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

A report to the KC STEM Alliance

Research team

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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. PLTW is a problem-based curriculum designed to increase science, technology, engineering and mathematics (STEM) interest, skills, and workforce readiness. We estimate that the program has been made available to students in approximately 17 percent of Missouri high schools.

We used regression analyses to examine how PLTW participation is related to four outcomes: enrollment in high school dual credit courses, high school graduation, enrollment in postsecondary education, and declaration of a STEM major in college. The models controlled for available measures of student and school characteristics associated with these outcomes. The analytic population of first-time 9th graders we studied includes 145,619 students, 13 percent of whom enrolled in at least one PLTW course.

The regression analyses estimate differences in outcomes between students who did and did not take PLTW courses. Estimated differences were calculated for two levels of PLTW participation—1 course taken and 2 or more courses taken. Separate estimates were also calculated for gender and race/ethnicity subgroups.

We found that students who took PLTW courses, when compared to those who did not, were significantly higher on all four outcomes. 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 their initial enrollment in college. These differences were observed after controlling for student and school characteristics.

Substantially more positive outcomes were observed for students taking 2 or more PLTW courses than for students taking only 1 PLTW course. For all outcomes, the estimated advantage of taking 2 or more PLTW courses was found to be twice as large as the advantage of taking just one PLTW course.

Within all gender and race/ethnicity subgroups examined, PLTW course takers had better outcomes than those who did not take PLTW courses. For most outcomes, the benefits of taking PLTW courses were similar for males and females. However, more complex patterns were observed when estimates were broken down by race/ethnicity. For example, the benefits of PLTW participation for high school graduation and enrollment in dual credit courses were highest for Hispanic females, Hispanic males, and Black males. Similarly, the estimated benefits of PLTW participation for postsecondary enrollment were highest for Hispanic females, Hispanic males, Black females and Black males. In contrast, the benefits of PLTW participation for STEM major declaration were highest for White females, White males, and Hispanic females.

We found evidence suggesting that taking PLTW courses helps students successfully persist to high school graduation and transition to postsecondary education. With the exception of STEM major declaration, students in historically underserved groups appear to have benefitted more from participation in PLTW. When the two cohorts of students under study were in high school, the program was available in a relatively small percentage of the high schools in the state and was reaching an equally small percentage of the state's high school students. Since then, the program has grown substantially. While we are planning additional research to more rigorously test PLTW's impact, and to better understand who benefits from the program, and under what conditions, we believe a reasonable implication of these preliminary findings is that more widespread implementation of the program in the state is likely to help more Missouri high school students make the transition to postsecondary education.

Introduction

Project Lead the Way (PLTW) is a curriculum designed to increase STEM interest, skills, and workforce readiness for careers based on science, technology, engineering and/or mathematics (STEM). The curriculum centers on hands-on activities, projects, and problems that help students connect classroom learning with real world applications. 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. Since then, enrollment has grown steadily and is currently offered in 384 schools (which includes elementary, middle and high schools) in 163 districts across the state. 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 curriculum and experiences at the secondary level.

The three high school pathway programs—Engineering, Computer Science, and Biomedical Science—are designed to build knowledge and skills through scaffolded learning experiences. Introductory or foundation-level courses are intended to develop an understanding of and enthusiasm for the field. Advanced courses are designed to extend student learning through deeper and more specialized content. Schools may choose from a variety of specialized courses. All courses include hands-on activities and students use acquired knowledge to offer solutions to real-world problems (Project Lead The Way 2021b). 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 approach enables us to determine if more PLTW participation is associated with stronger 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 National Student Clearinghouse (NSC) data 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 particularly outperformed their counterparts who did not participate in PLTW.

Three questions guided our investigation of student outcomes associated with PLTW program participation:

- 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?

In the next section we describe 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. Specifically, our analyses examined the characteristics of PLTW participants and their subsequent high school and postsecondary education outcomes as compared to those of students who did not participate in PLTW.

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 Data (CCD) for information on the local of schools (urban, suburban, town and rural) and they were used for the analysis of student program participation and their subsequent outcomes.

The student-level data contained records of students who 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, and
- College enrollments and majors in the year following high school graduation from the National Student Clearinghouse.[1]

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. Using these data, our main analyses estimated high school and post-secondary outcomes of PLTW participants compared to those of non-participants. The analytic population consisted of the 145,619 first-time 9th-grade students in AY2013 and AY2014.[2]

The rollout of PLTW in Missouri

Figure 1 shows that between 2005 and 2020, implementation of the PLTW program in Missouri grew substantially. 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 over time.

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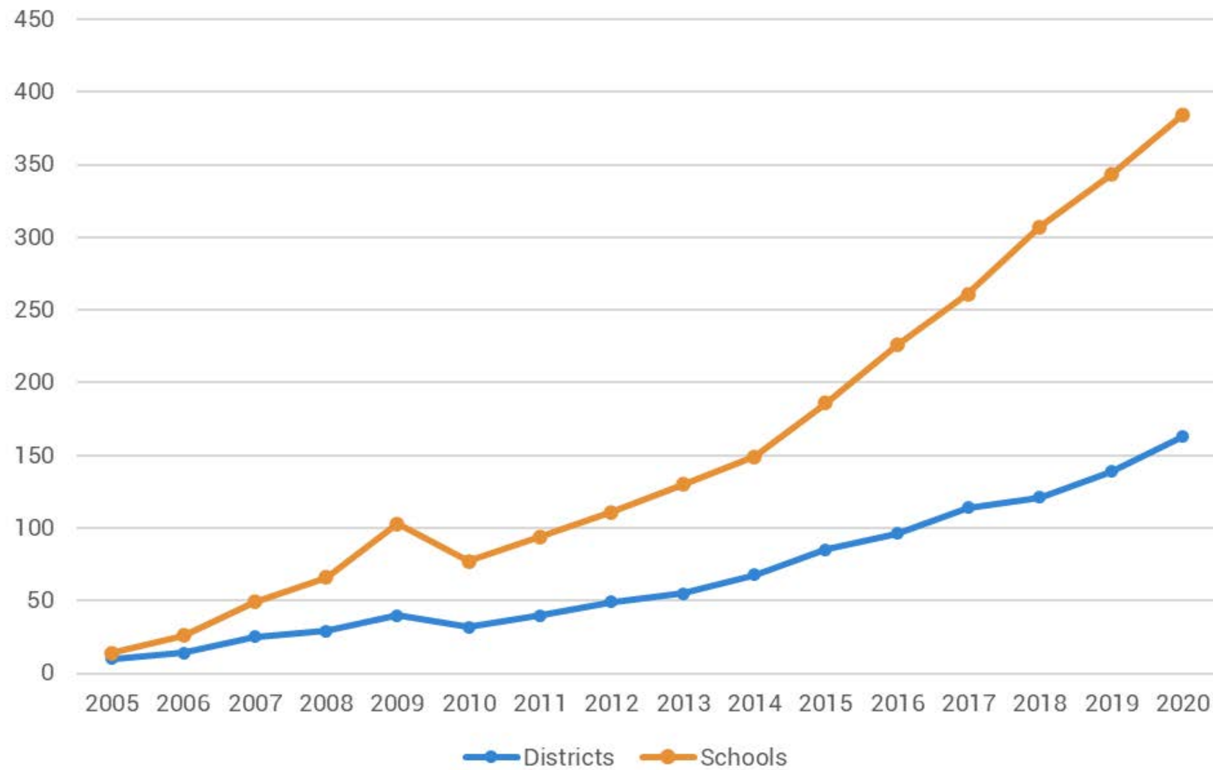
[1] Every fall, DESE collects data from the NSC on the college enrollment of Missouri high school graduates from the prior school year.

[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.

Figure 1

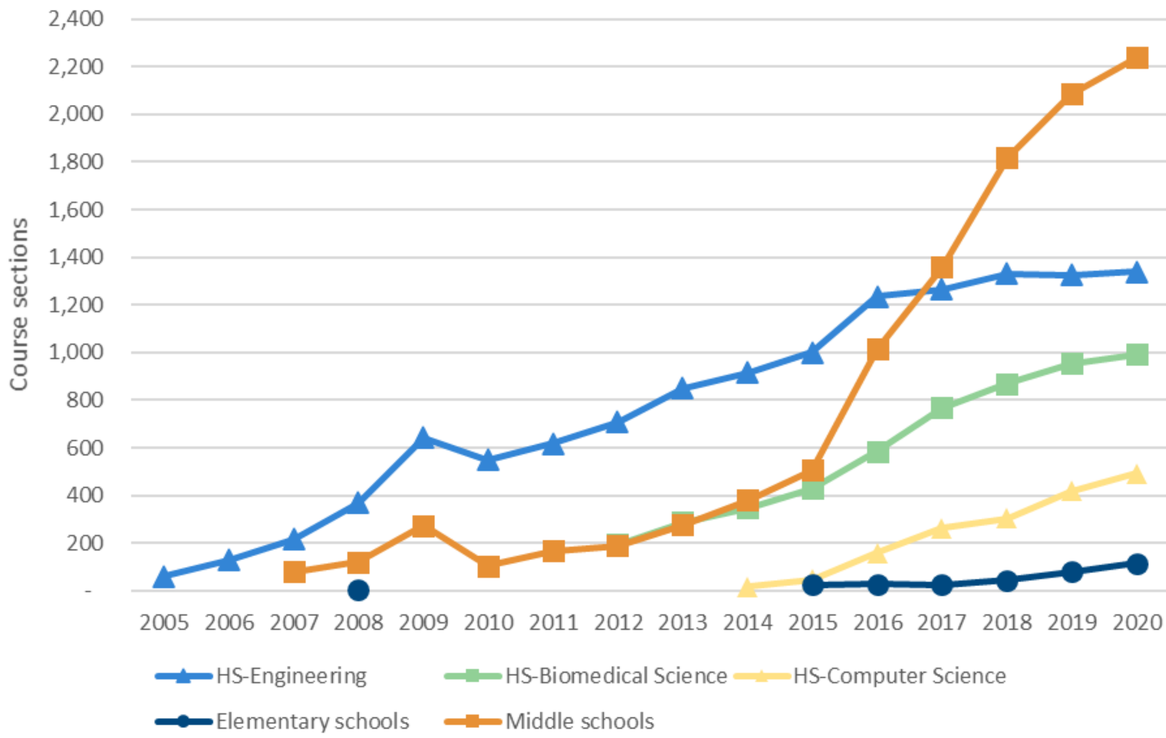
Growth in the number of districts and schools implementing PLTW, 2005-2020



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 five pathways have demonstrated growth in course offerings since their inception.

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, has grown from 80 sections in 2007 to 2,238 sections in 2020. Its growth, which was steady between 2007 and 2015, has accelerated 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.

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. 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 a presentation of study results. We begin by describing the students and schools studied, which is followed by presentations of analyses of high school and postsecondary outcomes.

As previously discussed, data for our analyses are based on 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 in which at least one student took a PLTW course (middle two columns), and schools in which no student took a PLTW course (right two columns). Of the 537 high schools attended by cohort members, 92 had PLTW courses available to their students during high school and 445 did not. We found that schools that provided PLTW courses were more likely to be in suburban settings with student enrollments in the mid- to large-sized range. 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

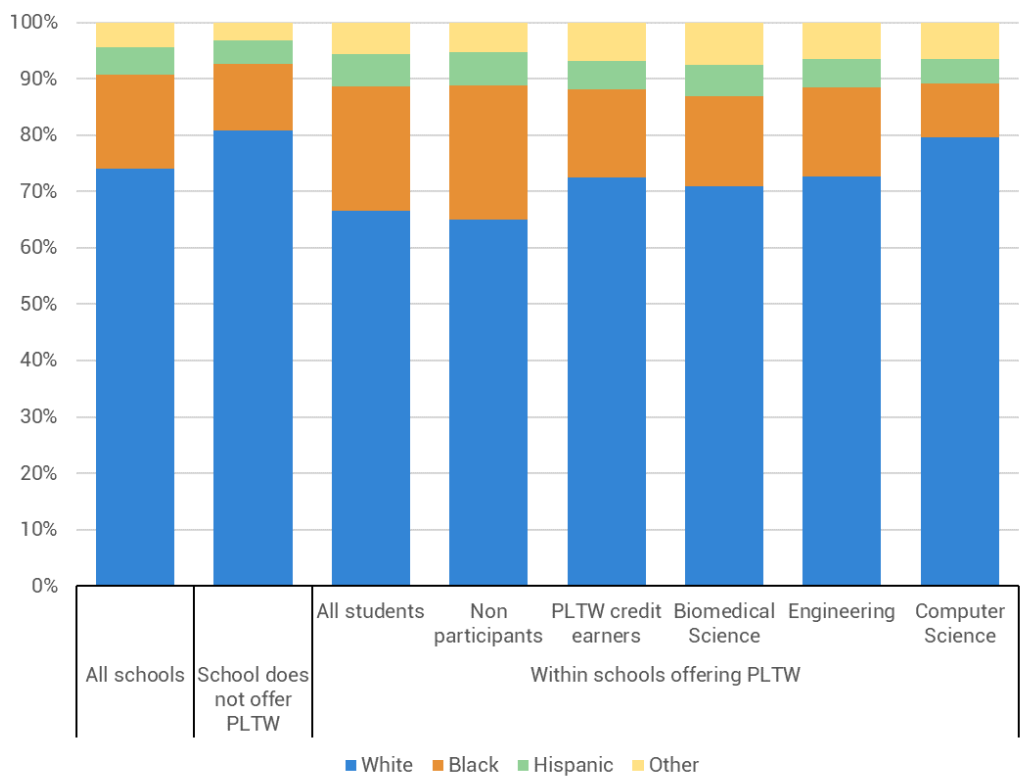
	All High Schools		School provided PLTW		School did not provide PLTW	
	N	Pct.	N	Pct.	N	Pct.
Sector						
Traditional public high school	524	98%	91	99%	433	97%
Public charter high school	13	2%	1	1%	12	3%
Total	537	100%	92	100%	445	100%
Location						
City	57	11%	18	20%	39	9%
Suburb	78	15%	47	51%	31	7%
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 schools) and schools that did not offer PLTW (non-PLTW schools). The remaining bars show the race/ethnic compositions of schools that offered PLTW[3] (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, compared to all students in PLTW schools, PLTW credit earners were slightly less likely to be African American and slightly more likely to be White. This pattern was even more 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



[3] For purposes of this report, a school "offering" PLTW means that PLTW courses were made available to students in that school.

Figure 4 shows the gender distribution of students in the study. The overall gender distribution did not differ by the school's PLTW status. However, credit earners were less likely to be female students, 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

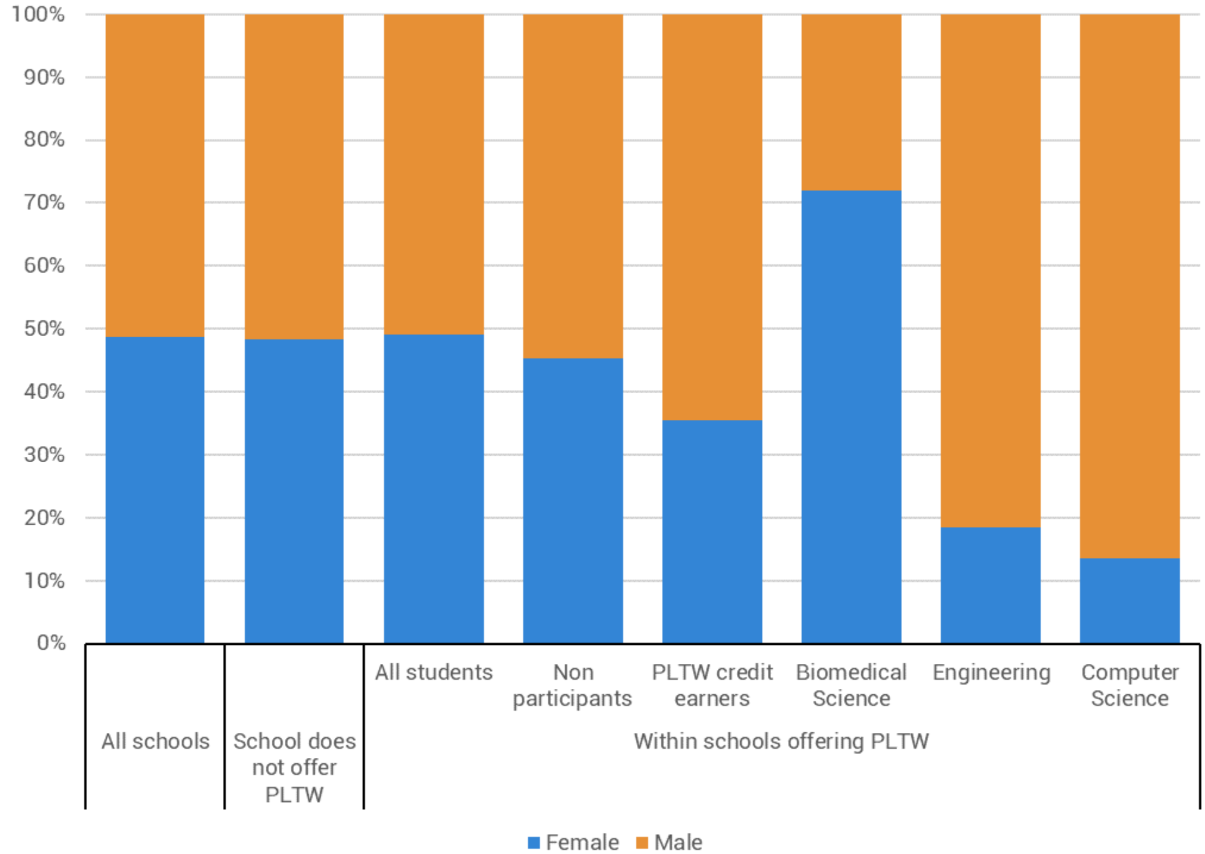
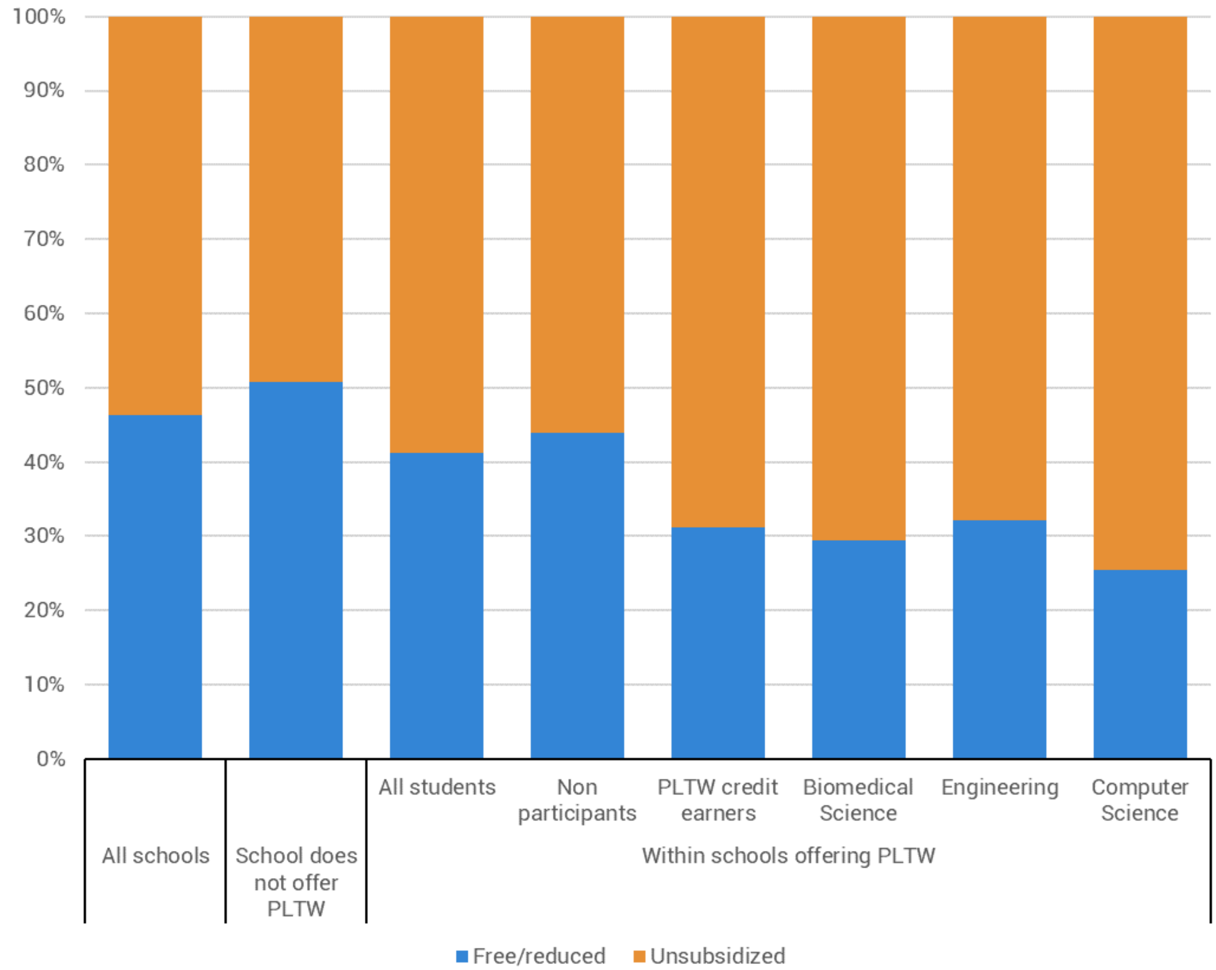


Figure 5 shows the distribution of students who were reported as receiving and not receiving free/reduced price lunch which we use as a proxy for income status. We found that schools offering PLTW served slightly fewer FRL students than schools not offering the program, and than all high schools in the state. 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 the study cohorts 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. In 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. For both subject, the average proficiency levels were similar whether or not the school offered PLTW, while credit earners had higher academic proficiency in both subjects than non-credit earners.

Figure 6

PLTW participation by 8th grade MAP math achievement

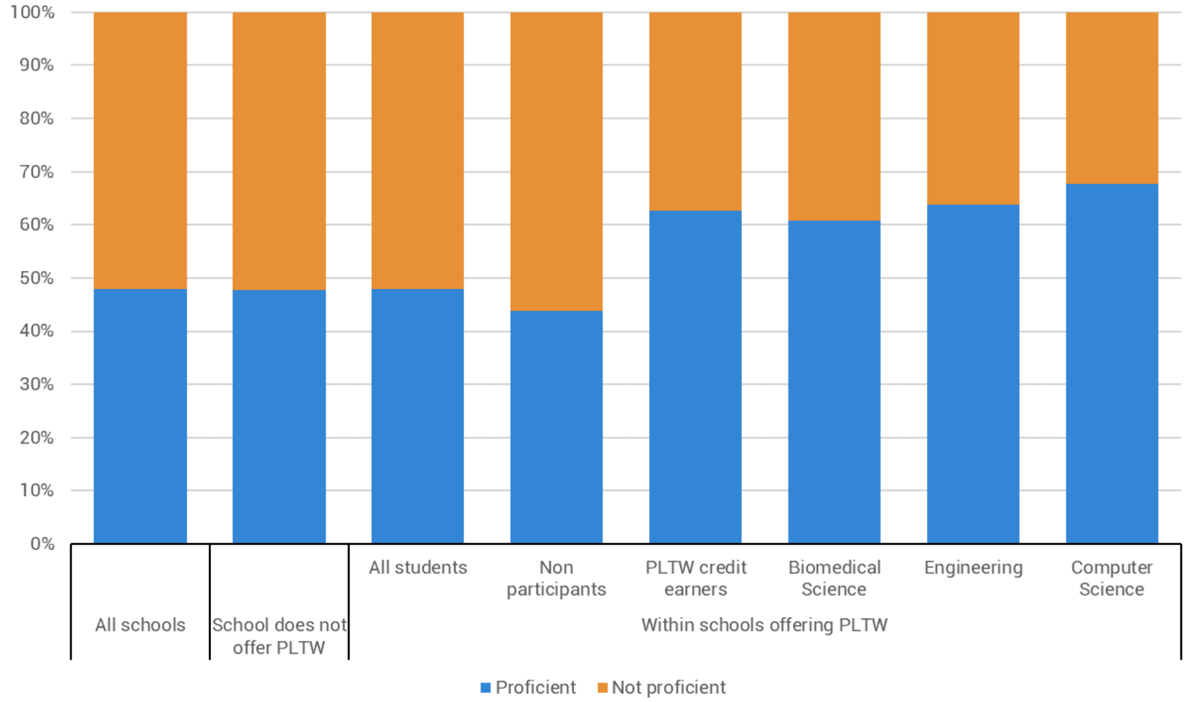


Figure 7

PLTW participation by 8th grade MAP science achievement

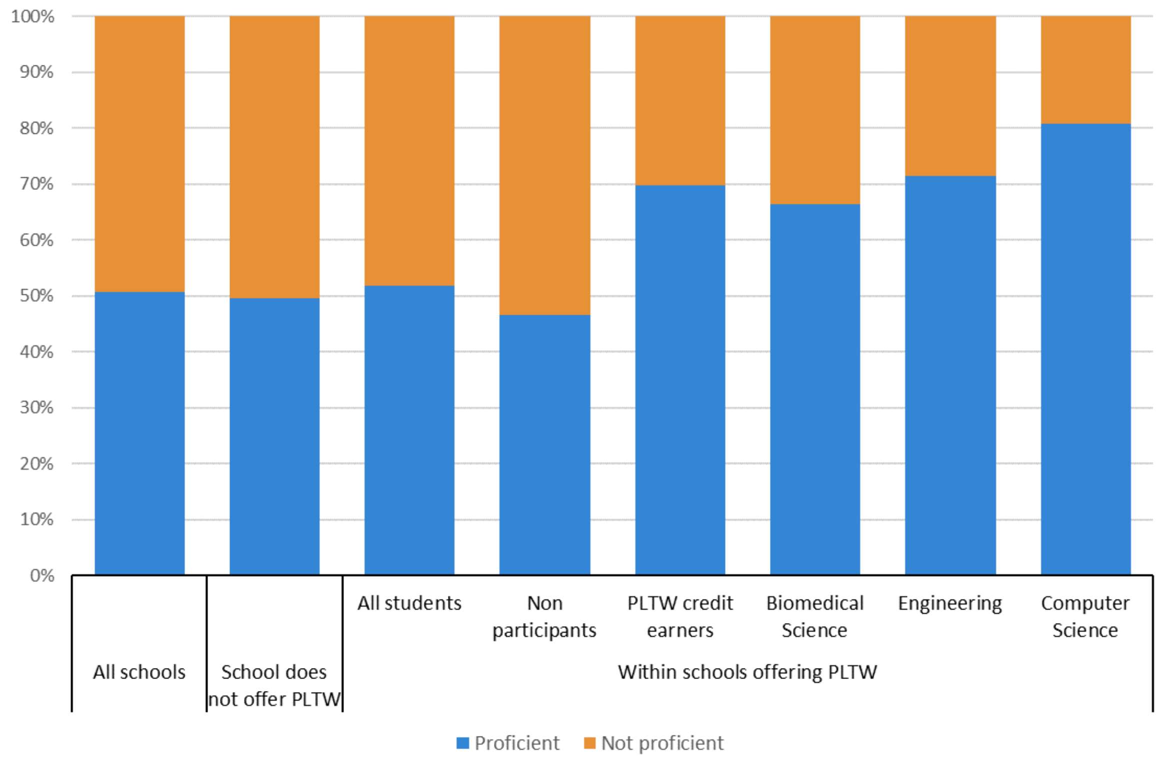
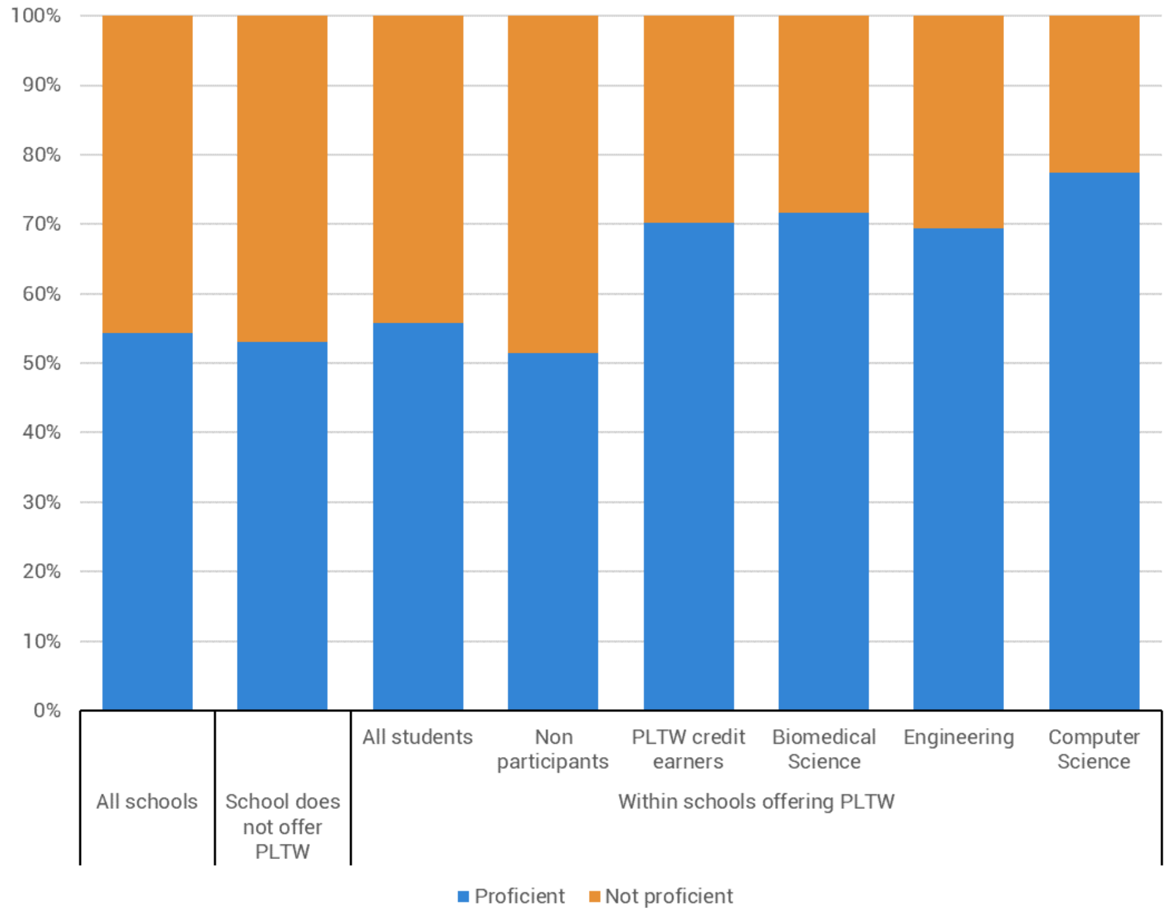


Figure 8

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



Results for high school outcomes

We now turn to an analysis of how high school outcomes differ by PLTW participation status. We address this question in two sets of analyses. We first examine overall average outcomes for cohort members who attended schools making PLTW available and those that did not. We report results for the following 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' high school outcomes differed by their PLTW participation levels (not enrolling in any PLTW course, enrolling in one PLTW course, or enrolling in two or more courses). The outcomes examined in the regression analyses are high school graduation and enrollment in dual credit courses.

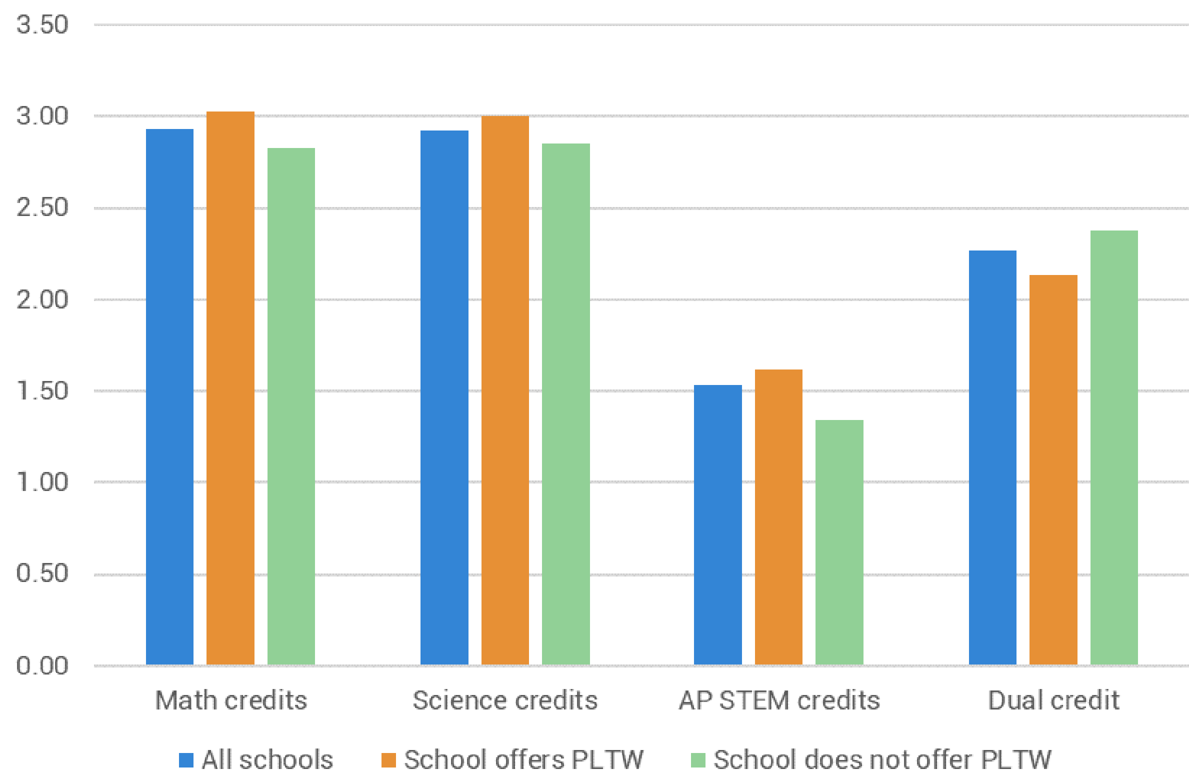
Differences in high school outcomes for students attending PLTW and non-PLTW schools

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

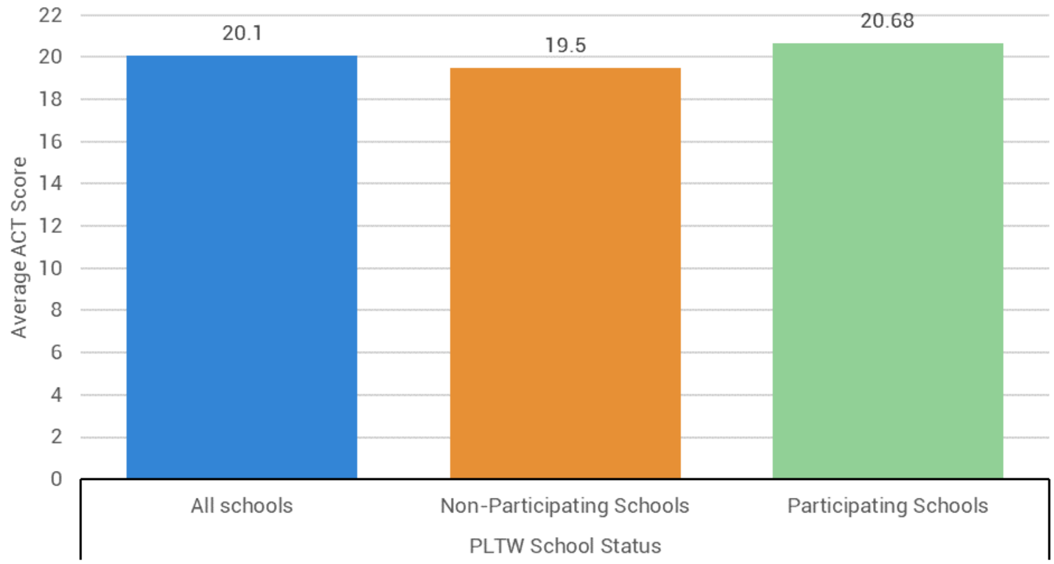


ACT scores

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

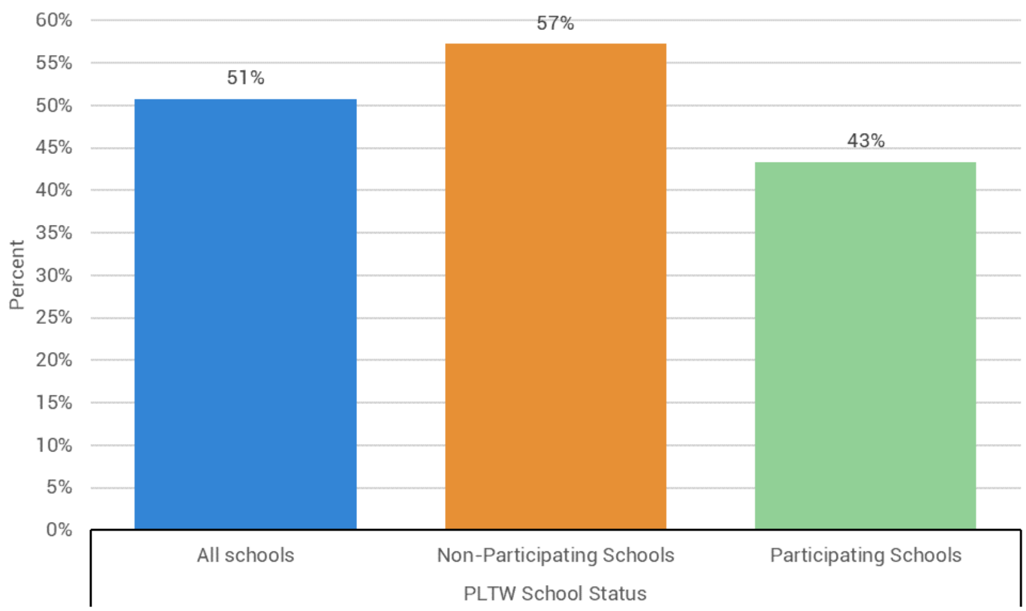


<u>*CTE enrollment*</u>

Schools that implemented PLTW had considerably lower rates of CTE course enrollment than schools that did not implement PLTW. 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

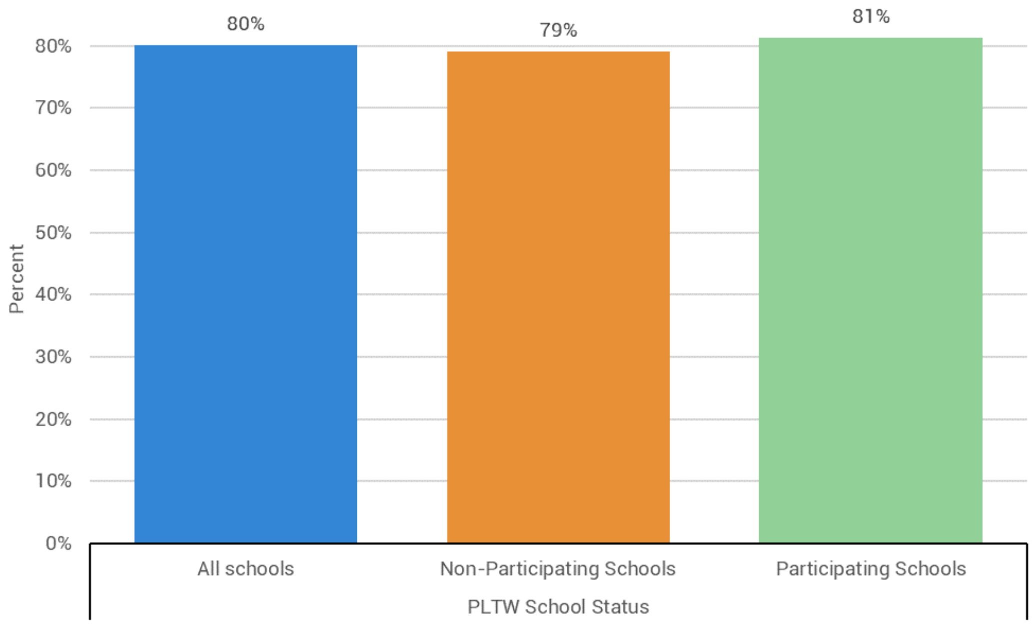


High school graduation

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. Also, different types of CTE programs may be offered in non PLTW schools.

Regression analysis of high school outcomes

Regression analyses were conducted to examine how students receiving different "dosages" of PLTW differed on two high school outcomes—enrollment in dual credit courses and high school graduation. The first set of analysis includes only the PLTW dosage variables (no PLTW courses as a reference category, one PLTW course, and two or more PLTW courses as predictors). These are what we call unconditional models and provide estimates of overall differences on the outcomes by PLTW dosage/participation level. However, as shown earlier, there are some student characteristics that are associated with PLTW participation—for example, academically stronger students are more likely to enroll in PLTW courses. Not taking such differences it account could lead to estimates that overstate the benefits of PLTW participation. To deal with this situation, the second set of regression analyses (conditional models) control for student and school characteristics that are likely to be related to the outcomes we examined. These conditional models thus provide estimates of outcome differences by PLTW "dosage" among students who are similar in student and school characteristics. A detailed discussion of the statistical methods used, including the logic of the regression analyses underlying our conclusions can be found in Appendix B. Appendix B also contains a list of all variables used in analyses.

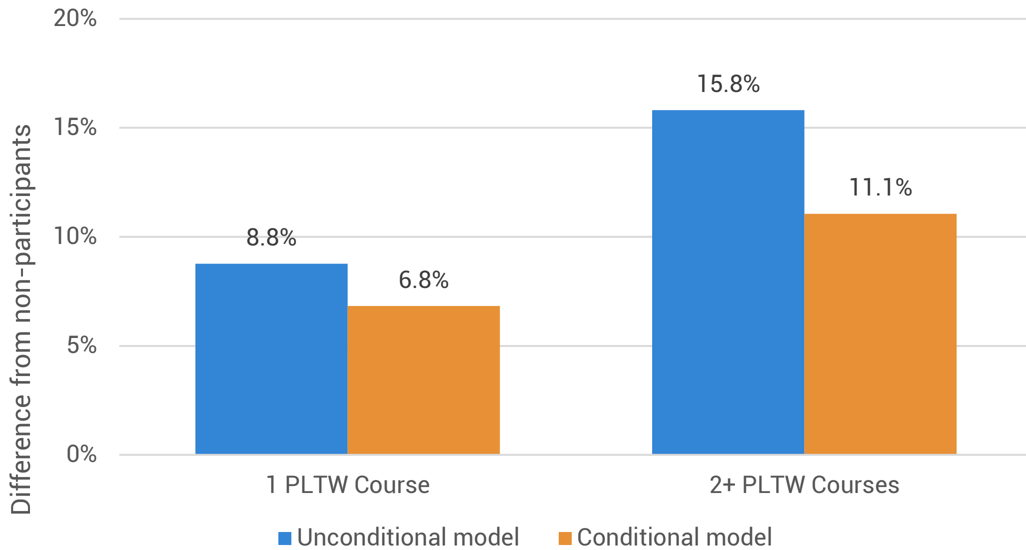
High school graduation

The first regression analysis examined the relationship between PLTW participation and students' graduation from high school. Figure 13 shows differences in the high school graduation rates of students who participated in PLTW and those who did not. The left side of the figure displays results for students who took one PLTW course and the right side shows the results for those who took 2 or more courses. The bars represent estimated differences between PLTW participants and those who did not take PLTW courses. In the remainder of the report we colloquially refer to these estimated differences as "benefits", "advantages" and "boosts" associated with PLTW participation.

According to the unconditional models, students who enrolled in 1 PLTW course graduated from high school at a rate that is nearly 9 percent higher than students who did not enroll in any PLTW courses. This model also estimates that the graduation rate of those taking 2 or more PLTW courses is nearly 16 percentage points higher than that of students who did not enroll in any PLTW courses. Results of the conditional models follow a similar pattern as those from unconditional models, indicating higher high school graduation rates for students with greater levels of PLTW participation. However the estimates are smaller when we take into account student 8th-grade achievement, student demographics, and school demographics and average achievement levels.

Figure 13

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



The next analysis compares high school graduation rates for PLTW participants versus non-participants *within* race/ethnicity and gender groups, using race/ethnicity categories defined by DESE[4]. Specifically, we present separate estimates of the estimated difference in high school graduation rates between students taking one PLTW course and those taking no PLTW courses, and between students taking 2 or more PLTW courses and those taking no PLTW courses. Separate sets of estimates are provided for females (Figure 14) and males (Figure 15). Within these results for each gender, estimates are further broken down by race/ethnicity (White, Black, Hispanic and Other). For example, as shown in Figure 14, 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.

[4] DESE's race / ethnicity categories used in the models include White, Black, and Hispanic. The Other value includes the Asian / Pacific Islanders, Native Americans, multi-racial and any other codes used to categorize students' race and ethnicity.

Figure 14

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

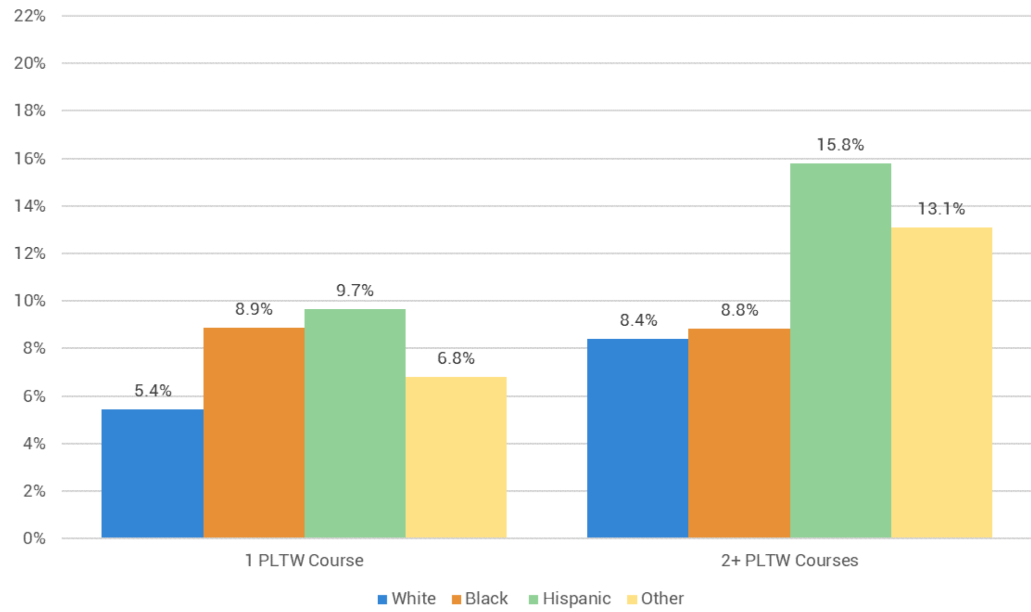
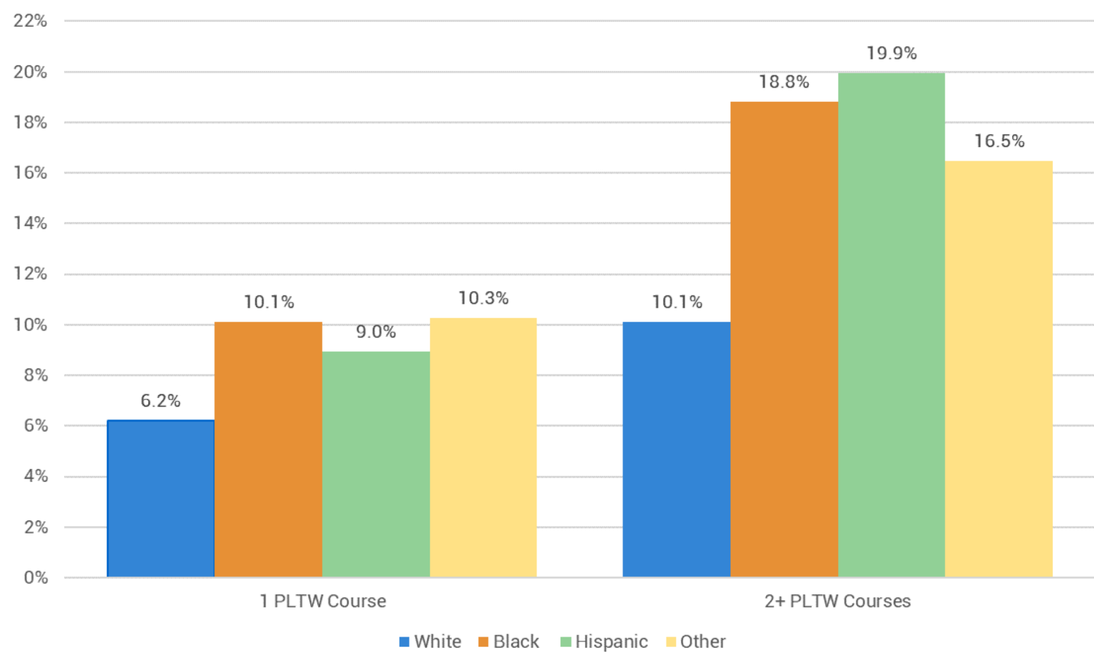


Figure 15

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



A number of general conclusions can be drawn from the estimates in 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 enrolling in PLTW courses were even larger for students enrolling in two more PLTW courses.

- The benefits of PLTW enrollment for high school graduation were 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. The one exception to this pattern is Black females who took two or more PLTW courses. The increase in their chance of graduating from high school associated with PLTW participation was similar to that of White females.

- The benefits of taking PLTW courses appears to be similar for males and females. Estimates for males and females within race subgroups are generally quite similar.

Enrollment in dual credit courses

The next regression analysis examined the relationship between students' participation in PLTW and enrollment in dual credit courses. Figure 16 shows differences in rates of participation in dual credit courses for students who participated in PLTW and those who did not participate in PLTW. Again, the left side of the figure displays results for students who took one PLTW course and the right side shows the results of those who took 2 or more courses and the bars represent estimated differences between PLTW participants and those who did not take PLTW courses. For purposes of the regression analysis, we define *enrollment in dual credit courses* as enrolling in one or more dual credit or dual enrollment course.[5]

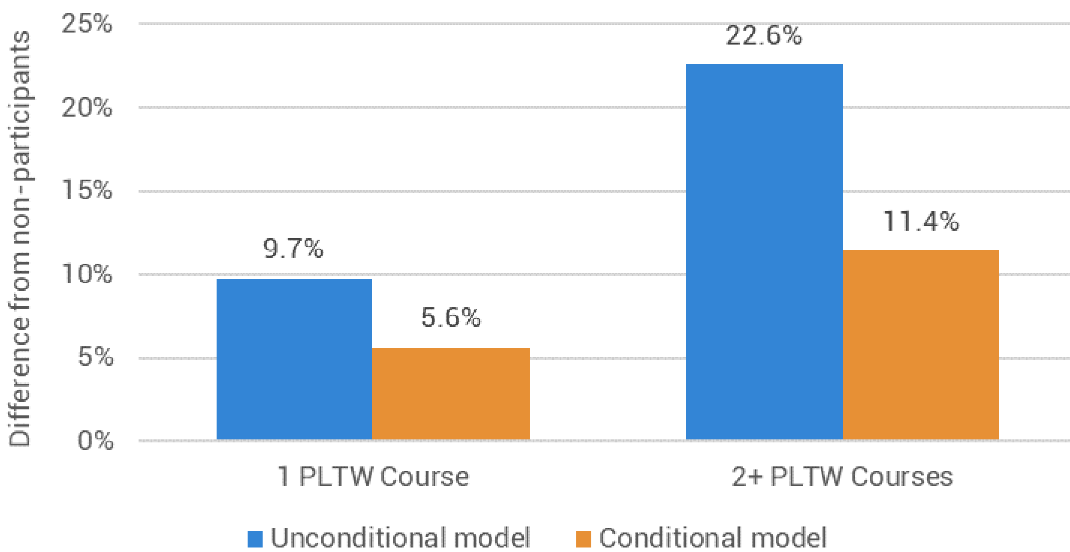
Students who took PLTW courses were considerably more likely to take dual enrollment courses than students who did not take PLTW courses. Unconditional model results show that students who took one PLTW course took dual enrollment courses at a rate that was nearly 10 percentage points higher than students 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

[5] 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.

were even more likely to take dual enrollment courses. The rate of dual enrollment course taking for students taking 2 or more PLTW courses was nearly 23 percent higher than the rate for students who did not take PLTW courses (unconditional model). Again this difference was cut in half after controlling for student and school characteristics to 11.4 percent.

Figure 16

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



Next we compared rates of enrollment in dual credit courses for PLTW participants versus non-participants _within_ race/ethnicity and gender groups. These analyses follow the same format as subgroup analyses presented earlier for high school graduation.

Students in all race/gender subgroups who took PLTW courses enrolled in dual credit courses at a significantly higher rate than those who did not take PLTW courses. The benefits of taking PLTW courses were even larger for those taking 2 or more courses, and this was true for all race/gender groups.

Differences in dual enrollment participation rates between PLTW participants and non-participants was highest for Hispanic students. Hispanic males taking one PLTW course were an exception to this pattern. 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. Black males taking two or more PLTW courses also had substantially higher rates of enrollment in dual credit courses than non PLTW counterparts (14.3 percent difference). Looking across Figures 17 and 18 we see a few differences between males and females within race/ethnicity groups. For example, among Hispanic students taking 1 PLTW course, the estimate for females is nearly twice the estimate for males (16.6 percent versus 8.5 percent). We see the reverse of this pattern among Black students taking 2 or more PLTW courses. Among that group, the estimate for males is nearly twice that of females (14.3 percent versus 7.8 percent).

Figure 17

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

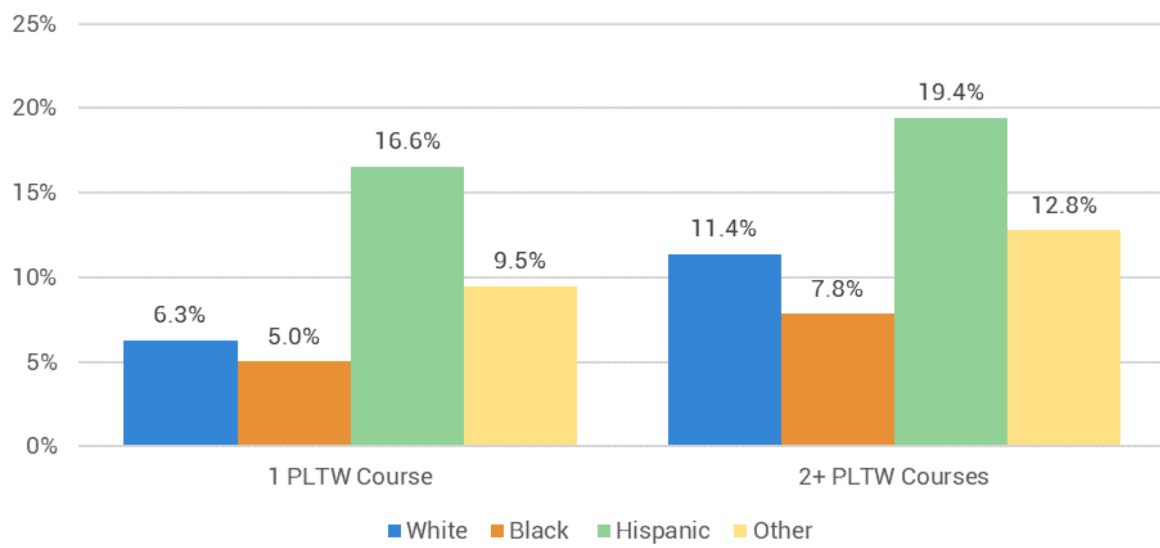
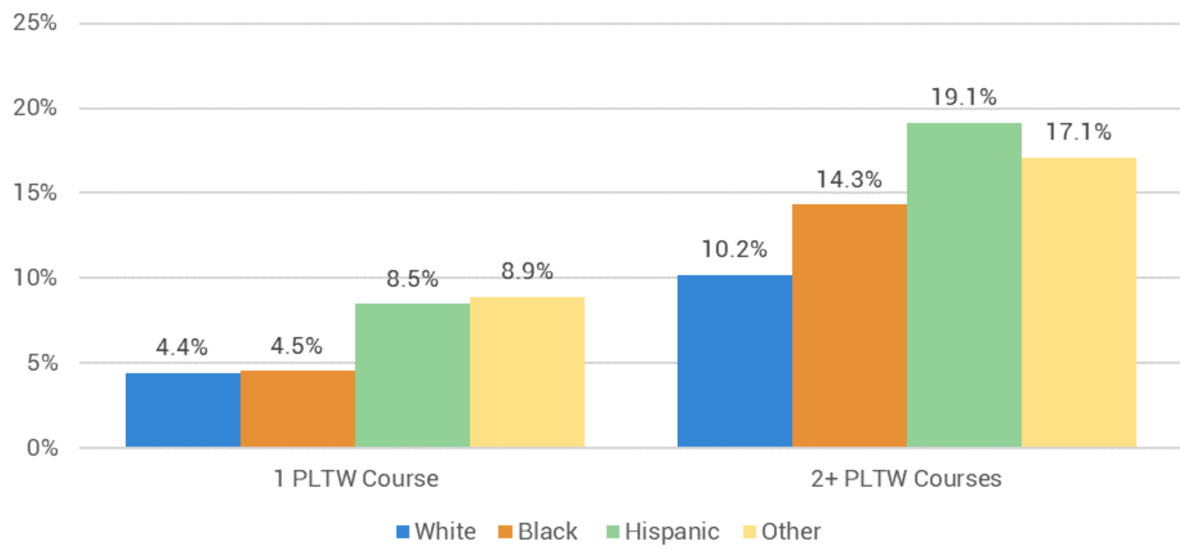


Figure 18

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



Postsecondary outcomes

We now turn to an analysis of how postsecondary outcomes of students who participated in PLTW differed from those of students who did not participate in the program. Mirroring analyses of high school outcomes, we first graphically examine how high schools implementing PLTW and those that do not implement the program differ 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. A second set of analyses used regression models to examine how students' postsecondary outcomes differed by the same PLTW participation levels used in analyses of high school outcomes (not enrolling in any PLTW course, enrolling in one PLTW course, or enrolling in two or more courses). The outcomes examined in the regression analyses are postsecondary enrollment and STEM major declaration at initial postsecondary enrollment.

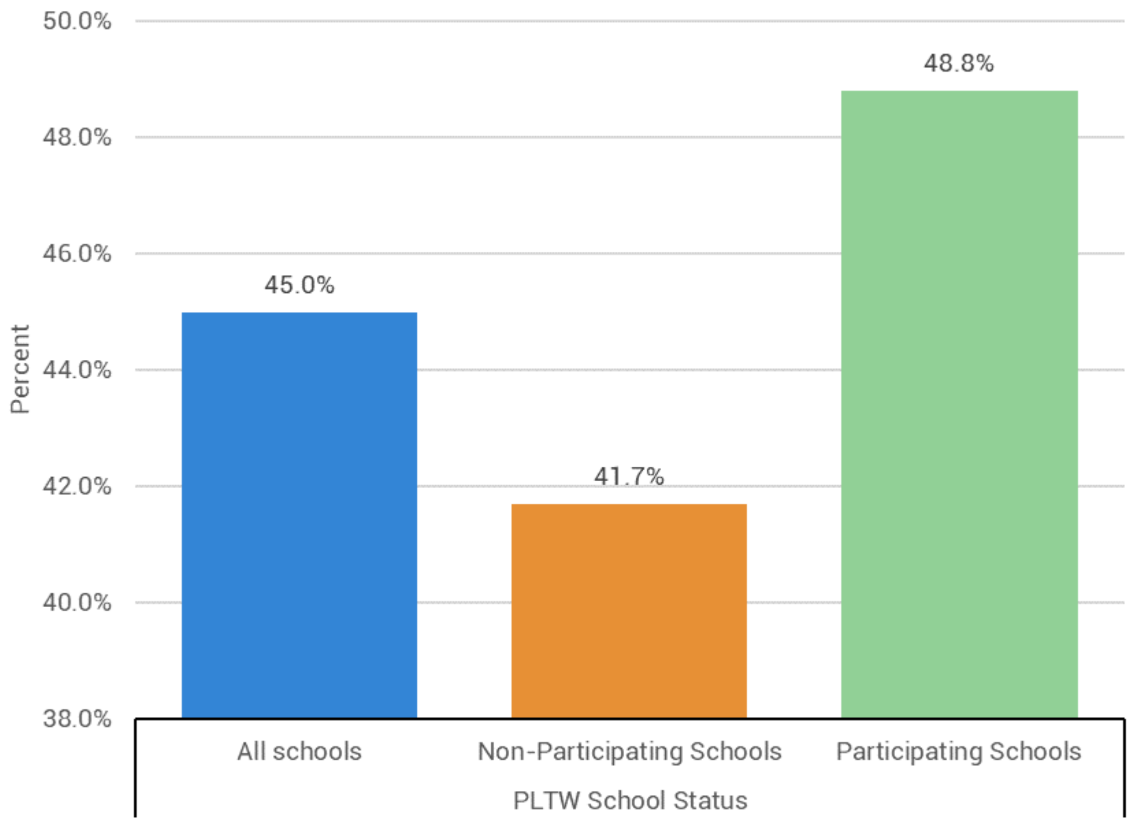
Differences in postsecondary outcomes for students attending PLTW and non-PLTW schools

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

We begin by comparing the overall postsecondary enrollment rates (in any post-secondary institution) of all high schools attended by cohort members, the rates of schools that participated in PLTW and the rates of schools that did not participate in the program. Figure 19 shows that, on average, 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, students attending PLTW schools were seven percent more likely to enroll in postsecondary education than students in non-PLTW schools.

Figure 19

Overall postsecondary enrollment rates by school participation in PLTW

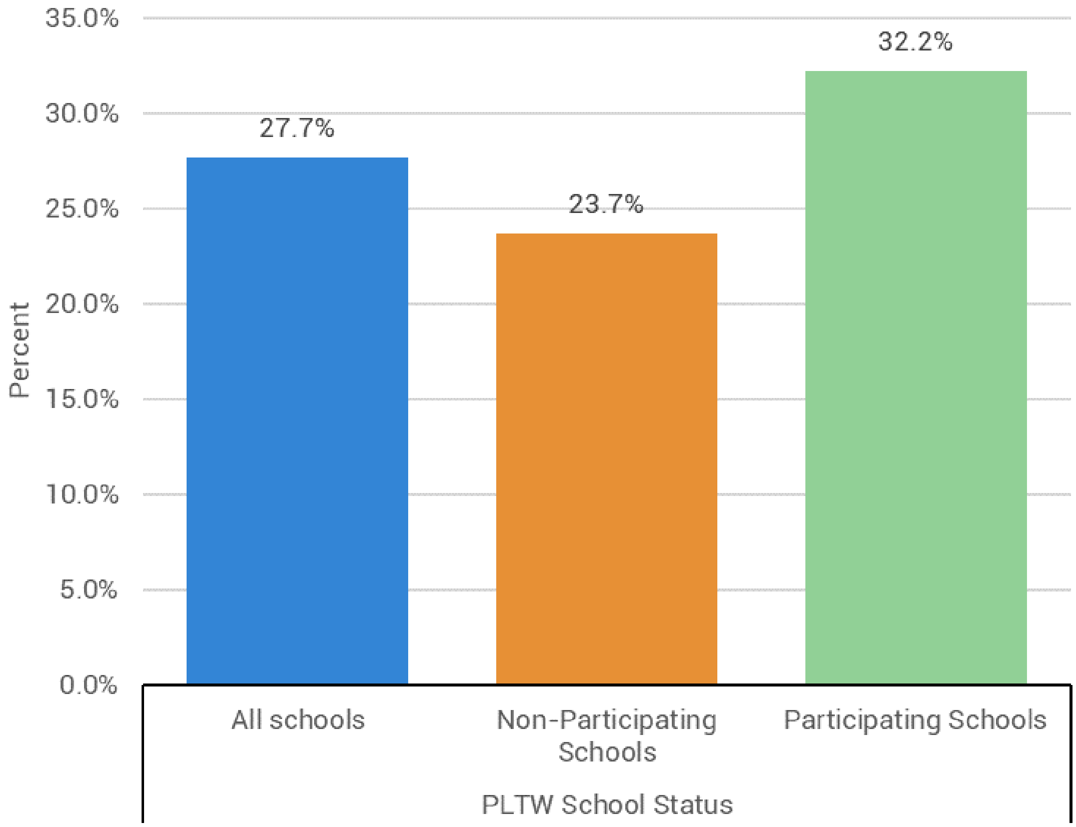


Four-year college enrollment

When we limited our focus to enrollment in four year postsecondary institutions, we again found higher enrollment rates 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



<u>*Declared STEM major*</u>

Beyond simply enrolling in postsecondary education, we found that students attending PLTW schools were also more likely to declare a STEM major when they got to college, though the differences observed for this outcome were smaller than those observed for other postsecondary outcomes. Figure 21 shows the differences in the rates of STEM major[6] declaration between students in PLTW schools and non-PLTW schools. The initial declared major reflects students intended major at the time of enrollment and does not reflect their final major at time of graduation.

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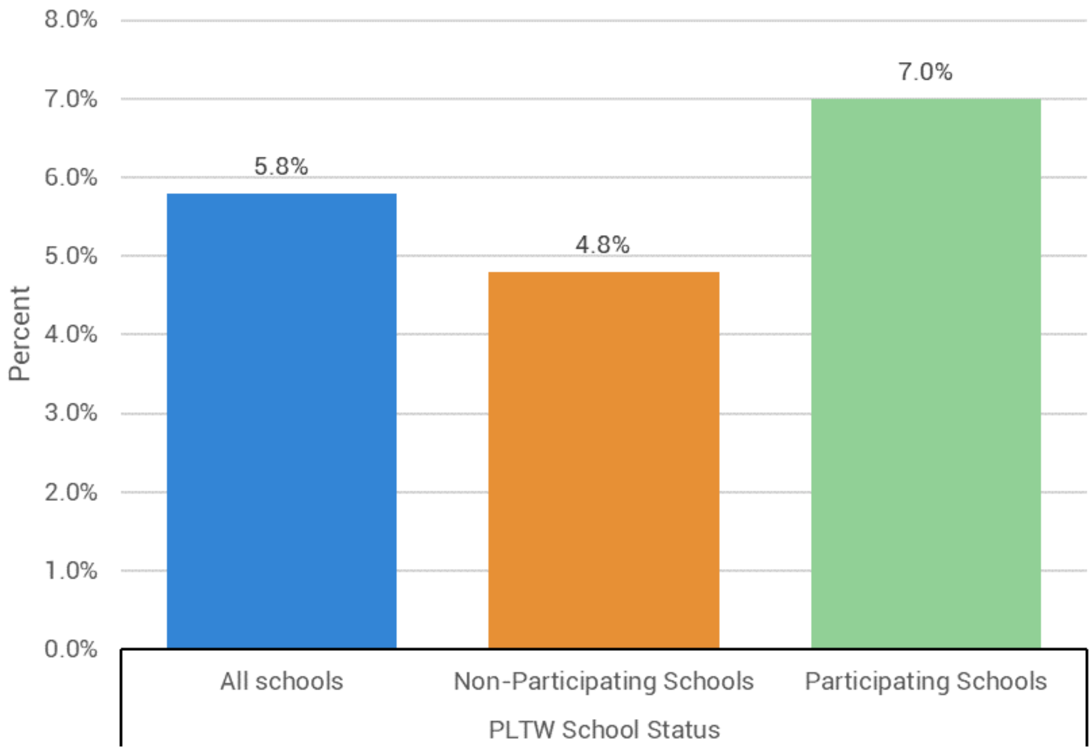
[6] NSC data provide students' declared majors and associated CIP codes if the colleges reporting the data to NSC provide them in their data submissions. We encourage some caution in interpreting results for STEM major selection as some colleges do not report information about majors to the National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

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.

Overall, only about 6 percent of students in the two study cohorts declared a STEM major when they initially enrolled in college. The corresponding rate for students in PLTW schools was only one percentage point higher than the overall rate. Students attending PLTW schools declared a STEM major at a rate that was approximately 2 percentage points higher than students in non-PLTW schools.

Figure 21

STEM major declaration rates by school participation in PLTW



<u>Regression analysis of postsecondary outcomes</u>

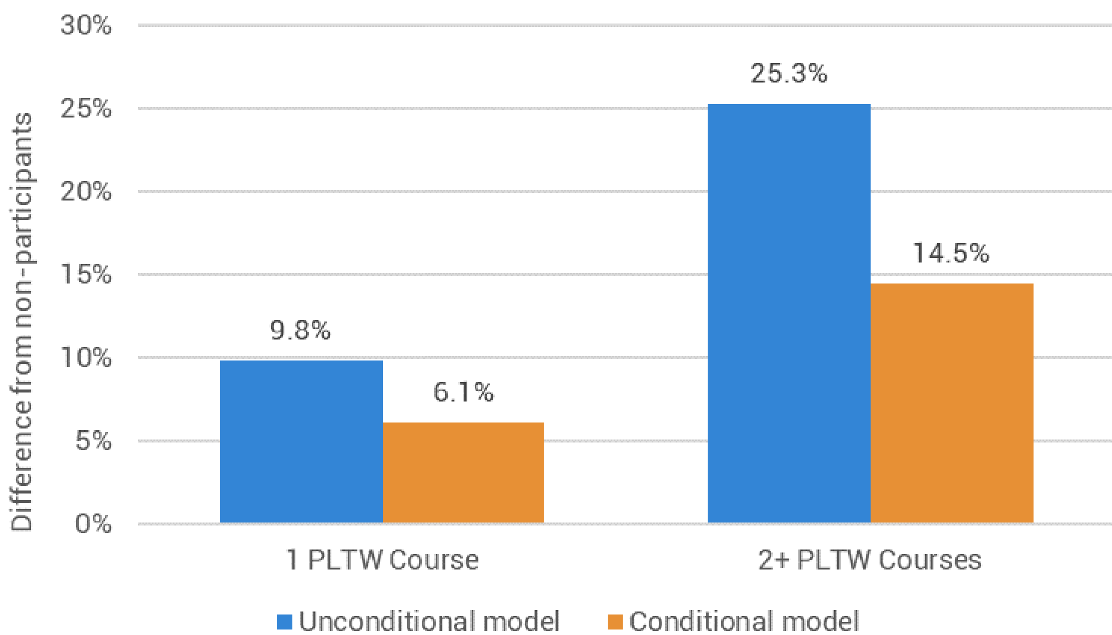
We next present the results of regression analyses predicting two outcomes: postsecondary enrollment (any college) and STEM major declaration. Our modeling strategy for these outcomes parallels that used for high school outcomes. A first set of "unconditional" models provides unadjusted "raw" estimates of the overall outcome differences by PLTW dosage/participation. A second set of "conditional" models provides estimates of outcome differences for students who are similar in terms of student and school characteristics. We remind readers that Appendix B contains a detailed discussion of the statistical methods used and a list of all variables used in analyses.

Postsecondary Enrollment

Figure 22 shows results for regression analyses of postsecondary enrollment. According to unconditional models, 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 any PLTW courses. Unconditional models also predict that students who took two or more PLTW credits enrolled in college at a rate that is 25 percentage points higher than students who did not take any PLTW courses. Results of the conditional models follow a similar pattern, indicating higher postsecondary enrollment rates for students with greater levels of PLTW participation. However the estimates are smaller when we take into account student 8th-grade achievement, student demographics, and school demographics. The advantage for students taking 1 PLTW course dropped by approximately 4 percentage points, and the advantage associated with taking 2 or more PLTW courses dropped 10 percentage points after taking into account differences between students and their schools.

Figure 22

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



The next analysis compares postsecondary enrollment rates for PLTW participants versus non-participants *within* race/ethnicity and gender groups. The analytic strategy is the same as that for the subgroup analysis of high school outcomes Separate sets of estimates are provided for females (Figure 23) and males (Figure 24). Within each gender, estimates are further broken down by race/ethnicity. For example, as shown in Figure 23, white females who took 1 PLTW course enrolled in college at a rate that is 6.3 percent higher than white females who did not take any PLTW courses.

Results from all models indicate that, in all race/gender subgroups, students who took PLTW courses enrolled in postsecondary education at a higher rate than students who did not take a PLTW course. The benefit of PLTW participation for college enrollment was even stronger 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 race/ethnic groups, the pattern of results was similar for males and females with only a few exceptions. One of the largest exceptions to this pattern 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

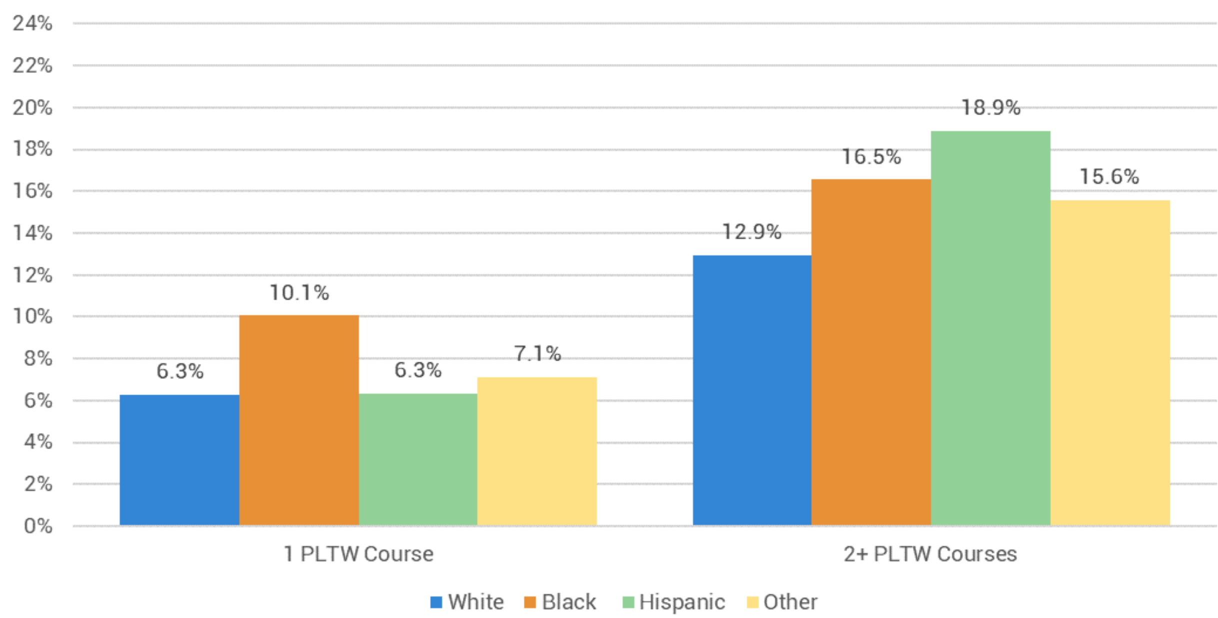
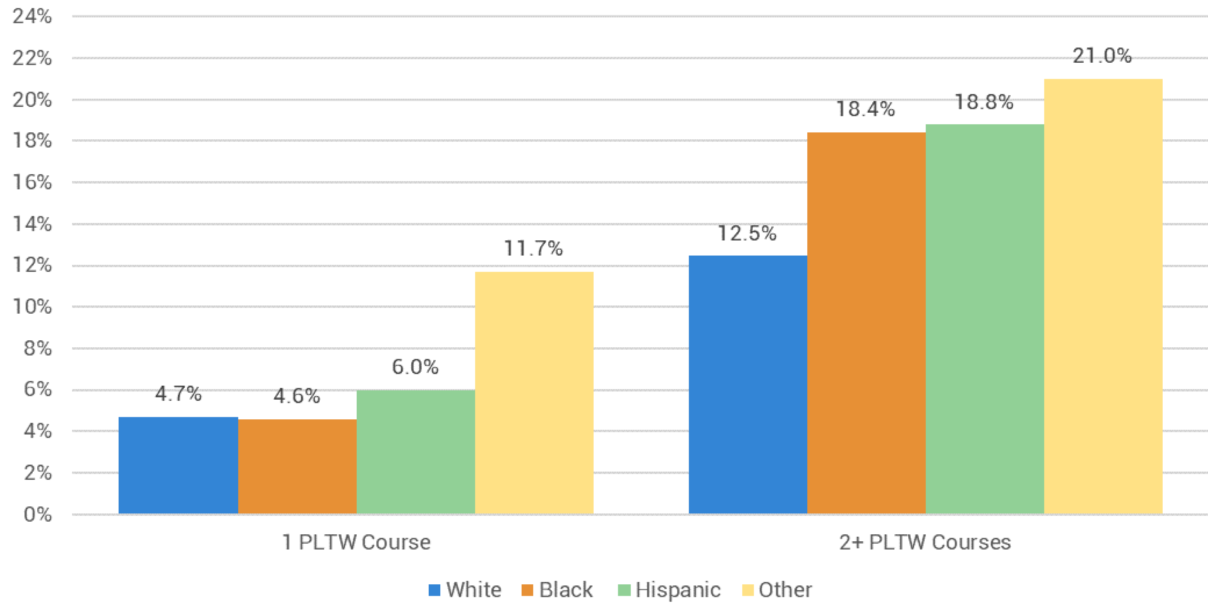


Figure 24

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



Declared STEM Major

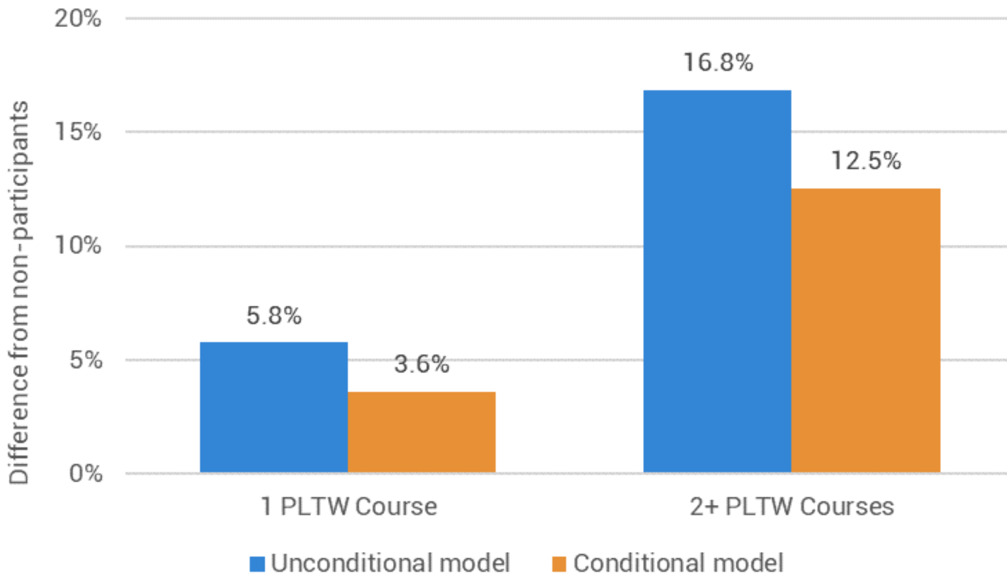
In a final set of regression analyses we examined differences in rates of STEM major declaration between students who participated in PLTW and those who did not. The pattern of results closely mirrored that for postsecondary enrollment. We found that PLTW students, regardless of the number of PLTW courses they took, were more likely to declare a STEM major in college than students who did not take PLTW courses. This was true overall, and across race and gender subgroups. We also found the PLTW-related advantage in STEM major declaration was higher for those taking 2 or more PLTW courses than for those taking 1 PLTW course. Again, this was observed overall, and for all race and gender subgroups.

The result of 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. Those students declared a STEM major in college at a rate nearly 17 percentage points higher than students who did not participate in PLTW.

As with other outcomes, estimates from conditional models are considerably reduced after taking into account student 8th-grade achievement, student demographics, and school demographics. After controlling for these factors, the advantage associated with taking 1 PLTW course dropped by approximately 2 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



Lastly, we compare rates of STEM major declaration for PLTW participants versus non-participants *within* race/ethnicity and gender groups. The analysis follows the same format as other outcomes. The results are provided for females (Figure 26) and males (Figure 27) where estimates are further broken down by race/ethnicity within each gender group. For example, as shown in Figure 26, 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.

Results from all models show that, in all race/gender subgroups, the likelihood of STEM major declaration is larger for students who took PLTW courses than for those who did not, and such differences are larger for students earning 2+ credits. Among students who took two or more PLTW courses, Black and Hispanic students got a bigger apparent boost from PLTW participation than White students in rates of STEM major declaration. Within race/ethnic groups, estimated PLTW benefits experienced by males and females were generally similar.

Figure 26

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

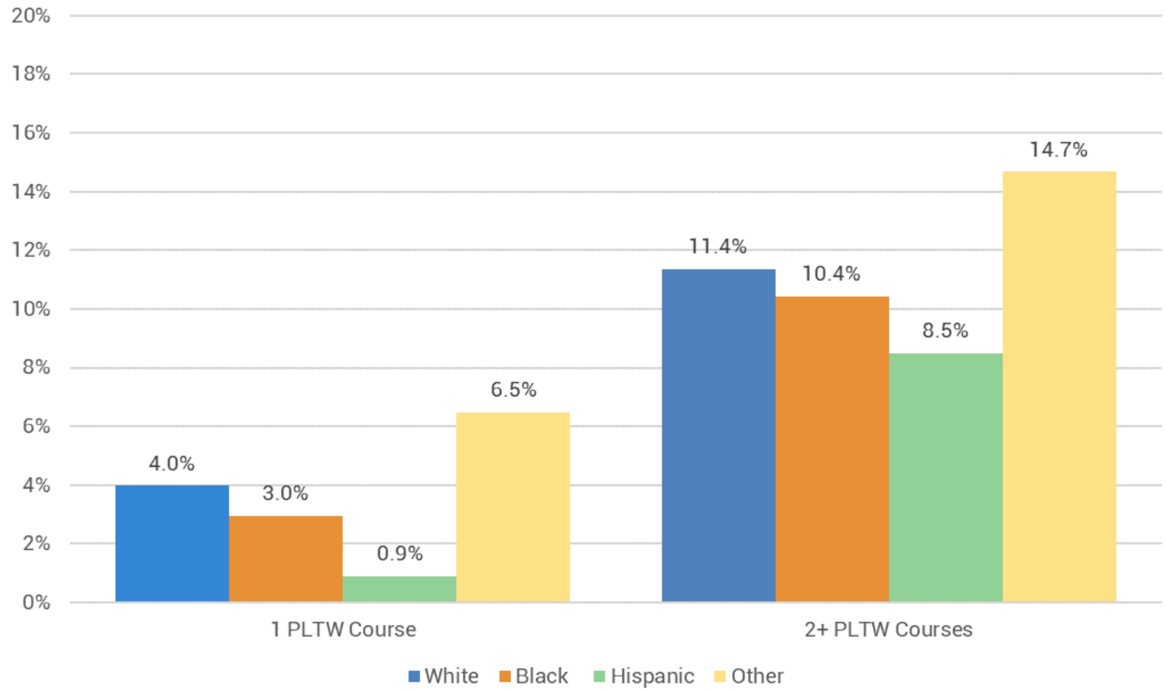
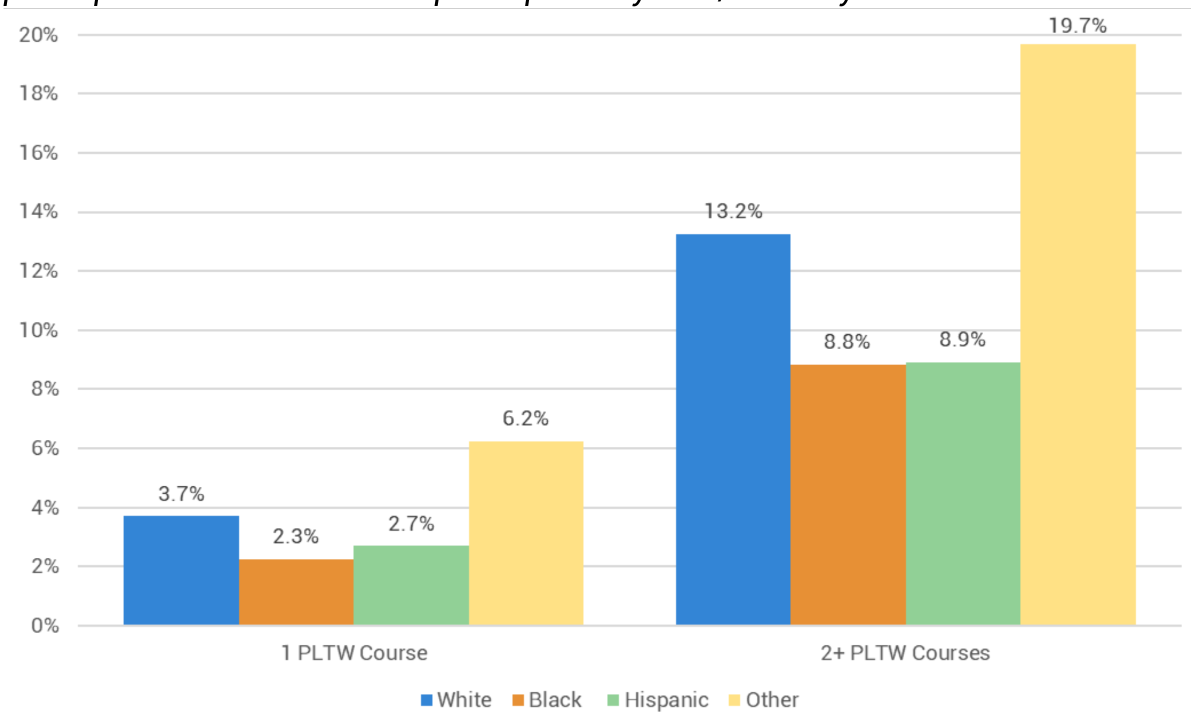


Figure 27

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



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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 – Research methods and data

Research Methods

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 underrepresented minority students 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:

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

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 8^{th} grade, and 8^{th}-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 8^{th} grade, and average 8^{th}-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.

Variable list

Variable Name	**Description**	**Definition**
Outcome Variables		
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)

Student-Level Variables		
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	8^{th} Grade MAP Scores: English Language Arts	Student's 8^{th} grade ELA MAP scores, centered
MAP_8Math	8^{th} Grade MAP Scores: Mathematics	Student's 8^{th} grade Math MAP scores, centered
MAP_8Sci	8^{th} Grade MAP Scores: Science	Student's 8^{th} 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		
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