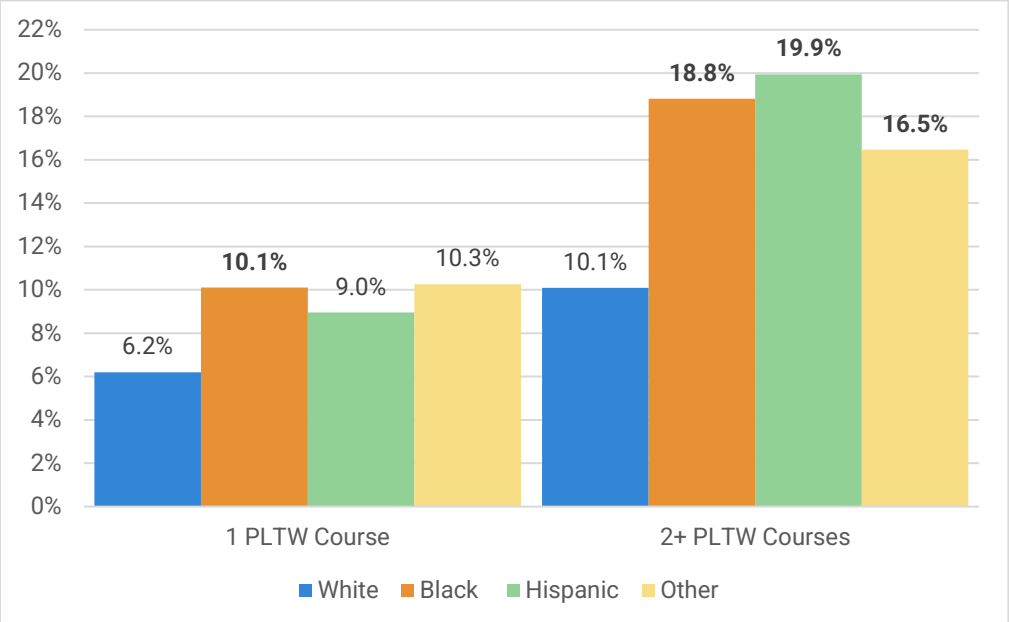


Figure 15

Regression adjusted differences in high school graduation rates for male PLTW participants versus male non-participants by race/ethnicity



Note: Statistical tests compare the estimates of Black, Hispanic, and Other race/ethnic group to the estimates of White students. Bold font indicates statistically significant difference at the $p < .05$ level.

A number of conclusions can be drawn from Figures 14 and 15.

- Students in all race/gender subgroups who enrolled in PLTW courses graduated from high school at significantly higher rates than students from the same subgroups who did not enroll in PLTW courses. Moreover, the benefits of PLTW participation were larger for students enrolling in two more PLTW courses.

- The benefits of PLTW enrollment for high school graduation tended to be larger for students of color than for White students. For both gender groups, the estimated PLTW benefit for high school graduation was higher for Black and Hispanic students than for White students. One exception to this pattern is Black females who took two or more PLTW courses. The increase in their likelihood of graduating from high school associated with PLTW participation was similar to that of White females.

- Within race subgroups, the benefits of taking PLTW courses for high school graduation appears to be similar for males and females. Estimates for males and females within race subgroups are generally quite similar, except for black students with 2 or more PLTW courses.

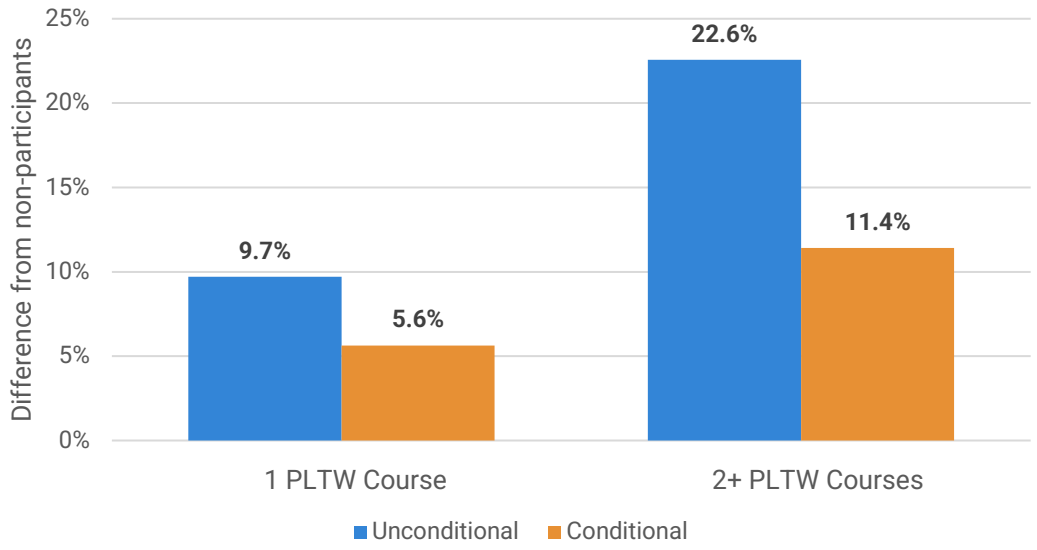
Enrollment in dual credit courses

We define *enrollment in dual credit courses* as taking one or more dual credit or dual enrollment courses.[6] Figure 16 shows that PLTW participants were considerably more likely to enroll in dual enrollment courses than non-participants. Unconditional model results show that students who took one PLTW course took courses with potential for dual credit at a rate that was nearly 10 percentage points higher than students who did not take any PLTW courses. Controlling for student and school characteristics nearly cut that difference in half to 5.6 percent. Students who took two or more PLTW courses were even more likely to take dual credit courses. The unconditional model provides an estimated of nearly 23 percent difference between students with 2 or more PLTW courses and non PLTW participants. Again this was cut in half after controlling for student and school characteristics to 11.4 percent, but this is still a sizable difference.

[6] Both dual credit and dual enrollment courses have the potential of generating college credit for students who successfully complete the course. Dual enrollment requires students to enroll at a college and take a college course from a college instructor. Dual credit allows high school teachers teaching select courses to offer an option to students to earn college credit at one or more colleges for successfully completing their high school course.

Figure 16

Differences in rates of enrollment in dual credit courses for PLTW participants versus non-participants



Note: Estimates in bold font are statistically significantly different from zero at the $p < .05$ level.

Next we examined differences from conditional models by race/ethnicity and gender groups. These analyses follow the same format as subgroup analyses presented earlier for high school graduation.

For all race and gender subgroups, PLTW participants are much more likely to enroll in dual credit courses than non-participants, and this difference tended to be larger for those taking 2 or more courses than for students only taking 1 course. More specifically, the largest benefit was found for Hispanic students (an exception being Hispanic males taking one PLTW course). Hispanic males and females who took two or more PLTW courses had rates of dual credit course taking that were nearly 20 percentage points higher than non PLTW students. Also, Black males taking two or more PLTW courses were much more likely to take dual credit courses than non PLTW counterparts (14.3 percent difference). Looking across Figures 17 and 18 we see a few gender differences. For example, among Hispanic students, the benefit of taking 1 PLTW course is nearly twice as large for females as that of their male counterparts (16.6 percent versus 8.5 percent). We see the reverse of this pattern among Black students with 2 or more PLTW courses, favoring males over females (14.3 percent versus 7.8 percent, respectively).

Figure 17

Regression adjusted differences in rates of enrollment in dual credit courses for female PLTW participants versus female non-participants by race/ethnicity

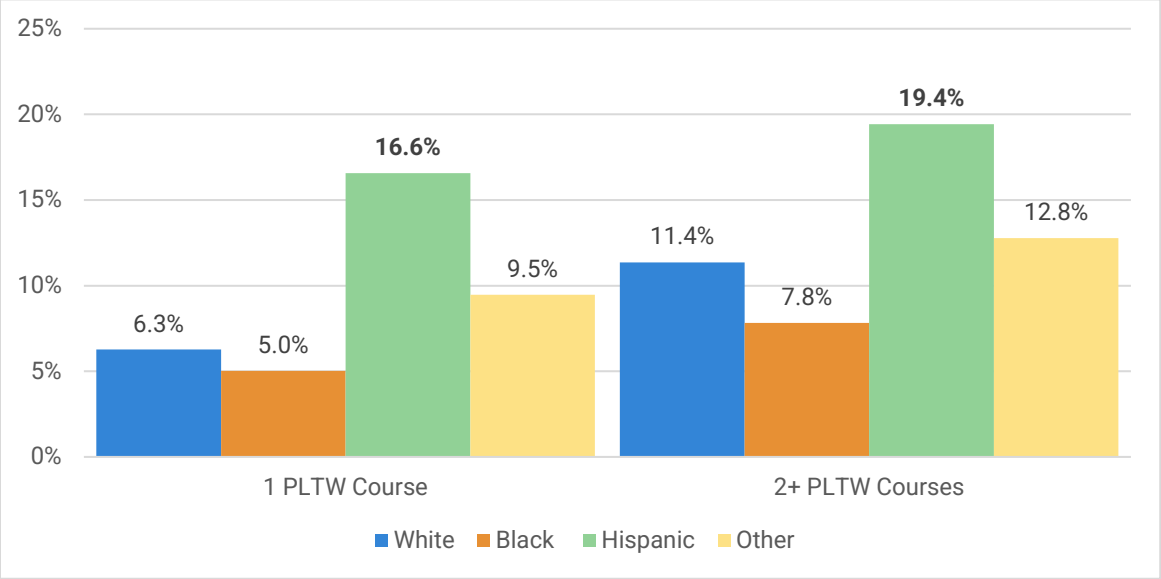
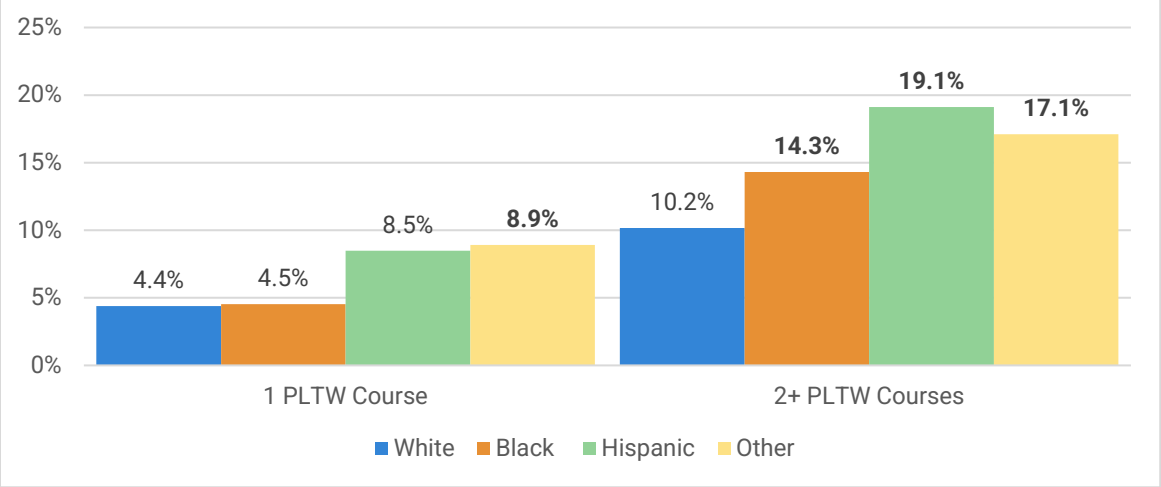


Figure 18

Regression adjusted differences in rates of enrollment in dual credit courses for male PLTW participants versus male non-participants by race/ethnicity



Note: Statistical tests compare the estimates of Black, Hispanic, and Other race/ethnic group to the estimates of White students. Bold font indicates statistically significant difference at the $p < .05$ level.

Postsecondary outcomes for all cohort members

We now turn to an analysis of postsecondary outcomes measured with NSC data for all cohort members. Mirroring previous analyses of high school outcomes, we first show

how high schools implementing PLTW differ from those without PLTW on three outcomes: 1) rates of enrollment in any postsecondary institution, 2) rates of enrollment in a 4-year institution, and 3) rates at which students declared a STEM major upon initial postsecondary enrollment. We then present regression analyses examining how students' PLTW course enrollment are associated with postsecondary enrollment and STEM major declaration at initial postsecondary enrollment.

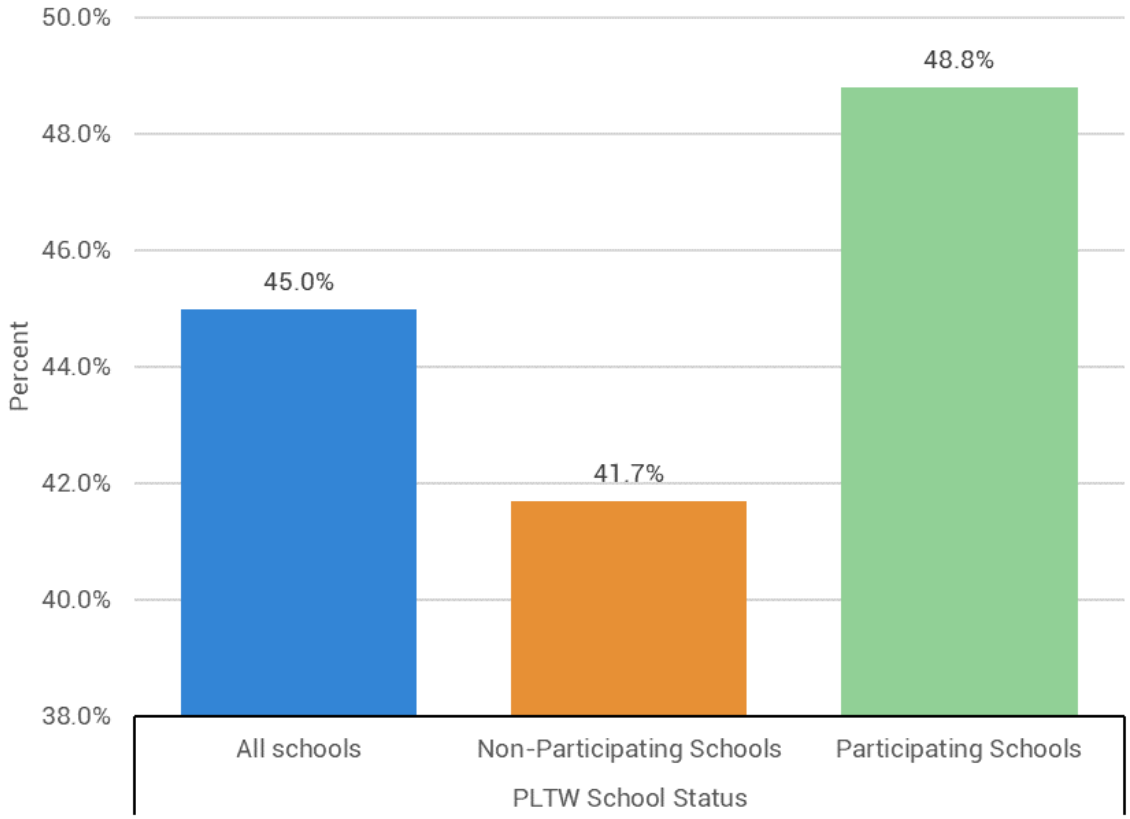
Differences in postsecondary outcomes for students attending PLTW and non-PLTW schools

Overall postsecondary enrollment (2- or 4-year institutions)

Figure 19 shows overall postsecondary enrollment rates (in any post-secondary institution) of all high schools attended by cohort members (the left bar) and the rates are broken down by school PLTW participation status. While the state-wide average post-secondary enrollment rates are 45%, students in schools offering PLTW are substantially more likely to pursue postsecondary education after high school than students in schools that did not offer PLTW. Specifically, their difference is seven percentage points.

Figure 19

Overall postsecondary enrollment rates by school participation in PLTW

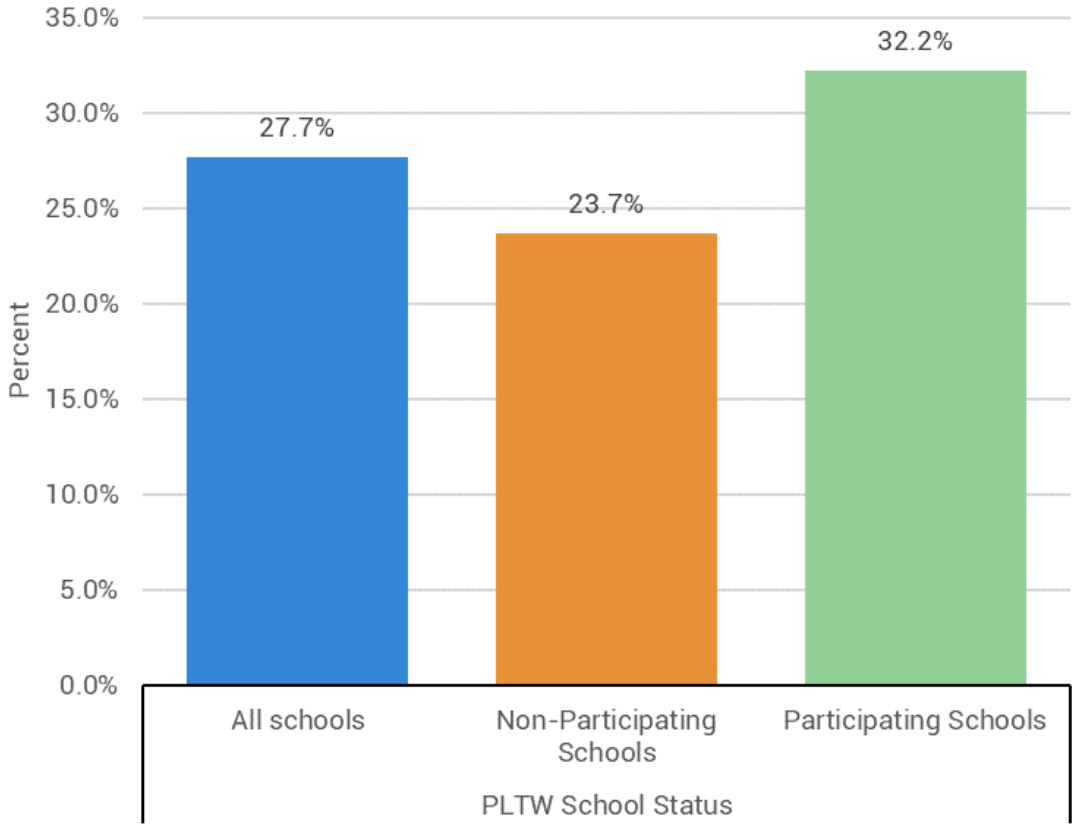


Four-year college enrollment

Enrollment in four year postsecondary institutions was also higher among students in PLTW schools compared to all students in the study cohorts and students in non PLTW schools (Figure 20). On average, students in schools that implemented PLTW were nearly 9 percentage points more likely than students in non-PLTW schools to enroll in 4-year postsecondary institutions.

Figure 20

Four-year college enrollment rates by school participation in PLTW



Declared STEM major

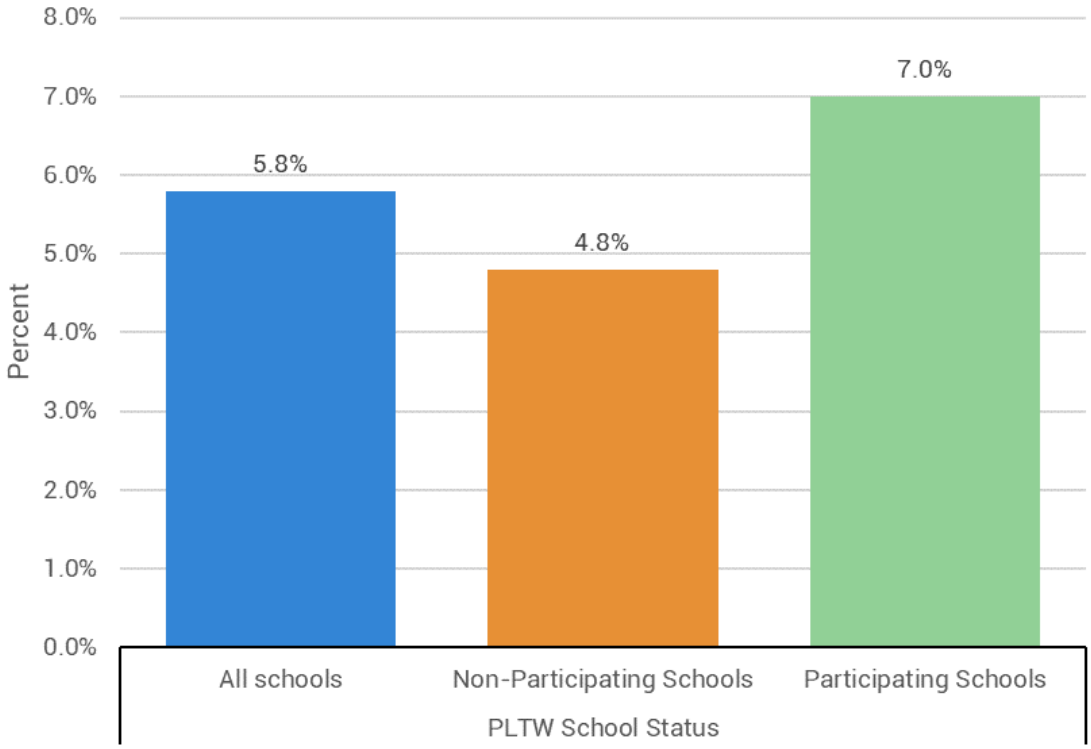
One of the main goals of PLTW is to increase the number of students who pursue and complete STEM degrees in college. We examined the initial declared major in STEM upon first college entry as a measure of students' intention to pursue a STEM degree[7].

[7] NSC data provide students' declared majors and associated CIP codes if the colleges reporting the data to NSC provide them in their data submissions. We encourage some caution in interpreting results for STEM major selection as some colleges do not report information about majors to the National Student Clearinghouse.

We found that students attending PLTW schools were more likely to declare a STEM major, though the magnitude of the difference is smaller than that for postsecondary enrollment outcomes reported earlier. Overall, only about 6 percent of students in the two study cohorts declared a STEM major when they initially enrolled in college (Figure 21, left bar). The corresponding rate for students in PLTW schools was seven percentage points, and this is approximately 2 percentage points higher than students in non-PLTW schools.

Figure 21

STEM major declaration rates by school participation in PLTW



Regression analysis of postsecondary outcomes for all cohort members

We next present the results of regression analyses of all cohort members predicting two outcomes: postsecondary enrollment (any college) and STEM major declaration. Our modeling strategy parallels that used for high school outcomes. A first set of "unconditional" models provides unadjusted estimates of the overall outcome differences by PLTW participation. A second set of "conditional" models estimate

Classification of Instructional Program (CIP) codes, developed by the National Center for Education Statistics, and the STEM Designated Degree Program list, created by the U.S. Department of Homeland Security, were used to determine what would be considered a STEM major.

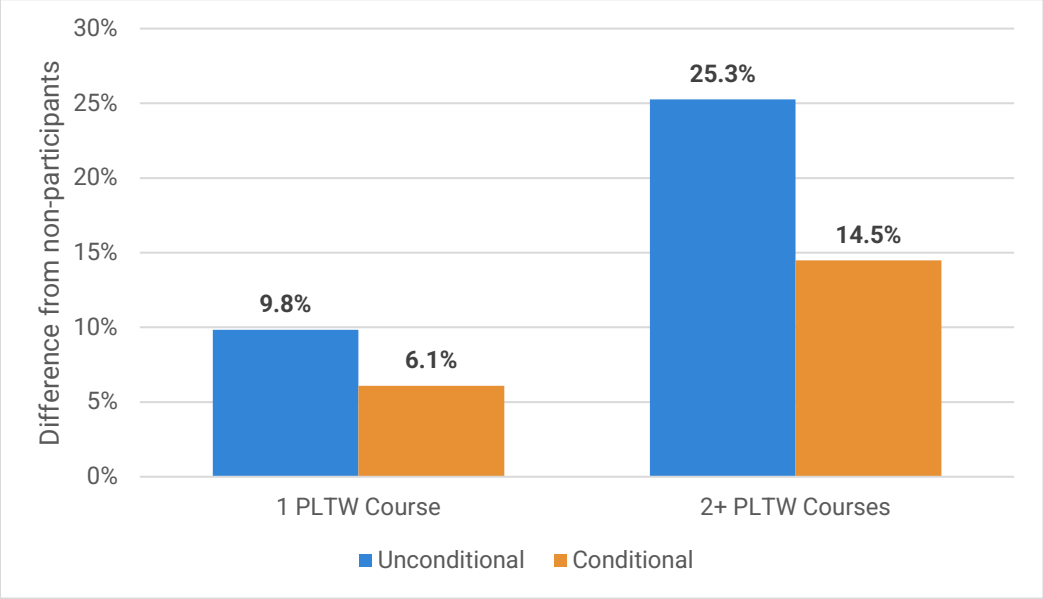
outcome differences for students who are similar in terms of student and school characteristics. We remind readers that Appendix B contains a list of variables and Appendix C contains a detailed discussion of statistical models.

Postsecondary Enrollment

Results of unconditional models show that students who took 1 PLTW course enrolled in postsecondary education at a rate that is approximately 10 percentage points higher than those who did not take PLTW courses. Similarly, students taking two or more PLTW courses were as much as 25 percentage points more likely to attend college than those not taking PLTW courses. Conditional model results also indicate higher postsecondary enrollment rates for students with greater levels of PLTW participation although the estimates are smaller. Specifically, after controlling for student 8th-grade achievement, student demographics, and school demographics, an increase associated with taking 1 PLTW course and 2 or more courses are, respectively, 6 percentage points and 14.5 percentage points.

Figure 22

Differences in postsecondary enrollment rates for PLTW participants versus non-participants



Note: Estimates in bold font are statistically significantly different from zero at the $p < .05$ level.

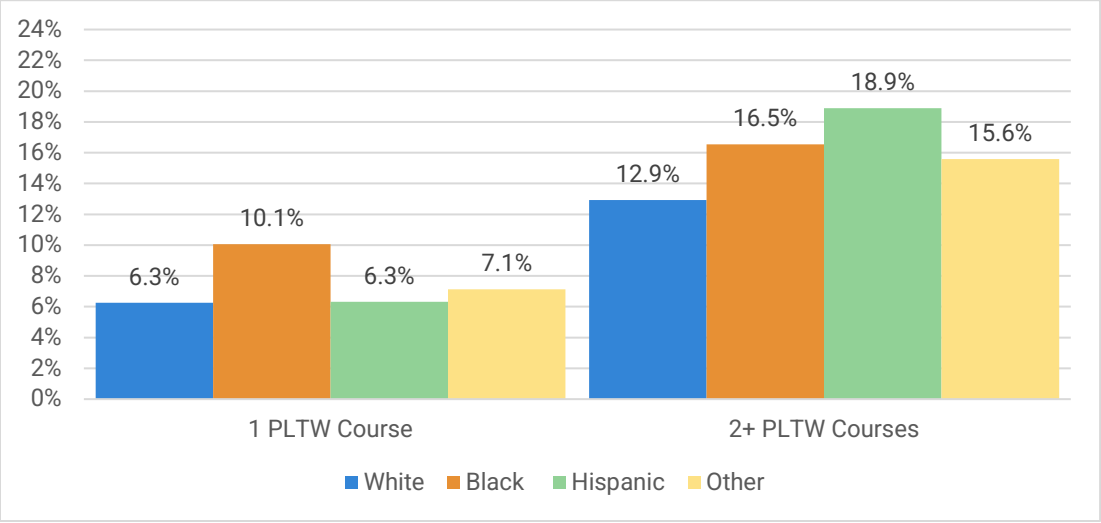
The next analysis provides separates estimates from conditional models by race/ethnicity and gender groups. The analytic strategy is the same as that for earlier subgroup analysis. Figures 23 and 24 show results for females and males that are further broken down by race/ethnicity.

We found that in all race/gender subgroups, students who took PLTW courses have higher postsecondary enrolment rates than students who did not take PLTW courses. The benefit of PLTW participation for college enrollment was larger for students taking 2 or more PLTW courses. Black and Hispanic students who took 2 or more PLTW courses appear to have benefited particularly well from PLTW participation. For example, for Hispanic and Black males, the estimated boost in postsecondary enrollment from taking 2 or more PLTW courses was approximately 5 percent higher than the corresponding boost received by White males.

Within the same race/ethnic groups, the pattern of results was generally similar for males and females with only a few exceptions. One of the exceptions was seen among Black students taking 1 PLTW course. Within this group, the boost in postsecondary enrollment from taking 1 PLTW course was twice as large for females as it was for males (10.1 percent versus 4.6 percent).

Figure 23

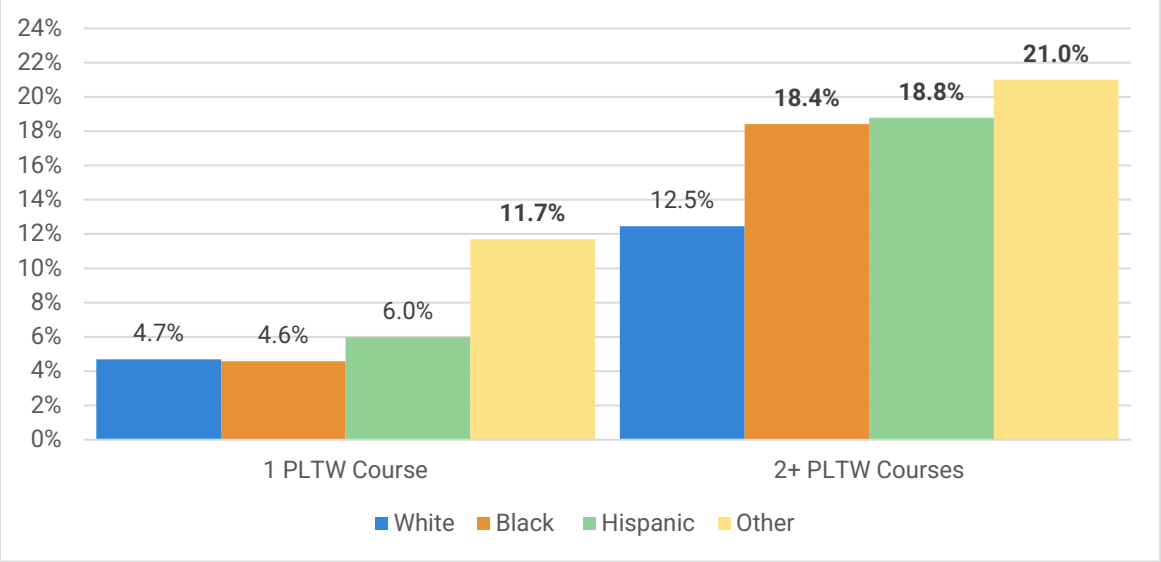
Regression adjusted differences in postsecondary enrollment rates for female PLTW participants versus female non-participants by race/ethnicity



Note: Statistical tests compare the estimates of Black, Hispanic, and Other race/ethnic group to the estimates of White students. Bold font indicates statistically significant difference at the $p < .05$ level.

Figure 24

Regression adjusted differences in postsecondary enrollment rates for male PLTW participants versus male non-participants by race/ethnicity



Note: Statistical tests compare the estimates of Black, Hispanic, and Other race/ethnic group to the estimates of White students. Bold font indicates statistically significant difference at the $p < .05$ level.

Declared STEM Major

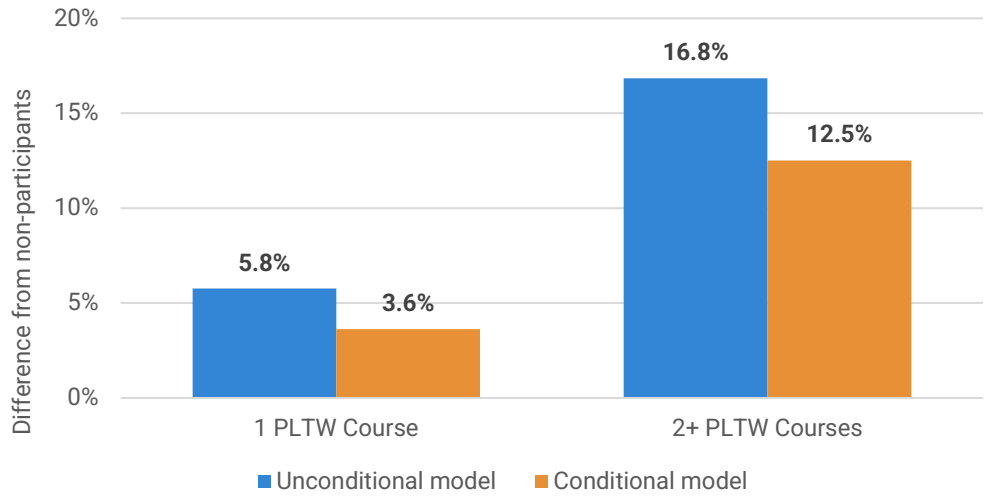
The final set of regression analyses of all cohort members examined differences in rates of STEM major declaration by levels of PLTW course taking. The pattern of results closely mirrored that for postsecondary enrollment: PLTW students were more likely to declare a STEM major upon initial enrollment in college than those not taking PLTW courses. This difference was higher for those taking 2 or more PLTW courses than for those taking 1 PLTW course. This was observed overall, and for all race and gender subgroups.

The results of the unconditional model shown in Figure 25 indicate that students who took one PLTW course had rates of STEM major declaration that were nearly 6 percent higher than that of students who did not take any PLTW courses. The advantage over non PLTW participants was nearly 3 times as large for students who took 2 or more PLTW courses. (17 percentage points higher than non PLTW course takers)

As with other outcomes, estimates from conditional models were considerably reduced. After taking into account student and school characteristics, the advantage associated with taking 1 PLTW course dropped to 3.6 percentage points, and the advantage associated with taking 2 or more PLTW courses shrunk by 4 percentage points.

Figure 25

Differences in STEM major declaration rates for PLTW participants versus non-participants



Note: Estimates in bold font are statistically significantly different from zero at the $p < .05$ level.

As in previous analyses, conditional results are broken down by race/ethnicity and gender groups. Gender specific results are presented in Figure 26 (females) and Figure 27 (males). For example, Figure 26 shows White females who took 1 PLTW course declared a STEM major in college at a rate that is 4 percent higher than White females who did not take any PLTW courses.

We found that in all race/gender subgroups, the likelihood of STEM major declaration was positively related to PLTW course enrollment, and differences between those who did and did not take PLTW courses were larger for students taking 2+ courses than for those taking only 1 PLTW course. However, notably, the benefit associated with taking 2 or more PLTW courses is smaller for Black and Hispanic males than White males (9% for Black and Hispanic males as compared 13% for White males). Within race/ethnic groups, estimated PLTW benefits experienced by males and females were otherwise generally similar.

Figure 26

Regression adjusted differences in STEM major declaration rates for female PLTW participants versus female non-participants by race/ethnicity

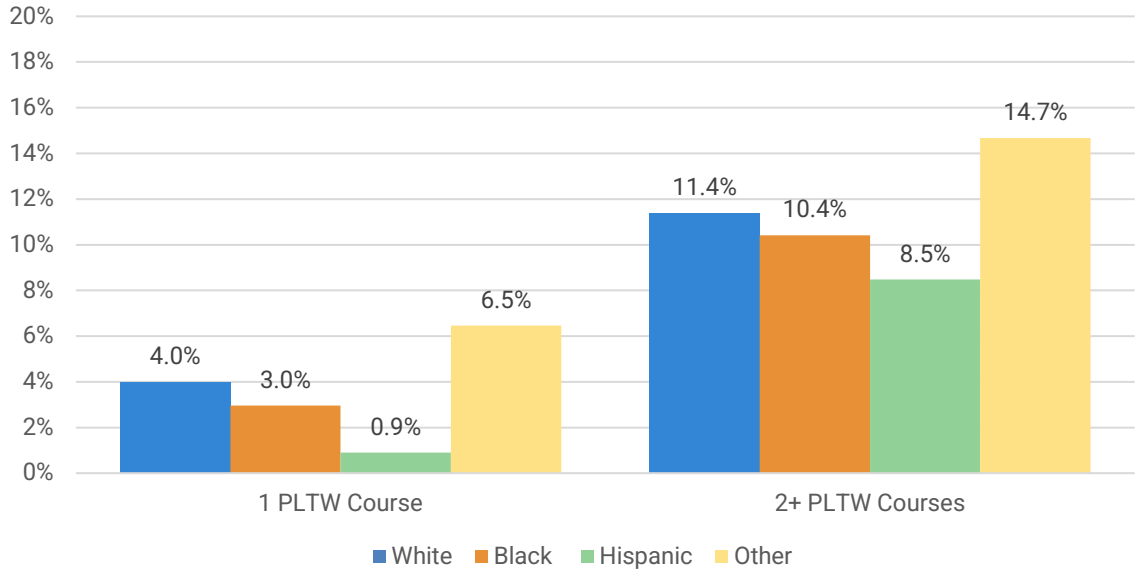
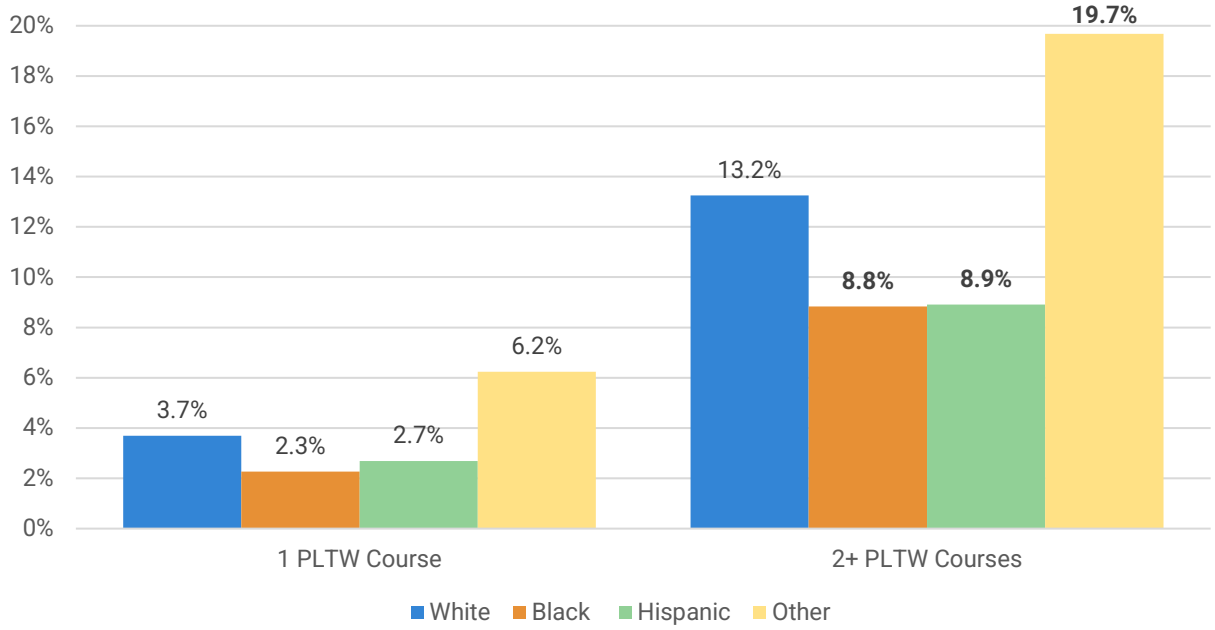


Figure 27

Regression adjusted differences in STEM major declaration rates for male PLTW participants versus male non-participants by race/ethnicity



Note: Statistical tests compare the estimates of Black, Hispanic, and Other race/ethnic group to the estimates of White students. Bold font indicates statistically significant difference at the $p < .05$ level.

Section 3: Postsecondary Outcomes for Cohort Members Attending Missouri Public Colleges and Universities

This section examines the college-going experiences of students in the 2013/14 9th-grade cohorts who attended Missouri public institutions of higher education following high school graduation. A description of the students analyzed for this section can be found in Appendix D. The data for this analysis comes from the Enhanced Missouri Student Achievement Study[8] (EMSAS) collected by DHEWD for academic years 2016-17 through 2019-20. These data allow us to follow graduates from our two 9th grade cohorts who attended Missouri public colleges for three to four years after high school graduation. This allows us to examine their college persistence, completion, or progress toward degree completion during this time frame.

To help contextualize the results, Table 2 shows the timing of hypothetical education progressions for cohort members who immediately enroll in college after on-time high school graduation. The years in green and yellow indicate, respectively, students' high school progression and college progression. For the 2013 high school freshman cohort, our data can capture 4-year college graduation by the end of Academic Year 2019-20. For the 2014 cohort, EMSAS data a maximum of the first three years in college. In recognition of this truncated time frame, our analysis uses an outcome indicator that captures degree completion or continued progress towards degree completion.

Table 2: Typical Progression from High School to College

Academic year	2013 cohort	2014 cohort
2012-13	Begin high school	
2013-14	HS year 2	Begin high school
2014-15	HS year 3	HS year 2
2015-16	HS year 4	HS year 3
2016-17	Postsecondary Y1	HS year 4
2017-18	Postsecondary Y2	Postsecondary Y1
2018-19	Postsecondary Y3	Postsecondary Y2
2019-20	Postsecondary Y4	Postsecondary Y3

Patterns of initial postsecondary enrollment in Missouri public postsecondary institutions

We begin by examining students' first college enrollments after graduating from high school. Table 3 reports the type of Missouri public college in which our analytic population first enrolled. The table breaks down enrollments by PLTW participation

[8] For more information about EMSAS data collection processes and data elements see https://dhewd.mo.gov/data/emsas/

levels and whether students did and did not declare a STEM major at their initial enrollment in a Missouri public postsecondary institution. Overall, initial enrollment of cohort graduates was somewhat higher in 2-year institutions than 4-year institutions (53 percent vs 47 percent, respectively). However, students who took PLTW courses are more likely to enroll in 4-year institutions (e.g., of the 2013 cohort who took 2+ PLTW courses, 1,023 students initially enrolled in 4-year colleges vs 645 of them in 2-year colleges). Also, overall initial STEM declaration rates are higher for 4-year than 2-year institutions. For both institutional types, STEM major declaration is positively related to PLTW course enrollment: students who took 2 or more PLTW courses are more likely to choose a STEM major than those who took 1 or no PLTW course.

Table 3

Initial, post-high school enrollment in Missouri public higher education institutions by institution level, cohort, PLTW participation level, and STEM major status

		1st Enrolled in MO Public 2-Year			1st Enrolled in MO Public 4-Year		
	Treatment	# Students	% STEM	% non-STEM	# Students	% STEM	% non-STEM
2013 Cohort	0 PLTW courses	10,014	9%	91%	8,717	21%	79%
	1 PLTW courses	821	17%	83%	912	36%	64%
	2+ PLTW courses	645	34%	66%	1,023	53%	47%
	Cohort Total	11,480			10,652		
2014 Cohort	0 PLTW courses	10,007	8%	92%	8,024	22%	79%
	1 PLTW courses	1,063	17%	83%	1,001	38%	62%
	2+ PLTW courses	752	31%	69%	1,191	51%	49%
	Cohort Total	11,822			10,216		
Grand Total		23,302			20,868		
		53%			47%		

Differences in the postsecondary outcomes of Missouri public college students associated with PLTW course taking in high school

Next we present a statistical analysis that examines associations between students' PLTW enrollment and five post-secondary outcomes, which roughly correspond with key stages in students' postsecondary careers.

The first outcome is remedial course enrollment. This is an important early college outcome as having to take remedial coursework at the beginning of one's postsecondary education can slow progress in degree attainment. Thus, we will examine whether taking PLTW courses in high school might have helped students bypass this barrier.

The next two outcomes are whether students ever enrolled in a bachelor's degree program and whether they ever enrolled in a STEM program. Recall that our analysis in Section 1 examined only the initial college enrollment and initial STEM major upon college entry using NSC data (similarly, Table 3 shows these initial outcomes for students in MO public colleges). In contrast, the outcomes reported in this section capture any 4-year college enrollment, including those who initially started at community college and transferred to 4-year college, as well as students who declared

a STEM major at any time between college entry and AY2019-20, the last year of EMSAS data.

Finally, we examine two indicators of *degree attainment progress* that capture a combination of *actual* degree attainment and the *continued pursuit* of a degree . Outcomes were created for bachelor's degree attainment progress and STEM degree attainment progress. For bachelor's degree attainment progress, students have a value of 1 if they received a bachelor's degree or were still enrolled in a bachelor's degree program in the spring 2020 semester. Similarly, the STEM degree attainment progress outcome indicates whether students received any STEM credential or were enrolled in a STEM degree program in Spring 2020.

The statistical analysis is similar to those presented in Section 1. First, an unconditional model estimates overall outcome differences by students' PLTW participation status[9]. Then, conditional models control for student and school characteristics that are related to PLTW participation and the outcomes.[10]

Remedial math course enrollment in college

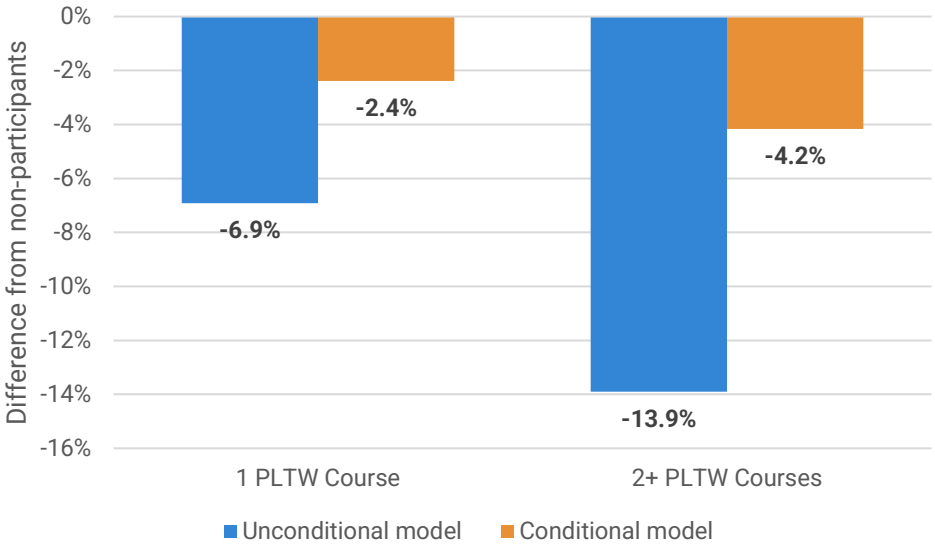
We first show the results for remedial math course enrollment. The left panel of Figure 28 presents the estimated differences between students who took 1 PLTW and non-PLTW takers and the right panel is the difference for those who took 2 or more PLTW courses. In each panel, the blue bars represent the total difference (unconditional model) and the orange bars indicate adjusted difference (conditional model). In general, students who took PLTW courses were less likely to take remedial math courses than PLTW non-participants. Differences were larger for students who took two or more PLTW courses than for students who took just one PLTW course (13.9% vs 6.9% unconditional). After controlling for student and school characteristics, these differences were reduced considerably to 2.4 percent for one PLTW course takers and 4.2 percent for 2 or more course takers.

[9] Two indicator variables distinguish PLTW concentrators who took 2 or more PLTW courses, students who took 1 PLTW course, and those who did not take PTLW courses (omitted group).

[10] A detailed discussion of the statistical models and a list of variables used in the analysis are found in Appendix B.

Figure 28

Differences in remedial math course enrollment for PLTW participants versus non-participants



Note: Estimates in bold font are statistically significantly different from zero at the $p < .05$ level.

We next present separate estimates for females (Figure 29) and males (Figure 30) by race/ethnicity (White, Black, Hispanic and Other). Statistical tests signified with bold text indicate whether the reduction in remedial course enrollment associated with PLTW course taking differs between White students and non-White populations. We find that reduction in remedial course enrollment is significantly greater for Black females who took 2+ PLTW courses than for White females (8.8% vs 3.1% in Figure 29). All other differences between White students and students of color are not statistically significant. We also note that, comparing Figures 29 and 30, patterns of remedial math course enrollment were very similar for females and males. Across all race/ethnicity groups, students who took 2 or more PLTW courses had lower rates of remedial math course enrollment.

Figure 29

Regression adjusted differences in remedial math course enrollment for female PLTW participants versus female non-participants by race/ethnicity

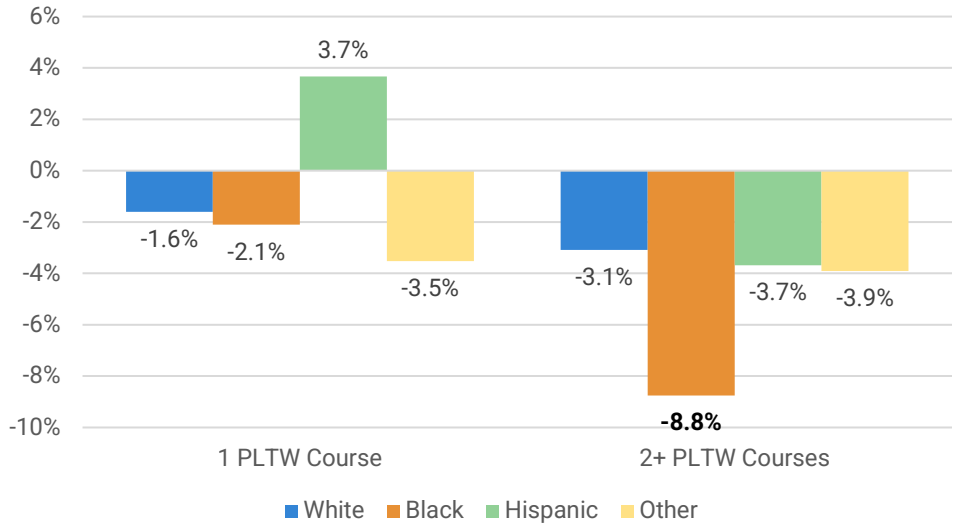
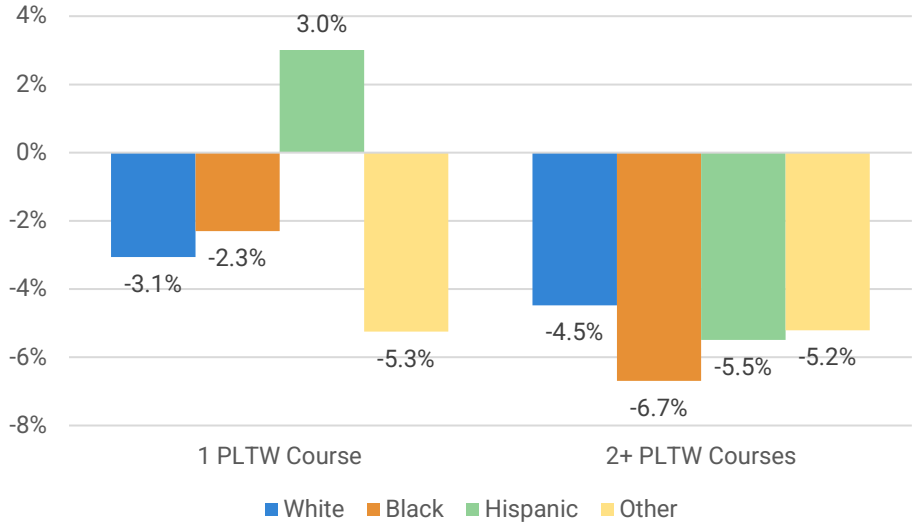


Figure 30

Regression adjusted differences in remedial math course enrollment for male PLTW participants versus male non-participants by race/ethnicity



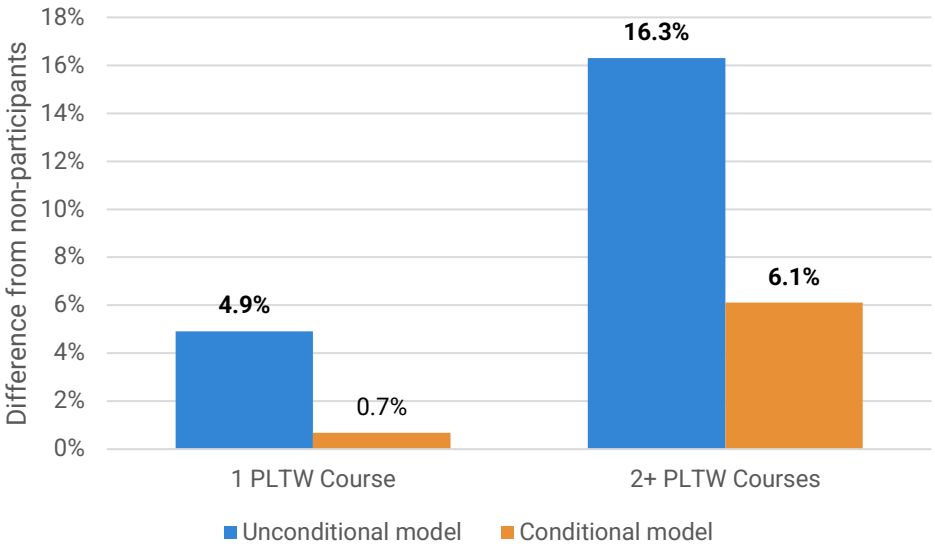
Note: Statistical tests compare the estimates of Black, Hispanic, and Other race/ethnic group to the estimates of White students. Bold font indicates statistically significant difference at the $p < .05$ level.

Ever enrolling in a Bachelor's degree program

Figure 31 shows that PLTW course takers were considerably more likely to enroll in a bachelor's degree program than those who did not take PLTW courses. The overall bachelor's degree enrollment rates were 5 percentage points higher for those who took 1 PLTW course, and 16 percent higher for those who took 2 or more PLTW courses. However, after controlling for student and school characteristics, these differences dropped to less than 1 percent (not statistically significant) and 6 percent, respectively.

Figure 31

Differences in bachelor's degree enrollment for PLTW participants versus non-participants



Note: Estimates in bold indicate statistically different from zero at the p<0.05 level

Next we break down these differences by race and gender. The boost to enrollment in a bachelor's degree program among females (Figure 32) for taking one PLTW course appeared to be negligible. But, for females taking 2+ PLTW courses, each race/ethnic group had higher bachelor's degree enrollment than non-PLTW takers, and this difference seems to be larger for non-White students than for White students. However, none of these race/ethnic differences are statistically significant from each other.

The story was quite different for males (Figure 33). For example, the estimated boost from taking 1 PLTW course is much larger for Hispanic boys (7.7%) than other groups. For those who took 2+PLTW courses, increases in bachelor's degree enrollment rates are quite high (about 6%-7%), except for Black boys whose increase was only 1 percent. However, none of these estimates for students of color are significantly different from the estimates for White students.

Figure 32

Regression adjusted differences in bachelor's degree enrollment for female PLTW participants versus female non-participants by race/ethnicity

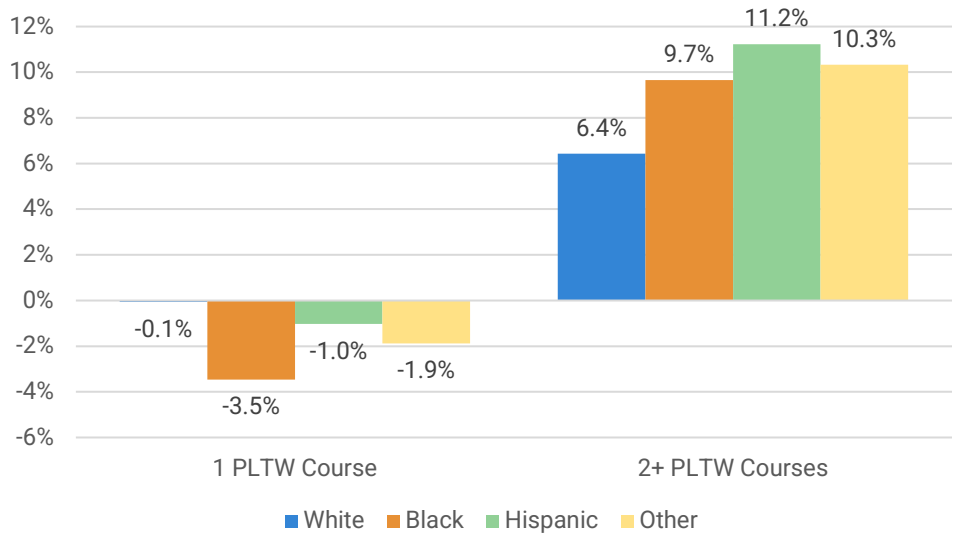
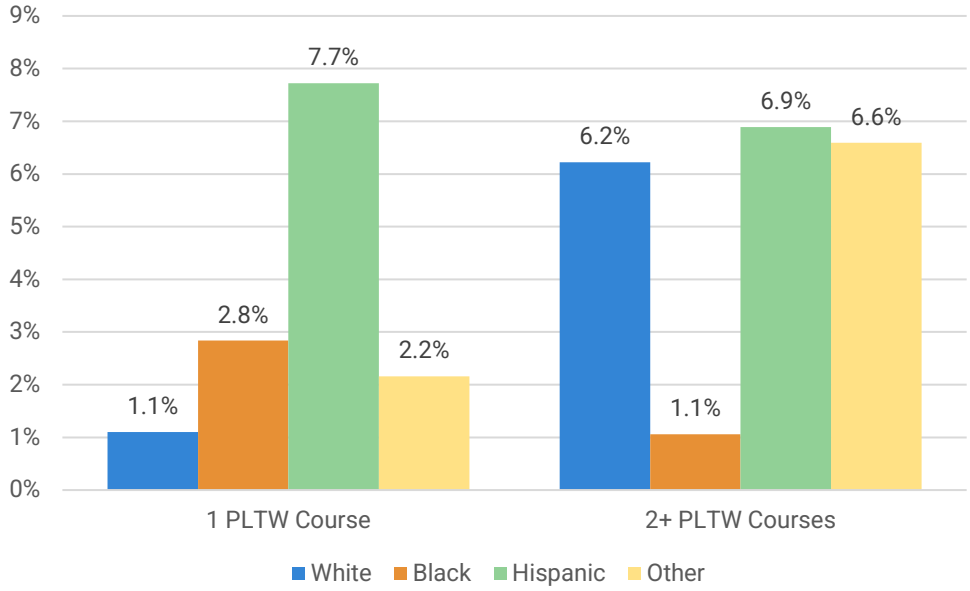


Figure 33

Regression adjusted differences in bachelor's degree enrollment for male PLTW participants versus male non-participants by race/ethnicity



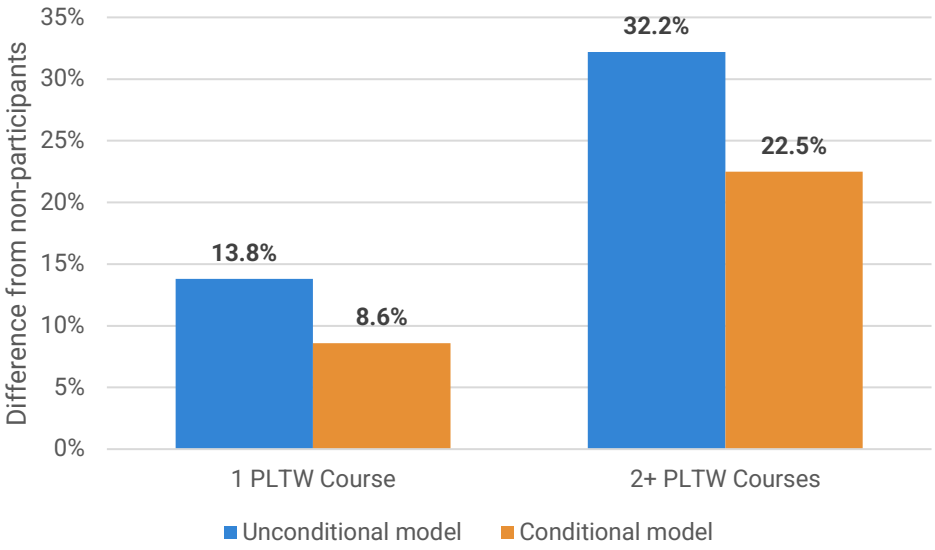
Note: Statistical tests compare the estimates of Black, Hispanic, and Other race/ethnic group to the estimates of White students. Bold font indicates statistically significant difference at the $p < .05$ level.

Ever Enrolling in a STEM degree program (STEM major)

For STEM degree enrollment (ever enrolling in a STEM degree), we find a very large difference between PLTW participants and non-participants. Overall, STEM enrollment rates were nearly 14 percentage points higher for those who took 1 PLTW course and as much as 32 percentage points higher for those who took 2 or more PLTW courses. Even after controlling for student and school characteristics, STEM degree participation rate is higher by 8.6 percent for 1 PLTW takers and 22.5 percent for 2+ PLTW takers.

Figure 34

Differences in STEM degree enrollment for PLTW participants versus non-participants



Note: Estimates in bold font are statistically significantly different from zero at the $p < .05$ level.

When STEM enrollment results are broken down by gender and race (Figure 35 and Figure 36), we see a number of statistically significant differences across race/ethnic groups. For females (Figure 35), estimated increases associated with taking 1 PLTW and 2+ PLTW courses are smaller for Black and Hispanic students than for White females. In comparison, the estimated increase associated with PLTW participation is considerably larger for females of "other" race/ethnicity. Among males, (Figure 36), Black and Hispanic students who took 2+ PLTW courses had smaller increases (12.7% and 19.4%, respectively) than their White counterparts (26.6%). Also, STEM enrollment is higher for males in the Other race group than White males who took 2 or more courses, but this difference is not statistically significant.

Figure 35

Regression adjusted differences in STEM degree enrollment for female PLTW participants versus female non-participants by race/ethnicity

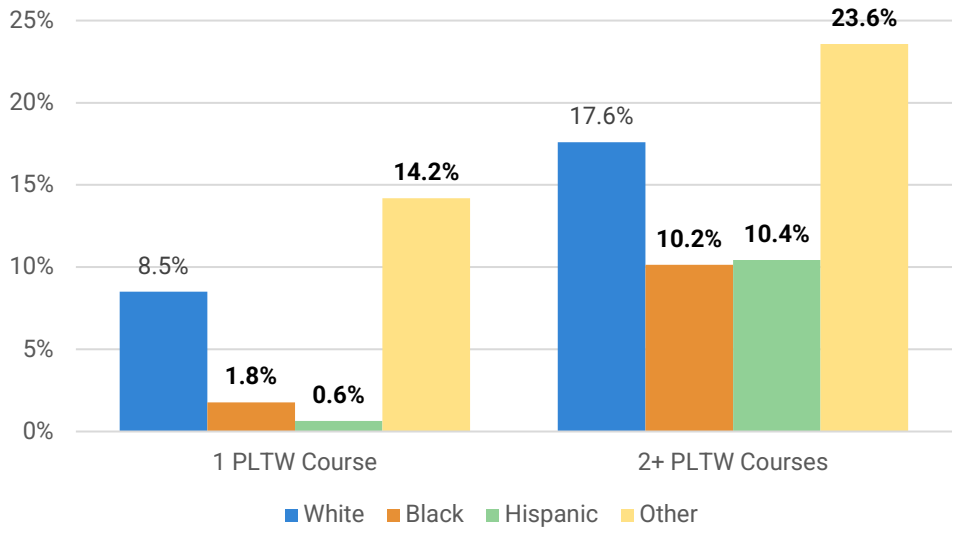
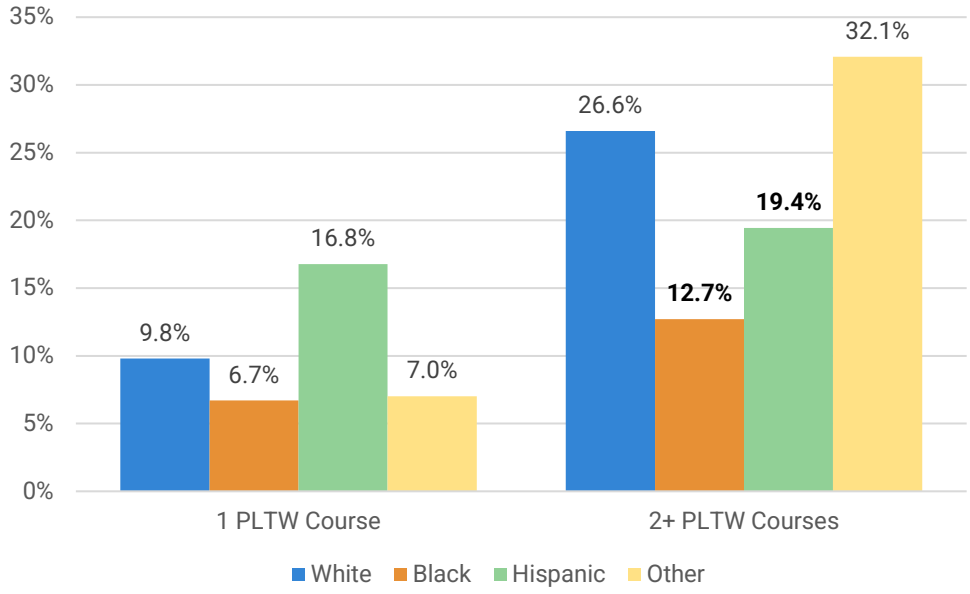


Figure 36

Regression adjusted differences in STEM degree enrollment for male PLTW participants versus male non-participants by race/ethnicity



Note: Statistical tests compare the estimates of Black, Hispanic, and Other race/ethnic group to the estimates of White students. Bold font indicates statistically significant difference at the $p < .05$ level.

Degree Attainment Progress

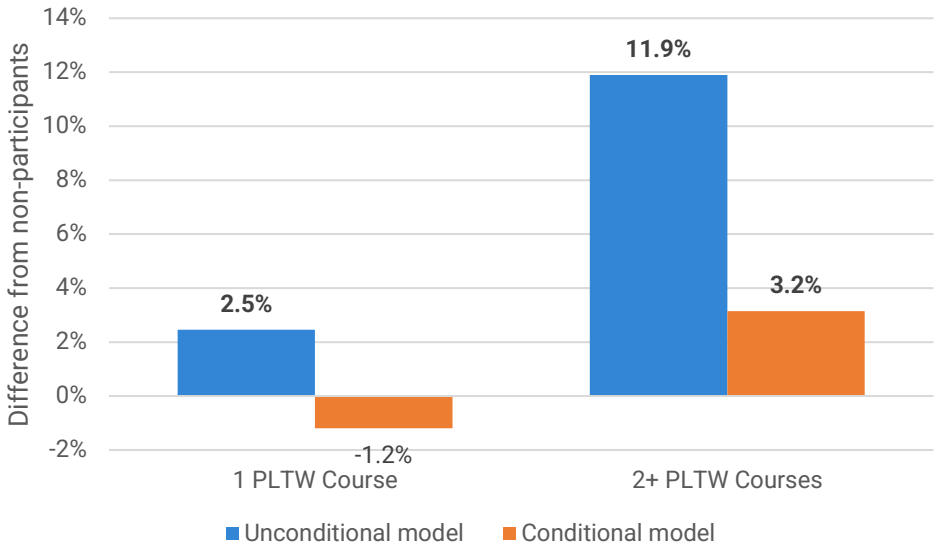
Lastly, we examined two degree attainment progress outcomes: 1) bachelor's degree attainment progress and 2) STEM degree attainment progress.

Bachelor's degree attainment progress

The results from unconditional models displayed in Figure 37 reveal that bachelor's degree attainment progress is only slightly higher for students who took 1 PLTW course than for students who did not take PLTW courses (2.5 percent difference) and this difference becomes statistically insignificant after controlling for student and school characteristics. The total increase associated with taking 2+ PLTW courses was much higher (nearly 12 percent), but was reduced to 3 percent after adjusting for student and school characteristics.

Figure 37

Differences in bachelor's degree progress rates for PLTW participants versus non-participants



Note: Estimates in bold font are statistically significantly different from zero at the $p < .05$ level.

Hispanic and Other race female PLTW course takers (both 1 and 2+ PLTW courses) seemed to be making greater progress toward degree completion as compared to their peers who did not take PLTW courses (Figure 38). In contrast, White and Black PLTW participants seem to be making less progress (both White and Black females taking 1 PLTW course had negative differences). However, overall, there are no significant race/ethnic differences in the association between PLTW enrolment and this outcome.

The results for males follow a complex pattern: only some groups of PLTW course takers are more likely to have attained or be making progress toward a bachelor's degree than non PLTW course takers (e.g., Hispanic males with 1 PLTW and White and

Other males with 2+ PLTW). Differences for other groups are near zero or negative. Again, the difference in the estimates between White students and students of color is not statistically significant.

Figure 38

Regression adjusted differences in bachelor's degree progress rates for female PLTW participants versus female non-participants by race/ethnicity

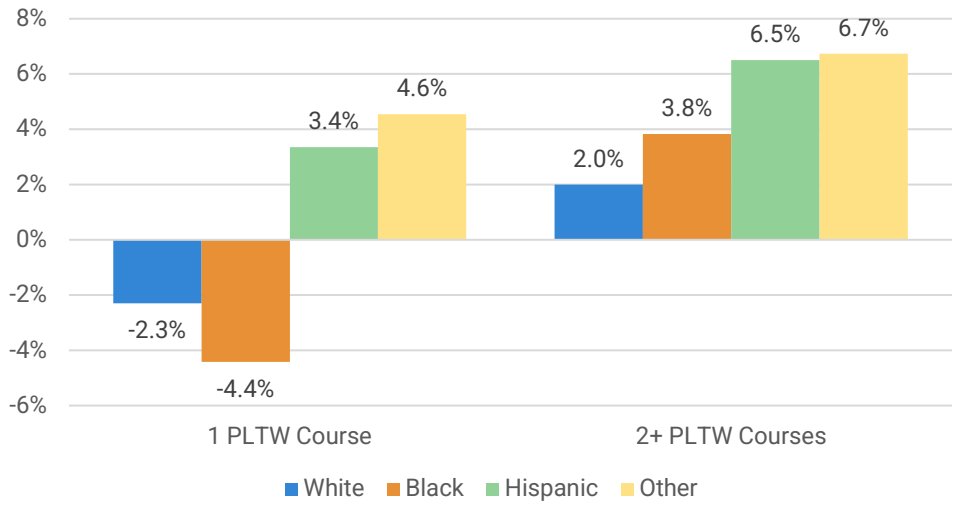
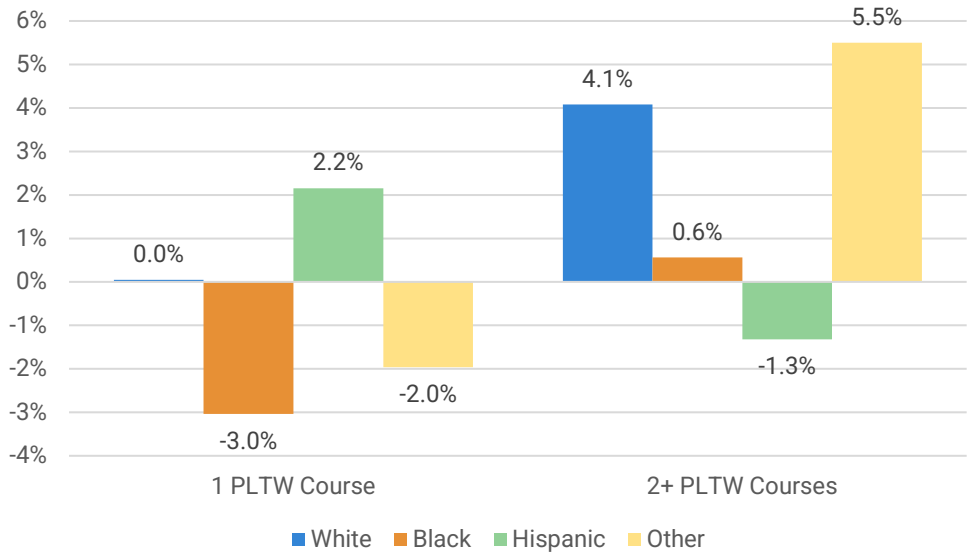


Figure 39

Regression adjusted differences in bachelor's degree progress rates for male PLTW participants versus female non-participants by race/ethnicity



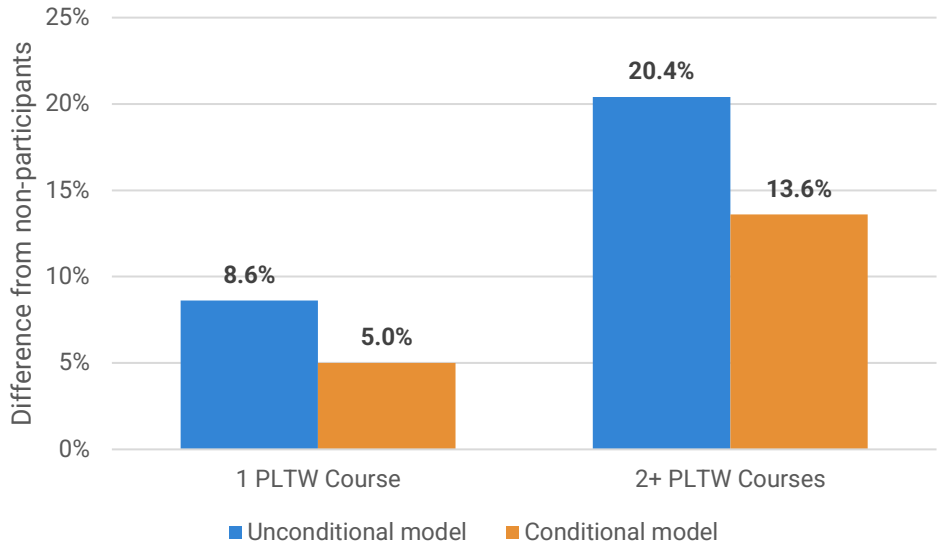
Note: Statistical tests compare the estimates of Black, Hispanic, and Other race/ethnic group to the estimates of White students. Bold font indicates statistically significant difference at the $p < .05$ level.

STEM degree attainment progress

Our final analysis compares STEM degree completion or continued enrollment in a STEM program by PLTW participation (Figure 40). Results of the unconditional model indicate that students who took 1 PLTW course are more likely to have completed or be still making progress toward a STEM degree at a higher rate than students who did not take PLTW courses (nearly 9 percent difference). The difference associated with taking 2+ PLTW courses was much higher (20 percent). Unlike the results of bachelor's degree attainment progress, we still find considerable difference even after student and school characteristics were taken into account. We found a 5 percentage point difference in STEM degree attainment progress for takers of 1 PLTW course and a 14 percentage point difference for takers of 2+ PLTW courses.

Figure 40

Differences in STEM degree progress rates for PLTW participants versus non-participants



Note: Estimates in bold font are statistically significantly different from zero at the $p < .05$ level.

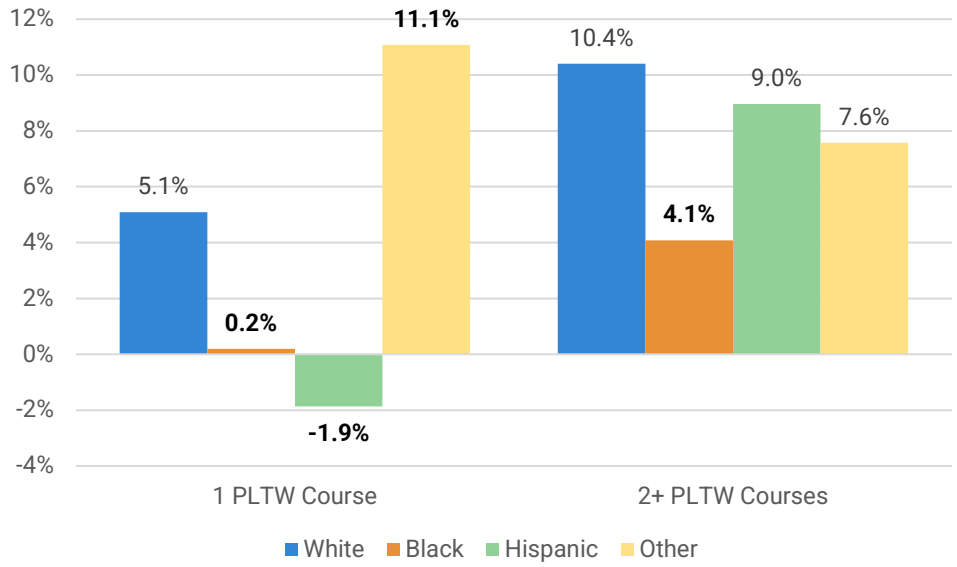
When the results are broken down by gender and race, complex patterns emerge. First, among females who took 1 PLTW (Figure 41), Black and Hispanic students are no more likely to have completed or be making progress toward a STEM degree than their peers who did not take PLTW. Females of Other race/ethnicity are making greater progress than White females (11% vs 5.1%), relative to the progress made by their non-PLTW counterparts. The difference in the estimates between students of color and White females for takers of 1 PLTW course is statistically significant. The estimated boost of taking 2 PLTW courses was smaller for Black females than for White females (4.1 % vs and 10.4%).

For males (Figure 42), taking just 1 PLTW course is not related to STEM degree attainment or progress for black students (only 0.5% difference), and this is significantly lower than the estimated 6% difference for White students. An estimated difference in

STEM degree attainment or progress associated with taking 1 PLTW course is not significantly different among the other three groups. The estimated differences for both Black and Hispanic males taking 2+ PLTW course are both less than 4%, and considerably lower than that for White males (which was nearly 17%).

Figure 41

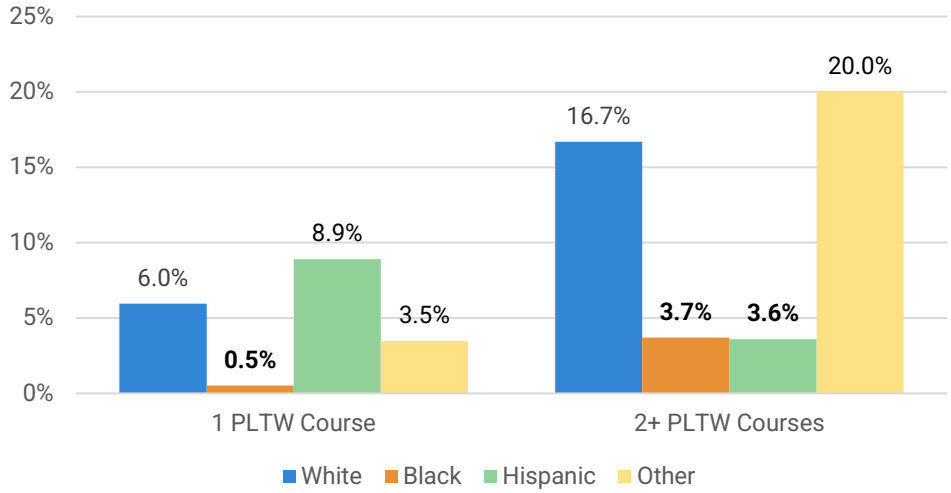
Regression adjusted differences in STEM degree progress rates for female PLTW participants versus female non-participants by race/ethnicity



Note: Statistical tests compare the estimates of Black, Hispanic, and Other race/ethnic group to the estimates of White students. Bold font indicates statistically significant difference at the $p < .05$ level.

Figure 42

Regression adjusted differences in STEM degree progress rates for male PLTW participants versus male non-participants by race/ethnicity



Note: Statistical tests compare the estimates of Black, Hispanic, and Other race/ethnic group to the estimates of White students. Bold font indicates statistically significant difference at the $p < .05$ level.

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Appendix A – Summary of research on PLTW

A number of studies have examined relationships between PLTW participation and student achievement and STEM interest. Several studies found that PLTW participants took significantly more math and science courses in high school and were more likely to complete a rigorous college preparatory curriculum in high school (Bottoms & Anthony 2005; Bottoms & Uhn 2007; Starobin et al. 2013). Multiple studies have also found that PLTW participation is associated with higher math scores on standardized tests (Bottoms & Anthony 2005; Bottoms & Uhn 2007; Schenk Jr. et al. 2011; Starobin et al. 2013; Van Overschelde 2013; Rethwisch, 2014). Finally, multiple studies have found that students who participated in PLTW are more likely to major in a STEM discipline in college (Schenk Jr. et al. 2012; Starobin et al. 2013; Pike & Robbins, 2019).

Research on PLTW has a number of limitations. First, studies have been inconsistent in defining a PLTW participant. Most studies have defined PLTW participation as taking at least one PLTW course (Schenk Jr. et al. 2012; Starobin et al. 2013, Pike & Robbins, 2014). However, Van Overschelde (2013) and Bottoms and Anthony (2005) defined PLTW participation as taking at least two PLTW courses, and Bottoms and Uhn (2007) defined participation as taking three or more PLTW courses. Only one study (Pike & Robbins, 2019), has defined PLTW participation as the total number of courses taken, thus more precisely measuring the actual "dosage" of PLTW received by a student.

Most researchers contributing to the research base on PLTW acknowledge a "selection bias" associated with who participates in PLTW, whereby program participants tend to have higher achievement or come from more affluent families compared to non-participants. Despite this recognition, few studies have used research designs that provide strong protection against selection and other challenges to making causal inferences about the impact of PLTW. For example, Bottoms and Anthony (2005) and Bottoms and Uhn (2007) relied on stratified random sampling using student demographics to account for differences in PLTW participants and non-participants, but did not control for students' achievement prior to high school. The early evaluations of PLTW in Iowa selected students for comparison groups but did not describe the selection procedures. Only three studies (Van Overschelde, 2013; Rethwisch, 2014; Pike & Robbin, 2014) have utilized student and school-level characteristics to control for differences between PLTW participants and non-participants.

Although PLTW includes a prescribed curriculum and rigorous training for its teachers, local and regional differences in implementation have been documented (Hess et al., 2016). Most studies to date have used relatively narrow samples of schools. A small number of large-scale studies conducted in Iowa, Indiana and Texas using the state's K-12 database are exceptions to this general pattern and these studies focused on schools offering PLTW (Van Overschelde, 2013; Rethwisch, 2014; Pike & Robbins, 2019). Many researchers contributing to research on PLTW recognize the limitations of small-scale studies and their limited ability to shed light on whether and how the program's impact varies across a wide range of school contexts.

Appendix B – Variables

Outcome variables – Section 1

Variable Name	Description	Definition
HSGrad	High School Graduation Status	Indicator of student's high school graduation status (Yes/No)
AttenCol	College Enrollment Status	Indicator of student's college enrollment status (Yes/No)
DHS_STEM	Enrolled in a STEM Major	Indicator of student declaring a STEM major during postsecondary education (according to the US Department of Homeland Security's list of STEM majors) (Yes/No)
Flag_dualC	Enrollment status in Dual Credit course	Indicator of student enrollment in dual credit courses in high school (Yes/No)

Outcome variables – Section 2

Variable Name	Description	Definition
Outcome Variables		
Bachelor	ever enrolled in bachelor's program	A binary indicator of whether a student has ever enrolled in a bachelor's program (Yes/No)
Bachelor_c	Completed a bachelor's degree	A binary indicator of whether a student has completed a bachelor's degree (Yes/No)
STEM	ever enrolled in STEM program	Indicator of student ever enrolled in a STEM major during postsecondary education (Yes/No)
STEM_c	Completed a degree in STEM program	A binary indicator of whether a student has completed a degree in STEM program (Yes/No)
re_taken	ever taken any remedial credits	A binary indicator of whether a student has ever taken any remedial credits (Yes/No)
re_math_taken	ever taken remedial math credits	A binary indicator of whether a student has ever taken remedial credits in math subject (Yes/No)

Student-level variables, both sections

Variable Name	Description	Definition
PLTW_treatment	PLTW Treatment	Categorical indicator for students' participation in PLTW (the treatment) during high school T0 = Never enrolled in a PLTW course T1 = Enrolled in 1 PLTW course T2 = Enrolled in 2 or more PLTW courses
cohort_year	Cohort Year	Indicates student's first high school year (i.e., cohort year)
Gender	Gender	Categorical indicator distinguishing student's gender with male as the reference group
raceEthnicity	Race/Ethnicity	Categorical indicator for student's race/ethnicity (Black, Hispanic, White, Other) with White as the reference category
lunchStatus	Free/Reduced Lunch Status	Indicator of student eligibility for free or reduced lunches (Yes/No)
MAP_8ELA	8th Grade MAP Scores: English Language Arts	Student's 8th grade ELA MAP scores, centered
MAP_8Math	8th Grade MAP Scores: Mathematics	Student's 8th grade Math MAP scores, centered
MAP_8Sci	8th Grade MAP Scores: Science	Student's 8th grade Science MAP scores, centered
flag_EOC_8Alg	Completed Algebra I before Grade 9	Indicator of students completing Algebra I before high school (i.e., grade 9)

School-level variables, both sections

School-Level Variables		
schl_enrollment_11	School Enrollment	School's enrollment during student's first high school year
charter_text	School Charter Flag	Indicates whether school is a charter school (Yes/No)
locale2	School Locale	Categorical indicator of school setting: rural, town, suburban, or urban with suburban serving as the reference category
schl_white_pct	School Racial Composition: Percent White	Student body racial composition during student's first year of high school; percent White
schl_FRL_pct	School Freed/Reduced Lunch Percent	School's ratio of students eligible for free or reduced lunches during student's first high school year
schl_MAP_8ELA_avg	School Average 8th Grade MAP Scores: English Language Arts	School's average English Language Arts MAP scores of incoming 9th graders
schl_MAP_8Math_avg	School Average 8th Grade MAP Scores: Mathematics	School's average Mathematics MAP scores of incoming 9th graders
schl_MAP_8Sci_avg	School Average 8th Grade MAP Scores: Science	School's average Science MAP scores of incoming 9th graders
schl_8EOC_pct	School Percent of Student Completing Algebra I Before Grade 9	School's ratio of incoming 9th graders who completed Algebra I before 9th grade

Appendix C – Statistical Models

This study conducted regression analyses to understand how high school and postsecondary outcomes differed between PLTW participants and non-participants. The outcomes for these analyses include: enrolling in dual-credit courses, graduating from high school, enrolling in college, and majoring in STEM upon first college entry.

When assignment to a program is random, it is safe to assume that the program is the only thing causing an outcome. If student enrollment in PLTW was random, we could therefore estimate the program's impact simply by comparing the average outcomes of students who did and did not participate in PLTW. Since enrollment in the program is not random, any conclusions we make about the impact of PLTW are susceptible to misinterpretation, because there may be factors besides PLTW participation that influence outcomes. We accounted for competing explanations of outcomes by controlling for student- and school-level characteristics identified previous PLTW evaluations (Rethwisch, 2014; Pike and Robbins, 2019) and analysis of our own sample. Student characteristics we controlled for include gender, race/ethnicity, free and reduced lunch status. We also included eighth-grade standardized test scores (MAP ELA and Math Scores) in models to control for students' achievement prior to high school. Our conditional estimates of PLTW impact also control for four high school characteristics: total enrollment, school location (rural, urban, town, suburban), the percent of students of color in the high school, and the percent of students on free/reduced lunch in the high school.

As an indicator for students' PLTW program participation, two categorical variables were created to distinguish the intensity of program participation: enrolling in 1 PLTW course and enrolling in 2 or more PLTW courses during high school years. These variables were created in two steps. We first scanned the DESE high school course completion data and counted up the number of PLTW courses each cohort student completed. We then created the categorical indicators of the intensity of PLTW course taking based on this count. Not enrolling in any PLTW course is the reference group in all models.

The regression analyses began by estimating the average overall difference in the outcome between of program participants (1 PLTW course noted as T1 and 2 or more PLTW courses noted as T2) and non-participants. Specifically, for student i in school j, we estimate the following model:

$$Y_{ij} = B0 + B1(T1)_{ij} + B1(T2)_{ij} + B3(Cohort)_{ij} + u_j + e_{ij.} \quad (1)$$

This model controls for Cohort, which indicates the year of high school entry (the 2014 cohort is the reference group), and u_j and e_{ij} are, respectively, school- and student-level error terms.

The parameters of interest, B1 and B2, represent the average outcome difference between students with 1 PLTW and 2 or more PLTW courses, respectively, and those who did not take any PLTW courses.

The next analysis adjusts for the base-line difference between program participants and non-participants as well as difference between schools offering the program (offered in the building or through career center) and schools without PLTW. The following model adds both student and school covariates to Model 1:

$$Y_{ij} = B0 + B1(T1)_{ij} + B2(T2)_{ij} + B3(Cohort)_{ij} + B2(X)_{ij} + B3(W)_j + u_j + e_{ij,} \quad (2)$$

where X is student covariates, and they include indicators for gender(male as a reference group), race/ethnicity (White students as a reference group, Black Hispanic, and Other), Free/Reduced lunch, and having taken EOC in 8th grade, and 8th-grade MAP scores in ELA, math and science. School-level variables, W, include school size (indicated by a set of dichotomous variables), charter school indicator, locals (City, Rural, Town, and Suburban as a reference group), and the following school average characteristics of incoming ninth-grade students: the percent of White students, the percent of students eligible for Free/Reduced lunch, and the percent of students who took EOC exam in 8th grade, and average 8th-grade MAP scores in ELA, math and science.

In Model 2, the parameters, B1 and B2 are interpreted as the average difference in the outcome between program participants (1 PLTW course and 2 or more PLTW courses, respectively) and non-PLTW participants with the same student and school characteristics.

We are also interested in understanding whether these outcome differences (i.e., B1 and B2) differ by race/ethnicity. This is analyzed by adding the interaction terms between the treatment indicators and race-ethnic indicator variables to Model 2. Specifically, the model is written as;

$$Y_{ij} = B0 + B1(T1)_{ij} + B2(T2)_{ij} + B3(T1)*(Race/Ethnicity)_{ij} + B4(T2)*(Race/Ethnicity)_{ij} + B5(Cohort)_{ij} + B6(X)_{ij} + B7(W)_j + u_j + e_{ij.} \quad (3)$$

where T1*Race/Ethnicity and T2*Race/Ethnicity are a set of interaction terms for each of the PLTW participation status and race/ethnic group indicators (Black, Hispanics, and Other with White students as an omitted group). Thus, the two parameters, B1 and B2, in Model 3 indicate the difference in the outcome for White students who enrolled in 1 PLTW course and 2 or more PLTW courses, respectively, from the outcome of White students who did not enroll in PLTW; B3 and B4 represent how the outcome difference between PLTW participants (1PLTW and 2 or more PLTW, respectively) and non-PLTW participants differed for Black, Hispanic, and Other groups. For each subgroup, the overall difference between program participants and non-participants is given by (B1+B3) for students with 1 PLTW course and (B2+B4) for students with 2 or more PLTW courses.

Lastly, we analyzed Model 3 separately by male and female students. This provides parameter estimates that are specific to each gender group.

Appendix D – Analytic Sample Analyzed for Section 3

Table D1 displays the characteristics of students who attended Missouri public postsecondary institutions (the analytic population) compared to all 2013/2014 cohorts with NSC college enrollment records. As 70% of all college enrollees attend Missouri public colleges (44,179 out of 63,421 of total students with NSC records), the difference between the two populations is negligible.

Analytic population

The logic and methods for creating the analytic population for this report are summarized below.

- 50,186 graduates from the AY2013 and AY2014 first time 9th grade cohorts were reported by NSC as attending a Missouri public higher education institution.[11] This represents approximately one third of all cohort members (the total number of first-time ninth-grade students is 145,619).
- These 50,186 graduates were sent back to the Department of Elementary and Secondary Education (DESE), which provided identifying information (primarily names and birth dates) to DHEWD to link EMSAS records to DESE records. DHEWD was able to provide EMSAS data for 48,844 students (97 percent)[12].
- EMSAS data was linked back to original high school records to obtain other variables used in analyses. The resulting analytic population is comprised of 44,170 students. The 4,674 students excluded from analyses due to missing data and/or because their only EMSAS data was for postsecondary attendance during high school.[13]

[11] A few Missouri public colleges do not report to the NSC, and students who attended these institutions are dropped from our analysis as they are not found in NSC. For more information on institutions that provide enrollment data for college searches see https://www.studentclearinghouse.org/high-schools/studenttracker/enrollment-reporting-institutions/

[12] It is likely that "fuzzy matching" methods based on student names and identifying information were unable to find reliable matches for all students submitted to DHEWD for data retrieval.

[13] The vast majority of students are omitted because of missing data on 8th-grade state assessment scores.

Table D1

Comparison of Missouri public postsecondary institution attendees to all postsecondary attendees in 2013/2014 cohort

	All Postsecondary Attendees								Attendees of Missouri Postsecondary Institutions							
	No PLTW courses		1 PLTW course		2+ PLTW courses		Total		No PLTW courses		1 PLTW course		2+ PLTW courses		Total	
	n	pct	n	pct	n	pct	n	pct	n	pct	n	pct	n	pct	n	pct
Cohort																
2013	26,587	51%	2,748	46%	2,277	45%	31,612	50%	18,731	51%	1,733	46%	1,688	46%	22,132	50%
2014	25,764	49%	3,290	54%	2,755	55%	31,809	50%	18,031	49%	2,064	54%	1,943	54%	22,038	50%
Gender																
Female	31,099	59%	2,483	41%	1,905	38%	35,487	56%	22,120	60%	1,533	41%	1,275	35%	24,948	56%
Male	21,252	41%	3,555	59%	3,127	62%	27,934	44%	14,642	40%	2,244	59%	2,336	65%	19,222	44%
Race/ethnicity																
White	41,517	79%	4,325	72%	3,828	76%	49,670	78%	29,918	81%	2,850	75%	2,814	78%	35,582	81%
Black	6,923	13%	975	16%	632	13%	8,530	13%	4,345	12%	565	15%	391	11%	5,301	12%
Hispanic	1,837	4%	269	4%	215	4%	2,321	4%	1,211	3%	141	4%	174	5%	1,526	3%
Other	2,074	4%	469	8%	357	7%	2,900	5%	1,288	4%	241	6%	232	6%	1,781	4%
Free/reduced lunch		33%		26%		22%		31%	12,423	34%	1,064	28%	831	23%	14,318	32%
MAP- percent proficient or adv.																
English		68%		73%		81%		69%		67%		71%		79%		68%
Math		60%		64%		70%		61%		58%		62%		69%		60%
Science		63%		71%		82%		65%		61%		68%		80%		63%
Initial postsecondary enrollment*																
2- year institution	22,281	43%	2,140	35%	1,241	25%	25,662	40%	20,021	54%	1,884	50%	1,397	39%	23,302	53%
4- year institution	30,047	57%	3,893	65%	3,790	75%	37,730	60%	16,741	46%	1,913	50%	2,214	61%	20,868	47%