



Project Lead the Way: Impacts of a High School Applied STEM Program on Early Post-Secondary Outcomes

Takako Nomi
Saint Louis University

Darrin DeChane
Saint Louis University

Michael Podgursky
2University of Missouri Columbia

Project Lead the Way (PLTW) is an applied STEM program first introduced nearly three decades ago to enhance the STEM content of Career Technical Education (CTE). Currently, more than 12,000 US high schools offer the program. Using data from three cohorts of public high school freshmen in Missouri, we investigate the impact of PLTW program offer (ITT) and participation (TOT) on initial post-secondary outcomes. We use a difference-in-difference (DiD) analysis for ITT and a principal score adjusted DiD to estimate TOT. The parallel trends assumption is explicitly tested. We find positive ITT impacts on STEM major declaration among students with higher STEM preparation levels, and this outcome improved substantially for PLTW participants. Impacts on college enrollment are less conclusive.

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Project Lead the Way:

Impacts of a High School Applied STEM Program on Early Post-Secondary Outcomes

Takako Nomi^{1*}, Darrin DeChane¹, Michael Podgursky¹²,

¹Sinquefield Center for Applied Economic Research, Saint Louis University

²University of Missouri Columbia

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*Corresponding Author: tnomi@slu.edu

Abstract

Project Lead the Way (PLTW) is an applied STEM program first introduced nearly three decades ago to enhance the STEM content of Career Technical Education (CTE). Currently, more than 12,000 US high schools offer the program. Using data from three cohorts of public high school freshmen in Missouri, we investigate the impact of PLTW program offer (ITT) and participation (TOT) on initial post-secondary outcomes. We use a difference-in-difference (DiD) analysis for ITT and a principal score adjusted DiD to estimate TOT. The parallel trends assumption is explicitly tested. We find positive ITT impacts on STEM major declaration among students with higher STEM preparation levels, and this outcome improved substantially for PLTW participants. Impacts on college enrollment are less conclusive.

In order to stimulate national and regional economic growth, policymakers and businesses seek to increase the supply of workers with skills in science, technology, engineering, and math (STEM). High school is a key period in the development of STEM skills, knowledge, and interests through coursework (e.g., Bottia et al., 2015; Lichtenberger & George-Jackson, 2013; Sadlar et al., 2014; Corin et al., 2020), and students with STEM degrees often enter the pipeline in high school (Tai et al., 2006; Maltese & Tai, 2011).

One of the national STEM initiatives during the early 2010's aimed at improving curricular opportunities and students learning experiences through integrated applied STEM courses (Gottfried & Bozick, 2016). By connecting traditional academic STEM disciplines to the real-world problems or in applied settings, the goal was to provide more meaningful and engaging STEM learning opportunities, increase student participation in those opportunities, and generate greater interest in pursuing post-secondary education in STEM or related fields.

Project Lead the Way (PLTW), which is now in over 12,000 US high schools, is one such program. For high school students, the PLTW currently offers coursework in three of the largest applied STEM fields—Engineering, Biomedical Sciences, and Computer Science. The development of the PLTW curricula was motivated, in part, by the need to strengthen the traditional career and technical education (CTE) curriculum in response to the changing economic landscape and a desire to increase STEM participation through courses with active, project-based learning. The PLTW curricula provide scaffolded and structured activities with real-world problems, while emphasizing student-centered instruction and collaborative learning.

Within each field, the PLTW curricula are organized to follow a sequence (“Pathway”). Introductory and foundation-level courses provide an overview of the field, which are intended to develop students’ understanding of major ideas of the field and stimulate enthusiasm for

further study. In advanced courses, students are expected to deepen their understanding of the field through more specialized content. The Engineering and Biomedical Science pathways end with a capstone course which requires students to take their own ideas from design through development of a product or plans to produce one.

Over the past two decades, the program has grown rapidly. In Missouri, the site of this study, the program grew from 13 high schools in 2005 to 174 schools by 2020 – roughly 35% of all public high schools. In addition, Black and Hispanic students in the state have a higher rate of access to the program partly due to efforts by local philanthropic organizations to support program implementation in districts serving students underrepresented in STEM fields.

Despite the recent proliferation of applied STEM coursework in high school, including the expansion of PLTW, relatively few studies have examined its impact on students' outcomes, using rigorous research designs. Prior studies on PLTW, examining associations between program participation and high-school or post-secondary outcomes, including STEM degree declaration, tend to find better outcomes for program participants (e.g., Bottoms & Uhn, 2007; Starobin et al., 2013; Van Overschelde, 2013; Rethwisch, 2014; Pike & Robbins, 2019; Camburn et al., 2022). These studies are often based on correlational analyses. Some studies have used a propensity score method (Starobin et al., 2013; Van Overschelde, 2013; Rethwisch, 2014; Pike & Robbins, 2019), but covariates are often limited. Other limitations include a lack of studies that address policy-relevant questions, such as the impact of program offer, the types of students who participate in the program if schools offer the program, and whether the impacts depend on how well students are academically prepared for STEM.

This study contributes to the literature on applied STEM coursework by addressing the following research questions and using a stronger quasi-experimental design than prior studies.

RQ1: What are the characteristics of PLTW participants in schools that introduced the program?

RQ2: What is the average impact of PLTW program offering on the outcome of all students in the school (Intent to Treat or ITT) and does the ITT differ by the levels of STEM readiness?

RQ3: a) What is the impact of PLTW program participation on the outcomes of program participants? and b) Did PLTW program offer affect non-participants?

The last question about the effect on non-participants addresses a possibility that the PLTW program offer might have affected students through channels other than program participation. This could happen, for example, if program implementation was accompanied by other concurrent resource changes (e.g., elimination of other courses and changes in teacher assignment), or the adaptation of PLTW might have spillover effects (e.g., having better prepared student peers). These factors could affect both program participants and non-participants. These issues are not considered in prior studies on applied STEM curriculum. The current study uses schools that did not offer PLTW as a comparison group to understand how PLTW offers might have affected student outcomes through channels other than program participation.

This study uses three cohorts of first-time 9th-grade students who began Missouri public high school in AY2010, AY2013, and AY2014 ($N \cong 68,000$ per cohort, 523 schools). Students' outcomes are college enrollment and STEM major declaration within 6 months of entering college, which are currently available for all three cohorts. Our identification strategies utilize a subset of high schools, consisting of the following two types: schools that began offering PLTW for the 2013 and/or 2014 cohorts, but not for the 2010 cohort ($N=96$ schools and 49,224 students, referred to "PLTW schools" hereafter); and schools that never offered PLTW for the three cohorts ($N=284$ schools and 57,286 students, referred to "non-PLTW schools" hereafter).

Our empirical strategies are arguably stronger than those of most other observational studies on this topic. Specifically, to estimate the ITT impact (RQ2), we employ a Difference-in-Differences analysis (DiD). Here, students in non-PLTW schools never had program exposure; thus, they serve as a comparison group to capture the between-cohort outcome differences unrelated to PLTW under the common trend assumption. Also, the DiD analysis is conducted by deciles of student “prognostic scores”, defined as the predicted probability a student completes a STEM degree, given pre-treatment predictors (math and science test scores and GPAs) in the absence of PLTW¹. This allows us to investigate how program participation, as well as ITT impacts, vary by students’ STEM readiness.

To estimate the program participation impact on participants and the program offer impact on non-participants (RQ3), we apply the principal stratification method (Frangakis & Rubin, 2002; Jo & Stuart, 2009; Ding & Lu, 2016) combined with the DiD analysis. This method constructs two subpopulations (program participants and non-participants) that are observed only among the 2013 and 2014 cohorts in PLTW schools. The general idea is that, for each subpopulation, we construct their counterparts among the 2010 cohort and students in non-PLTW schools by applying principal score weights. After reweighting the data, we remove cohort effects through a difference-in-differences analysis.

Our results show that, on average, 3.6 percent of the 2013 cohort participated when offered the program, and program participation more than doubled for the 2014 cohort (8.7 percent). Also, participation rates are higher for students with higher STEM readiness. College enrollment appeared to be unaffected by the program offer. However, initial STEM major declaration increased, on average, by 1 percentage point for the 2013 cohort and 1.5 percentage points for the 2014 cohort when schools offered the program. The decile specific estimates

showed STEM major declaration increased only among students in the top three deciles. Consistent with this result, we find positive and significant impacts of program participation on initial STEM major declaration among participants with estimates ranging from 5 to 10 percentage points. The TOT impact on college enrollment was also positive and statistically significant in some cases. However, since this finding on college enrollment is not consistent with the results of ITT impacts, evidence on college enrollment is less conclusive. Finally, we find no evidence that PLTW offer affected the non-participant population or that it affected participants through channels other than program participation.

The remainder of this paper is organized as follows: The next section provides a literature review on STEM high school curricular opportunities, student coursework, and their impacts on students' outcomes. We then discuss our data, methods, and identification assumptions, followed by the findings of our analyses. We conclude with a summary of findings and implications for policy and future research.

Literature Review

A large body of literature investigates whether high school curricular opportunities and student coursework affect their students' subsequent academic or labor market outcomes. The theoretical framework underlying this body of research is Opportunity to Learn (OTL) (Carroll, 1963), which considers access or exposure to academic curriculum as a fundamental element for skill formation (Walkowiak et al., 2017). Also, human capital theory in education considers acquisitions of skills and knowledge through high school coursework as well as the signaling effects (Spence, 1973; Rose & Betts, 2004). Not only does an additional year of schooling affect labor market outcomes, but taking higher level math and science courses can also be viewed as a signal for students' abilities, influencing college admission. In comparison, the social cognitive

career theory focuses on how students develop career paths through interplays among multiple factors (e.g., self-efficacy, attitudes, interests, prior achievement, curricular exposures, and other institutional factors, see Wang, 2013).

Much of this body of research has focused on traditional academic math and science subjects, and their results generally showed positive relationships. For example, Adelman (2006) finds that the highest math completed is a key predictor of college degree completion. Brody and Benbow (1990) show that the number of semesters of math and science courses taken by students and enrolling in advanced courses, in particular, is related to higher SAT math scores. Rigorous high school coursework in math and science is related to college persistence (Horn & Kojaku, 2001). For community college students, taking more academic math courses in high school is related to higher rates of transferring to four-year colleges (Lee & Frank, 1990).

For STEM specific outcomes, high school math and science course enrollment is related to choosing a STEM major in college (Trusty, 2002; Federman, 2007). Burkam and Lee (2003) find that enrolling in higher level math courses is strongly related to students' intention to pursue a STEM degree in college measured at the end of high school. STEM degree completion is also predicted by the number of high school STEM courses taken by students (Wang, 2013). Tyson, Lee, and Hanson (2007) showed that racial gaps in STEM degree completion are explained by differences in enrollment in high-level math and science courses.

A key methodological challenge is removing student endogeneity in course selection. Some studies included an extensive set of covariates in their analyses, such as earlier STEM interests, attitudes towards and knowledge of math and science, self-efficacy, STEM career expectations, as well as math test scores and grades (e.g., Federman, 2007; Maltese & Tai, 2011;

Wang, 2013). Even after controlling for these variables, a statistically significant association was found between STEM course enrollment and STEM degree completion.

To address student selection, other researchers used econometric identification strategies. These studies tended to show only negligible impacts of STEM curricular offerings or student coursework. Darolia et al. (2020), using data on multiple cohorts of Missouri public college students, exploited between-year variation in STEM course offering in the same high school through school fixed effects. This study found that greater access to traditional STEM courses has little effect on STEM major or degree attainment. However, year-to-year variation in STEM course availability was small and only weakly related to the number of STEM courses completed by students. This limits the ability to understand the impact of STEM course enrollment. Also, earlier studies by Altonji (1995) and Levine and Zimmerman (1995) used similar strategies to examine the effect of high school curricula on labor market outcomes. Using the nationally representative data, taking more math and science courses was found to increase wages and the likelihood of entering STEM fields only for females (Levine & Zimmerman, 1995), and taking more rigorous courses had only a small effect on wages (Altonji, 1995).

However, other studies using a similar method found positive impacts of increasing the rigor of STEM courses on labor market outcomes. This highlights the importance of the quality of coursework, and not just the number of courses completed by the student. Rose and Betts (2004) showed that enrolling in more advanced courses had positive impacts on earnings 10 years after high school graduation. Goodman (2019) also showed positive effects of math curricular reforms that raised minimum requirement on later earning for black students, but not for white students. These differential impacts may be explained by the fact that the curricular reform raised the level/rigor of math courses taken by black students (Goodman, 2019).

Applied STEM Course Enrollment and Its Impact

There is a small, but growing body of research investigating applied STEM course enrollment and subsequent students' outcomes. Several studies utilized the Educational Longitudinal Survey (ELS). These studies included an extensive set of covariates, including demographic and socio-economic backgrounds, academic preparation levels, participation in extra-curricular activities, self-efficacy in Math, expectation for college, and college choice considerations. While covariates differ somewhat by each study, enrollment in applied STEM courses are found to be related to higher 12th-grade math scores (Gottfried et al., 2014) and higher rates of STEM major declarations (Gottfried & Bozick, 2016). Similarly, Phelps et al. (2018) showed enrolling in engineering and engineering technology courses improves STEM enrollment in college.

Past studies on PLTW are generally consistent with these findings, with some exceptions. For example, during high school, PLTW participants were found to take significantly more math and science courses, complete a more rigorous college-prep curriculum, and score higher on standardized math tests (Bottoms & Anthony, 2005; Bottoms & Uhn, 2007; Starobin et al., 2013; Van Overschelde, 2013; Rethwisch, 2014). One exception is Tran and Nathan (2010) who found an opposite pattern: PLTW participants had smaller test score gains in math than non-participants and did not differ in science score gains. However, this study is based only on 140 students across five high schools, and generalizability is limited.

For post-secondary outcomes, prior studies generally showed positive effects on initial college outcomes, such as higher rates of choosing a STEM major and lower enrollment in remedial coursework for PLTW participants than non-participants (Starobin et al., 2013; Pike & Robbins, 2019, Camburn, et.al., 2022). Utley et al. (2019) compared college students majoring in

Engineering and found that those who participated in PLTW during high school had higher retention rates. However, no significant difference was found in engineering degree completion.

The main methodological challenge of these studies is selection bias as discussed earlier. This can occur at both student- and school-levels. Not only are students self-selected to PLTW, but also school factors are often related to curricular offerings. STEM curricular opportunities are generally constrained by organizational resources and capacity, which tend to be associated with community conditions, and the capacity constraint is particularly acute for resource intensive, and elective STEM courses. Likewise, access to high-quality and rigorous STEM coursework (e.g., higher level math and science courses) tend to be stratified by race and family SES (e.g., Adelman, 2006; Lucas, 1999; Goldrick-Rab, 2010; Gamoran, 2001).

Among the extant studies on PLTW, some (Bottoms & Anthony, 2005; Bottoms & Uhn, 2007) only controlled for students' demographic characteristics. Others (Starobin et al., 2013; Van Overschelde, 2013; Rethwisch, 2014; and Pike & Robbins, 2019) used propensity score matching using administrative data from three states (Texas, Iowa, and Indiana, respectively). Among them, only Pike & Robbins (2019) considered both student- and school-level factors, and covariates are not as comprehensive as those available in the national survey data.

This study uses the principal stratification method, combined with a difference-in-differences analysis. To remove student- and school-level selection, we construct a control group using a cohort of students who attended the same high school before their school adopted PLTW. Cohort effects are removed by including schools that never offered the program. This differs from studies that construct a comparison group based on students who did not take PLTW courses even though the program was available to them. Importantly, most prior studies did not clarify whether comparison groups come from students in the school offering PLTW, or different

schools that offer or do not offer PLTW, or whether they are from the same cohort or a different cohort when their data have multiple cohorts of students (e.g., Van Overschelde, 2013; Rethwisch, 2014).²

Another limitation of prior studies is sample selection on the basis of the outcome that is likely to be affected by the intervention of interest. Specifically, the PLTW impact is estimated with bias in studies using a sample of high school graduates, college enrollees, or STEM majors if these outcomes are affected by PLTW. We avoid this problem by following the high school entering cohorts through college entry.

Data and Methods

This study uses three cohorts of first-time 9th-grade students who began public high school in the academic years 2010, 2013, and 2014. Each cohort has approximately 68,000 students attending 500 high schools. The overall racial/ethnic compositions are: 75.8% White, 16.5% Black, 4.2% Hispanic, and 3.6% other. About 40 percent of students are eligible for Free or Reduced-Price Lunch (FRL). We utilize K-12 student data from the Missouri Department of Elementary and Secondary Education (DESE) matched to National Student Clearinghouse data for post-secondary outcomes. Covariates include demographic variables (race/ethnicity, gender, and FRL status); 8th-grade Missouri Assessment Program (MAP) scores in math, science, and English Language Arts (ELA) that are converted into Z-scores; Algebra enrollment in 8th-grade; 9th-grade GPAs and attendance rates. We also construct a variable capturing a relative strength in math skills by dividing the Z-score in math by that in ELA. See Table 1 for descriptive statistics.

Table 1 about here

To provide the Missouri context, Figure 1 depicts the STEM pipeline of the base (2010) cohort. We see that only 3 percent of the entering high school students earn a STEM degree

within 6 years of college. Specifically, of the first-time 9th graders, 80.4 percent graduated from Missouri public high schools within 4 years, 53.8 percent of the 9th-grade students attended college (67% of high school graduates), and 12.7 percent declared a STEM degree (23.6% of college enrollees). Also, 26.1 percent and 19.9 percent of the 9th-grade cohort earned, respectively, any degree and 4-year degree within 6 years with 3 percent earning a STEM degree. This implies that, of college enrollees, 48.5 percent and 37 percent earned any and 4-year degrees, respectively, and of earned degrees, 12.6 percent of any degree and 15 percent of 4-year degrees are in the STEM fields. This study examines college enrollment and STEM major declaration upon college entry as an outcome. They are the initial milestones of eventual STEM degree completion and currently available to the research team for all cohorts.

Figure 1 about here

Our identification strategies rely on students who attend two types of schools. First, the “PLTW schools” are schools that offered PLTW for the 2013 and/or 2014 cohorts, but not for the 2010 cohort (N=96 schools and 49,224 students). Their overall program participation rates are 4.3 percent for the 2013 cohort and 10.2 percent for the 2014 cohort. Second, the “non-PLTW school” consists of schools that never offered PLTW for the three cohorts (N=284 schools and 57,286 students). The two types of schools are relatively similar in the academic characteristics of the base (2010) cohort (Table 2). The average 8th-grade test scores and 8th-grade algebra completion rates are only slightly higher for PLTW schools, but their differences are negligible. However, their demographic characteristics differ considerably: PLTW schools are much larger in size than non-PLTW schools (649 vs. 287 students); are much more likely to be located in city and suburban areas (33% for PLTW schools vs. 8.7% for non-PLTW schools); have larger Black and Hispanic student populations (13.5% Black and 3.6% Hispanic for PLTW

schools vs. 6.2% and 2.9%, respectively, for non-PLTW schools); and have lower FRL rates than non-PLTW schools (50% vs. 58.8%). These differences highlight the structural constraints small rural schools face in offering specialized courses, and perhaps less the student academic characteristics that are likely to determine PLTW participation.

Table 2 about here

The post-secondary outcomes are also similar for the base cohort (Bottom panel of Table 2). PLTW schools have slightly higher rates of college enrollment than non-PLTW schools (45% vs. 42.4%) with a similar rate of STEM major declaration rates (5.8% vs. 6%). Any STEM degree completion rates are slightly higher for PLTW schools. Specifically, for PLTW schools, the average percentage of students completing any degree is 23.1% (vs. 22% for non-PLTW schools) and that for STEM degree is 3.1% (vs. 2.4% for non-PLTW schools).

We now describe our analytic approach.

Notation

We distinguish two types of school by G_j where $G_j=1$ for PLTW schools and $G_j=0$ for non-PLTW schools. The program offer status is indicated by Z_{cj} where $Z_{cj}=1$ if school j offered PLTW for cohort c and $Z_{cj}=0$ if not. For student i , in cohort c , and school j , the treatment indicator is $T_{icj} = 1$ if students participated in the program and $T_{icj}=0$ if not.

Defining Principal Scores

To estimate the causal effect of PLTW on program participants and non-participants, we apply the principal score stratification method in a case of one-sided compliance (Frangakis & Rubin, 2002). Let S indicate stratum membership where $S = 1$ if students participate in PLTW if the program was offered and 0 otherwise. This is similar to the notion of “compliers” and “never-takers” in the experimental design with imperfect compliance to random assignment to

the treatment. The key identification problem is that the stratum membership is observed for students only after the program is offered by their school. The notion of principal scores is similar to that of propensity scores in observational studies, and they are defined as the probability of the latent strata given covariates:

$$P(S=1|X=x) = P(S=1, Z=1|X=x)/[P(S=1, Z=1|X=x) + P(Z=0|X=x)].$$

The identification assumption required for principal causal effect is principal ignorability, which states that potential outcomes are independent of principal stratum membership, given $P(S=1|X=x)$. The current study uses the following covariates to estimate principal scores: gender, race, the FRL status, 8th-grade test scores in math, science, and ELA, relative strength in math skills, 8th-grade Algebra enrollment, 9th-grade GPA, and 9th-grade attendance rates.

To achieve covariate balance between the observed program participants/non-participants and their counterparts in the absence of the program (e.g., the 2010 cohort in PLTW schools) we apply the principal score weights ($W_{(s)}$) to the data of the latter group. The weight to construct the participant population is given by $W_{(1)} = \pi_i/(1 - \pi_i)$ (“treated weights”) and the weight to construct the non-participant population is $W_{(0)} = (1 - \pi_i)/\pi_i$ (“untreated weights”) where π_i is the predicted probability of being in the participant stratum given X . Table 3 depicts the populations being created by applying these weights to the 2010 students in PLTW schools (Version 1). The weights can also be constructed and applied to students in non-PLTW schools, such that they resemble the observed program participants and non-participants in PLTW schools (Version 2).

Table 3 about here

We create these weights separately for the 2013 and 2014 cohort because more schools offered PLTW for the 2014 cohort than the prior cohort. Also, student participation increased (4.4% for the 2013 cohort vs 10.2% for the 2014 cohort), and participants’ characteristics are

likely to differ between the two cohorts. For conciseness, we present our analytic approach for studying the effects for the 2013 cohort, but the effect for the 2014 cohort is entirely analogous.

Defining Causal Effects of PLTW

The key population of interest for causal inference is program participants ($S=1$) in PLTW schools ($G=1$). The average effect of PLTW program offer (ITT), $B_{(S)}$, on program participants is depicted in Figure 2-a). This is defined as:

$$B_{(1)} = E[Y_{(Z=1,T=1)} - Y_{(Z=0,T=0)} \mid G = 1, S = 1]. \quad (1)$$

Also, the effect of program participation on participants (TOT), $\delta_{(S)}$, is:

$$\delta_{(1)} = E[Y_{(Z=1,T=1)} - Y_{(Z=1,T=0)} \mid G = 1, S = 1]. \quad (2)$$

The second quantity, $Y_{(Z=1,T=0)}$, represents the outcome of program participants had they counterfactually not participated in the program (e.g., they could not participate because the program was oversubscribed). Note that for this subpopulation if program offer affects their outcomes only through program participation, that is,

$$E[Y_{(Z=1,T=0)} \mid G = 1, S = 1] = E[Y_{(Z=0,T=0)} \mid G = 1, S = 1],$$

then,

$$B_{(1)} = \delta_{(1)}.$$

In this case, the program offer is fully mediated by program participation as depicted in Figure 2-b) where there is no direct effect of pathway from program offer to the outcome.

Figure 2 about here

For the non-participant population, the effect of PLTW offer is:

$$B_{(0)} = E[Y_{(Z=1,T=0)} - Y_{(Z=0,T=0)} \mid G = 1, S = 0]. \quad (3)$$

We can imagine that the effect ($B_{(0)}$) is non-zero for this group if, for example, the program offer led to other changes in PLTW schools (e.g., changes in non-PLTW course offering and teacher assignment to courses) or PLTW offer had spillover effects (e.g., having academically stronger

peers). In such a case, we can also suspect the presence of the direct effect of the program offer as depicted in Figure 2-c). This is similar to the failure of the exclusion restriction in the instrumental variable approach where Z is an exogenous variable.

The weighted average of these two PLTW program impacts provides the average effect of program offer (ITT) across all students. To identify the ITT impact, we apply the standard difference-in-differences (DiD) analysis by using non-PLTW schools as a comparison group.

$$\begin{aligned}
 B_{ITT} &= (E[Y_{(Z=1)} | coh13, G = 1] - E[Y_{(Z=0)} | coh10, G = 1]) - \\
 &\quad (E[Y_{(Z=0)} | coh13, G = 0] - E[Y_{(Z=0)} | coh10, G = 0]) \\
 &= (B_{ITT} + \lambda_{(G=1)}) - \lambda_{(G=0)},
 \end{aligned} \tag{4}$$

where λ is the outcome difference between the 2010 and 2013 cohorts not attributable to PLTW program offer (i.e., cohort effects) and assumed to be the same for students in PLTW and non-PLTW schools (the common trends assumption): $\lambda_{(G=1)} = \lambda_{(G=0)}$.

We estimate the average ITT impact (RQ2) using the following model;

$$Y_{icj} = \alpha + \beta_c(G_j * Coh_c) + Coh_c + \psi(X_i) + \varphi_j + \varepsilon_{ij}, \tag{5}$$

where the indicator G distinguishes PLTW schools ($G=1$) and non-PLTW schools ($G=0$); X is student covariates (demographics and prognostic scores as described below); Coh_c are cohort indicators; φ_j are school fixed effects, removing the base-line difference between PLTW and non-PLTW schools. The coefficient β_c , indicates the cohort-specific ITT impact.

To understand how the ITT effect differs by students' STEM readiness, we construct a composite measure of STEM readiness (or "STEM prognostic scores"), defined as the predicted probability of completing a STEM degree given pre-treatment predictors under the control condition. Specifically, the model is estimated using the 2010 cohort (no students had PLTW exposure) and this model is applied to later cohorts to predict their scores. The predictors are the

same as those used to predict the principal scores. We then conduct a DiD analysis by deciles of STEM prognostic scores by including decile indicators, their interaction terms with cohort fixed effects, and the three-way interaction terms (PLTW group indicator, cohort indicators, and decile indicators) in Equation (5). In addition, we construct “outcome-based prognostic scores” that are specific to the outcome of analysis (college enrollment and STEM major declaration). These “outcome-based prognostic scores” are included as an additional control variable.³

Analysis by STEM prognostic score deciles allow us to see not only how program participation is related to STEM readiness, but also how ITT impacts differ by STEM readiness. As discussed in the result section, the introduction of the program induced students’ participation primarily from higher deciles. Thus, if PLTW has a positive effect, we would expect to find a positive ITT impact only in those higher deciles. This clarifies the limit of the generalizability of our results. Specifically, our study cannot answer a policy question such as whether students would benefit if schools expanded the program to students with lower STEM readiness.

Estimating the Effect of Program Participation on Participants using DiD with Principal Score Weighting

To remind the reader, we estimate PLTW program impacts separately for the 2013 and 2014 cohort. For illustrative purposes, we describe our analytic approach to estimate the impact on the 2013 students.

Let us first define the total outcome difference between the 2010 and 2013 cohorts for program participants ($S=1$) in the PLTW school ($G=1$) as;

$$E \left[Y_{(Z=1,T=1)}^{(coh13)} - Y_{(Z=0,T=0)}^{(coh10)} \middle| G = 1, S = 1 \right]. \quad (6)$$

This is identified by applying the participant weights (w_s) to the 2010 cohort:

$$E[Y|coh13, G = 1, S = 1] - E[w_1 Y|coh10, G = 1] = B_{(1)} + \lambda_{(1)}, \quad (7)$$

where w_1 is the principal score treated weights applied to the 2010 students in PLTW schools.

Also, if PLTW has no direct effect on participants, then $B_{(1)} = \delta_{(1)}$.

The cohort effects, $\lambda_{(1)}$, for program participants are defined as:

$$\lambda_{(1)} = E\left[Y_{(Z=0,T=0)}^{(coh13)} - Y_{(Z=0,T=0)}^{(coh10)} \mid G = 1, S = 1\right] \quad (8)$$

We do not observe $B_{(1)}$ or $\lambda_{(1)}$, and the identification of PLTW impacts on program participants rests on obtaining an unbiased estimate of $\lambda_{(1)}$ by conducting a DiD analysis. We propose two different DiD strategies and clarify their identification assumptions in the next section.

Strategy 1) Within-school DiD, Assuming Program Offer Does Not Affect Non-Participants

The standard within-school DiD. The first strategy uses non-PLTW participants in the PLTW school as a comparison group to remove the cohort effects, defined as:

$$\lambda_{(0)} = E\left[Y_{(Z=1,T=0)}^{(coh13)} - Y_{(Z=0,T=0)}^{(coh10)} \mid G = 1, S = 0\right] = \left[Y_{(Z=0,T=0)}^{(coh13)} - Y_{(Z=0,T=0)}^{(coh10)} \mid G = 1, S = 0\right] \quad (9)$$

with an assumption that the program offer has no effect on non-participants, that is,

$$E\left[Y_{(Z=1,T=0)}^{(coh13)} \mid G = 1, S = 0\right] = E\left[Y_{(Z=0,T=0)}^{(coh13)} \mid G = 1, S = 0\right]. \quad (10)$$

Then, their cohort effect can be identified by:

$$\lambda(0) = E[Y \mid coh13, G = 1, T = 0] - E[w_0 Y \mid coh10, G = 1, T = 0], \quad (11)$$

where w_0 is non-participant weights.

To estimate the effect of program participation on participants, we analyze the following model by applying the treated and untreated weights to the 2010 students:

$$Y_{icj} = \alpha_0 + \alpha_1(Coh10S1_{ij}^{(w1)}) + \lambda(Coh13_c) + \delta_{(1)}(Coh13_c * Treat_i) + \varphi_j + \varepsilon_i, \quad (12)$$

where $Coh10S1_{ij}^{(w1)}$ is an indicator variable taking a value of 1 for observations receiving the treated weights (and 0 for observations with untreated weights) among the 2010 cohort, Coh13 is an indicator for the 2013 cohort, Treat is the indicator for PLTW program participants, φ_j is

school fixed effects, and ε_i is an error term. The intercept represents the outcome of the “would be untreated” students from the 2010 cohort receiving the untreated weights, α_1 represents the difference for the “would-be-treated” 2010 students, λ is the cohort effect for non-participants, and $\delta_{(1)}$ is the effect of program participation for the participants.

Three identification assumptions are relevant to this analysis. First, program offer (Z) does not affect non-participants (i.e., $B_0 = 0$ in Equation 3). Or, if the direct effect was present, the same effect applies to participants. Second, we assume the parallel trends for the program participant and non-participant populations in the absence of PLTW, $\lambda_0 = \lambda_1$. Third, the principal ignorability assumption states that the potential outcomes are independent of stratum membership, given $P(S=1|X=x)$.

These assumptions are not empirically testable, but we can assess the plausibility of the first two assumptions by using non-PLTW schools as a comparison group as discussed in the next section. Also, the parallel trends assumption would be violated when the cohort effects are heterogeneous with regard to students’ characteristics. To minimize this threat to validity, we propose the following analysis.

The modified within-school DiD. We apply the treated weights to both the 2010 cohort and the 2013 observed untreated students to make them resemble the treated students. Then, the cohort effect is defined within the treated subpopulation as:

$$\lambda^*(1) = E[w_1 Y | coh13, G = 1, T = 0] - E[w_1 Y | coh10, G = 1]. \quad (13)$$

We then analyze the following model:

$$Y_{icj} = \alpha_{0_{S1}} + \lambda_{(1)} \left(Coh13_c^{(w1)} \right) + \delta_{(1)} (Coh13_c * Treat_i) + \varphi_j + \varepsilon_{ij}, \quad (14)$$

where the intercept represents the average outcome of the “would-be-treated” students in the 2010 cohort; $\lambda_{(1)}$ is the cohort effect, representing the counterfactual outcome difference of the

program participants in the 2013 cohort had they not participated in PLTW; and $\delta_{(1)}$ the PLTW program participation impact on participants. When the program offer only affects their outcomes through program participation, then:

$$E[Y_{(Z=1,T=0)} | G = 1, C = c, X = x] = E[Y_{(Z=0,T=0)} | G = 1, C = c, X = x]. \quad (15)$$

When the program offer affects other channels than program participation, such an effect is removed by the cohort effect.

Strategy 2) Between-school DiD, Using Non-PLTW Schools

Standard between-school DiD. The second strategy uses students in non-PLTW schools as a comparison group for the DiD analysis. Under the assumption of the common cohort effects, the TOT is given by:

$$\begin{aligned} \delta_{(1)} = & (E[Y|coh13, G = 1, S = 1] - E[w_1 Y|coh10, G = 1]) - \\ & (E[Y|coh13, G = 0] - E[Y|coh10, G = 0]), \end{aligned} \quad (16)$$

and the effect of program offer on the untreated (TOUT) is:

$$\begin{aligned} B_{(0)} = & (E[Y|coh13, G = 1, S = 0] - E[w_0 Y|coh10, G = 1]) - \\ & (E[Y|coh13, G = 0] - E[Y|coh10, G = 0]). \end{aligned} \quad (17)$$

To estimate these two effects, we combine students in non-PLTW schools with the data used for the within-school analysis (Table 3 Version 1). We then analyze the following statistical model:

$$\begin{aligned} Y_{icj} = & \alpha_{0_G0} + \alpha_{1_G1S0} (G1_j^{(w0)}) + \alpha_{2_G1S1} (G1_j^{(w1)}) + \lambda_{_G0} (Coh13_c^{\square}) \\ & + B_{(0)} (Coh13_c^{\square} * UnTreat_i) + \delta_{(1)} (Coh13_c^{\square} * Treat_i) + \varepsilon_i. \end{aligned} \quad (18)$$

The intercept represents the average outcome of the 2010 cohort in non-PLTW schools; α_{1_G1S0} represents the difference for the 2010 “would-be-untreated” students in PLTW schools, α_{2_G1S1} is the difference for the 2010 “would-be-treated” students in PLTW schools; $\lambda_{_G0}$ represents the cohort effect for students in non-PLTW schools, and under the common trends assumption, the

coefficient $B_{(0)}$, is the impact of program offer on the untreated students in PLTW schools and $\delta_{(1)}$ is the TOT. For the between-school comparison analysis, we cluster the standard error to take into account students clustering in school j .

Modified between-school DiD. As in the case of within-school analysis, we can relax the common trends assumption with respect to students' characteristics by applying the treated and untreated weights to students in non-PLTW schools (Table 3, Version 2). We then estimate the PLTW impacts separately by the principal strata subgroup status.

For the TOT, after applying the treated weights, we analyze the following model:

$$Y_{icj} = \alpha_{0_G0S1} + \alpha_{1_G1S1} \left(Coh10G1_j^{(w1)} \right) + \lambda_{_G0S1} \left(Coh13_c^{(w1)} \right) + \delta_{(1)} \left(Coh13_c^{(w1)} * Treat_i \right) + \varepsilon_i + u_j, \quad (19)$$

where the intercept represents the average outcome of the 2010 “would-be-treated” students in non-PLTW schools (receiving the treated weights); α_{1_G1S1} is the difference for the 2010 “would-be-treated” students attending PLTW schools. This is expected to be zero if school type ($G=1$ vs 0) is not related to their outcomes in the absence of PLTW; $\lambda_{_G0S1}$ represents the cohort effect for the “would be treated” students in non-PLTW schools, providing the counterfactual outcomes of the observed treated students had they not participated in PLTW; and $\delta_{(1)}$ is the PLTW participation effect on participants. For the analysis for the untreated students, we estimate Equation 19 using untreated students and the untreated weights are applied to the 2010 students in PLTW schools and students non-PLTW schools.

Extended version of between-school DiD. Lastly, we explicitly test the common trends assumption by combining the modified between-school comparisons with within-school analysis. Specifically, we apply the treated weights to non-participants from the 2013 cohort in PLTW schools, such that their outcomes would provide the counterfactual outcomes of program

participants had they not participated in PLTW even though the program was offered (i.e., $[Y_{(Z=1,T=0)}|G = 1, S = 1]$). This is compared to the counterfactual outcomes associated with non-participation estimated from students with participant weights attending non-PLTW schools.

The statistical model is:

$$Y_{icj} = \alpha_{0_G0S1} + \alpha_{1_G1S1} \left(Coh10G1_j^{(w1)} \right) + \lambda_{G0S1} \left(Coh13_c^{(w1)} \right) + \lambda_{G1S1} \left(Coh13_c^{\square} * Untreat_c^{(w1)} \right) + \delta_1 \left(Coh13_c^{\square} * Treat_i \right) + \varepsilon_i + u_j. \quad (20)$$

In this model, $Coh13_c^{\square} * Untreat_c^{(w1)}$ is the indicator for the 2013 untreated students in PLTW schools, but the treated weights are applied to them. All the other terms are defined earlier. For the participant population, if the cohort effect is the same for PLTW schools and non-PLTW schools and if PLTW program offer does not affect non-participants, then $\lambda_{G1S1} = 0$.⁴

Results

Characteristics of PLTW participants in PLTW schools (RQ1)

Table 4 compares characteristics between PLTW participants and nonparticipants. The most notable demographic difference is female under-representations among PLTW participants. Roughly 30 percent of participants are females, while gender distribution is evenly split among nonparticipants. During the study period, Engineering was the most common program, and only 23 and 36 schools out of 96 schools offered the biomedical science pathway for the 2013 and 2014 cohorts, respectively (70 percent of all participants took Engineering courses, and female students are much less likely to take Engineering courses). Racial composition is relatively similar between the two groups for the 2013 cohort, but for the 2014 cohort, black students are underrepresented among participants by five percentage points. For both cohorts, participants are less likely to be FRL eligible than nonparticipants by eight to ten percentage points.

Academic characteristics differ substantially by participation status. PLTW participants have much higher prior skills than non-participants. For the 2013 cohort, the average 8th-grade standardized test scores are higher for the participants by .0356 SD in ELA, 0.541 SD in math, and 0.447 SD in science. The pattern is similar for the 2014 cohort. Participants are stronger in math than ELA, particularly among the 2013 cohort, as indicated by higher mathematics-to-ELA score ratios (relative strength in math). Also, nearly 30 percent of PLTW participants took Algebra during 8th-grade, as compared to 15.7 percent and 15.9 percent of the 2013 and 2014 non-participants, respectively. PLTW participants have higher 9th-grade GPAs and attendance rates as well. Difference between program participants and non-participants are eliminated after applying the treated weights to non-participants (Appendix Table 1).

Table 4 about here

Impact of PLTW program offer on PLTW participation and outcomes (RQ2)

Program Participation

We first estimate the average impact of PLTW program offer (ITT) on program participation overall and by the deciles of STEM prognostic score, a composite measure of STEM readiness. Table 5 presents the mean PLTW participation rates as the difference from the base-cohort whose participation rates are near zero on average and all deciles.⁵

First, we see that program participation rates are generally very low among the 2013 cohort. On average, only 3.6 percent of the 2013 9th-grade students took at least one PLTW course during high school when schools offered the program. Program participation increases as STEM academic preparation levels increase. Specifically, for the 2013 students below the 80th percentile, less than five percent of students participated in the program. In contrast, participation rates for students in Deciles 9 and 10 are, respectively, 6.3 and nearly 10 percentage points.

PLTW participation more than doubled for the 2014 cohort with the overall rate of 7.9 percentage points, and the rate is much higher for higher decile students. Specifically, 17.1 percent of the 2014 students in Decile 10 and approximately ten to thirteen percent of students between Deciles 6 and 9 participated in the program. For students between the bottom decile and Decile 5, participation rates ranged from 3.3 to 8.1 percentage points.

Table 5 about here

Post-secondary outcomes

Table 6 presents the estimated impact of program offer (ITT) on college enrollment and initial STEM major declaration.⁶ The first model (M1) controls for STEM prognostic scores and student demographics and the second model (M2) adds the outcome prognostic scores and school fixed effects to Model 1 to remove potential additional confounding not captured by covariates in Model 1. The results of the two analyses are similar and the results from the second model are reported here. First, we find that PLTW program offer has no average impact on college enrollment overall, but small positive effects on initial STEM major by 1.1 percentage points (SE=.003) for the 2013 cohort and 1.5 percentage points for the 2014 cohort (SE=.004).

For the decile specific impacts, we find no evidence that PLTW participation increased college enrollment. If anything, the direction of ITT impacts for the 2013 cohort is negative for some students and statistically significant (e.g., Deciles 7 and 9), while none of the decile specific ITT impacts is statistically significant for the 2014 cohort. In comparison, we find increases in initial STEM major declaration for students in higher deciles when schools offered PLTW. Specifically, the estimated impacts for the 2013 students are 1.8 percentage points in Decile 8 (SE=.008), 1.2 percentage points (SE=.008) in Decile 9, and 2.2 percentage points (SE=.009) in Decile 10. The size of the impacts is small, but not trivial given that program

participation increases are also relatively small for the 2013 cohort (5.0, 6.3, and 10.1 percentage points for Deciles 8,9, and 10, respectively). For the 2014 cohort whose PLTW participation rates were higher than their 2013 counterparts, we also find positive and significant impacts in the top three deciles with larger magnitude. Specifically, their estimated impacts for Deciles 8 and 9 are, respectively, 2.4 and 2.2 percentage points, and for students in the top decile PLTW program offer is related to an increase in STEM major declaration by 5.6 percentage points. For students in lower deciles, we find no evidence of ITT impacts on STEM major declaration. This is not surprising as their PLTW participation rates are very low, and these students generally tend not to choose a STEM major.

Table 6 about here

PLTW Participation Impacts on Participants and Program Offer Impacts on Non-Participants (RQ 3)

To reiterate, we conducted four types of principal score weighted DiD analyses to address RQ3. The first two analyses are: 1) Within-school comparisons where the treated subpopulation is compared to the untreated subpopulation in the same school (treated weights and untreated weights are applied to the 2010 cohort in PLTW schools, and the between-cohort difference of the treated subpopulation is compared to that of the untreated subpopulation); and 2) Modified within-school comparison where treated weights are applied to the 2010 cohort and the 2013/2014 non-participants in PLTW schools, such that these students resemble the observed treated students (i.e., DiD analysis based on the treated subpopulation only). These two analyses estimate TOT. The next set of analyses adds non-PLTW schools as a comparison group to estimate both TOT and TOUT: 3) Between-school comparisons where the treated and untreated weights are applied to the 2010 students in PLTW schools and their between-cohort difference is

compared to that of the average students in non-PLTW schools; 4) Modified between-school comparisons where the treated and untreated weights are also applied to the 2010 and 2013/2014 students in non-PLTW school; 5) Extended version of (4) where the treated weights are also applied to observed untreated students in PLTW schools. The last analysis allows us to estimate two counterfactual outcomes for the treated population with one being the outcome had they not participated in PLTW when the program was offered and the other being the outcome had their school not offered the program. Appendix Table 2 shows covariate balance between the treated students in PLTW schools and three groups of students before and after the treated weights are applied to them (the 2010 students in PLTW schools, the 2010 students in non-PLTW schools, and the 2013 and 2014 students in non-PLTW schools). Similarly, Appendix Table 3 presents covariate between the untreated students in PLTW schools and the same three groups of students before and after the untreated weights are applied to them. These results indicated that the weights effectively eliminated differences between the target population and the other groups.

Results of Within-school Comparisons

The results of two within-school DiD are presented in Table 7 where Model 1 is based on the statistical model without any additional covariates (weights adjustment only) and Model 2 includes the STEM and outcome-based prognostic scores as well as school fixed effects as control variables. We find that college enrollment increased for program participants somewhat and the estimates range from 4.9 percentage points (SE=0.31) to 7 percentage points (SE=0.31). The standard within-school DiD analysis uses the untreated subpopulation (Table 7, top panel), and we note that the baseline difference between the two subpopulations (the 2010 “would be treated” and “would be untreated” students) is eliminated by including additional covariates in

the model (see M2, Table 7, top panel). Also, the cohort effects appear to be similar between these two subpopulations as they are not significantly different from zero for both groups.

For the initial STEM major, program participation appears to have substantial and statistically significant positive impacts. For example, the estimated impacts for the 2013 cohort based on the standard within-school DiD from Model 2 are 6.2 percentage points (SE=.023) and that based on the modified DiD is 6.5 percentage points (SE=.023). The estimated impact is even greater for the 2014 cohort. Our models with additional covariates (Model 2) estimate that PLTW participation increases the likelihood of choosing a STEM major by approximately 10 percentage points. This is twice as large as the estimated STEM declaration rates of the participant subpopulation for the baseline (2010) cohort, which is roughly 10 percentage points. We also observe an upward trend in STEM declaration rates, particularly for the 2014 cohort, indicated by the coefficients on the *Post* variable, and this increase appears to be slightly greater for the “would be treated” students than the “would be untreated” students. This suggests potential heterogeneity in cohort effects on this outcome by students’ subgroup status.

Table 7 about here

Results of Between-school Comparisons

The next set of analyses adds students in non-PLTW schools as a comparison group. The standard between-school DiD analysis uses all students (unweighted) in non-PLTW schools. As in our earlier analyses, Model 1 makes no covariate adjustment, and Model 2 includes the STEM and outcome-based prognostic scores as additional covariates in the statistical model (Table 8). First, for college enrollment, we find no evidence that non-participants are affected by PLTW program offer. The magnitude of TOUT is near zero and not statistically significant. For program participants, PLTW participation is related to higher college enrollment rates with the estimated

impact ranging from 4.7 (SE=.02) to 6.2 (SE=.032) percentage points, and one of the four estimates is statistically significant. We also make the following observations from our results: the baseline outcomes of the 2010 “would-be-untreated” students are similar between PLTW and non-PLTW schools, indicated by near zero coefficients on Coh10_G1S0; the baseline “would-be-treated” students have higher college enrollment rates than their “would-be-untreated” counterparts (see coefficients on Coh10_G1S1 in M1), and this is eliminated after two prognostic scores are added to the model (M2); and there is no evidence of secular trend in this outcome.

For the STEM major outcome, we find no effect of PLTW offer on non-participants, but positive PLTW participation impacts are found for the participant subpopulation. The magnitude of impacts ranges from 5.7 (SE=.014) to 10.1 (SE=.021) percentage points and is larger for the 2014 cohort. Adding student covariates in Model 2 might have over-adjusted the baseline difference. We see that initial STEM major declaration is higher for the “would-be-treated” students in PLTW schools than the average students in non-PLTW schools by 3.8 and 3.1 points for the 2013 and 2014 cohorts, respectively (see coefficients on Coh10_G1S1 from M1). This difference is reversed when students’ covariates are added to the model (M2).

Table 8 about here

Next, the modified between-school DiD estimates TOT only using the participant population. Here, students in non-PLTW schools also receive treated weights (Table 9, top panel). Additionally, we add the observed non-participants in PLTW schools with treated weights to make them resemble the observed treated students (Table 9, bottom panel). The results of the two analyses are similar to earlier results. Program participation is related to higher college enrollment by about 5 percentage points with the estimates ranging from .48 (SE=0.18) to .63 (SE=.031), and only some estimates are statistically significant. For STEM major

declaration, we also find positive and statistically significant impacts. The magnitude appears to be larger for the 2014 participants with the estimated impacts of approximately 8 percentage points than those of the 2013 participants (5.1 to 5.8 percentages points). Again, these impacts are substantial given their baseline STEM enrollment rates of 9.9 percentage points⁷.

We also find no evidence that the program offer affected program participants through channels other than program participation. This is indicated by similarity in the cohort effects for the treated subpopulation under the two types of control condition. Specifically, the between-cohort outcome difference for non-participants in PLTW schools, who are made to resemble program participants with treated weights, is similar to that for their counterparts in non-PLTW schools as indicated by the near zero coefficients on Post*Untreat_w1. This implies that the outcome of PLTW participants in PLTW schools had they not participated in the program even though their schools offered the program is likely similar to the outcomes had they not participated in the program because their schools did not offer the program.

Table 9 about here

Finally, we estimate the effect of PLTW offer on the untreated students by applying untreated weights to students in non-PLTW schools (rather than comparing them to the average students in non-PLTW schools). Results show no evidence of such effects (Table 10). While college enrollment declined somewhat for the untreated students in PLTW schools as compared to similar students in non-PLTW schools, this difference was eliminated after STEM and outcome-based prognostic scores are controlled for (M2). Thus, overall, we conclude that non-participants share the same outcome trends regardless of the schools they attend.

Table 10 about here

Conclusion

Project Lead the Way was first introduced more than two decades ago to better align high school CTE coursework to the needs of STEM workforce. Their curricula were designed to stimulate students' interest and engagement in STEM learning. Lower-level courses introduce students to foundational knowledge and overview of the field. Upper-level courses offer materials that are project-based and connect the traditional academic STEM disciplines to real-world problem solving. Programs like PLTW are expanding across the country, and nearly 35 percent of all public high schools in Missouri currently offer the program.

In this study, we used a subset of Missouri high schools to study the impact of PLTW program offer and program participation. Our evidence suggests the potential of this type of program particularly to increase the number of students pursuing a STEM major in college.

Program participants tend to have much stronger math and science knowledge and skills when they begin high school than non-participants. Positive ITT impacts are only found among students with high STEM preparation levels. For the 2013 cohort, most participants come from the top decile although their participation rates are still low (approximately 10%) and we find positive impacts of PLTW offer on STEM major declaration, but not college enrollment. For the 2014 cohort, program participation rates are 10% or greater for students in the top three deciles (17% for the top decile) and we also find positive ITT impacts on initial STEM major declaration for these students. The pattern of ITT results indicates that PLTW participation impacts on STEM major declaration may also depend on students' initial skills. Specifically, the 2014 cohort in Deciles 6 and 7 are as likely to participate in PLTW as the 2013 cohort in the top decile. However, we found no ITT impacts on initial STEM declaration for the former. However, this differential effect may be explained by the number of PLTW courses taken by students (i.e., dosage), and this is a topic of future research.

Also, for the STEM major declaration outcome, the TOT results are consistent with the ITT results with positive and significant impacts across the board. The magnitude of the TOT impacts is substantial. While the identification strategy for TOT assumes strong ignorability, this is not required for the identification strategy for ITT. Thus, the strong ignorability assumption appears to be reasonable. We tested the parallel trends assumption based on students who did not take PLTW in PLTW schools and their trend is compared to that of students in non-PLTW schools, both groups are weighted to resemble the observed program participants or the observed non-participants. We found no evidence that the cohort effects—the outcome difference in the absence of PLTW—differ for these students between PLTW and non-PLTW schools.

In contrast, the TOT results for college enrollment are not consistent with those of ITT. On one hand, we find PLTW participation improved this outcome for program participants with the magnitude of approximately 5 percentage points or higher. This is not trivial although some estimates fail to reach statistical significance. On the other hand, we find no such evidence that program offer improved college enrollment even among students with higher STEM academic preparation levels. Taken together evidence on college enrollment is less conclusive.

An unexplored question in this study is how PLTW offer might have affected students' course-taking. Given the constraints of the school day, PLTW must have replaced something (if only a study hall). Part of the treatment effect may be that PLTW replaced a less productive course. On the other hand, part of the PLTW effect may be that the PLTW coursework stimulated more intensive or extensive coursework in high school courses such as math or science, which, in turn increased interest in post-secondary STEM education.

Lastly, our findings on PLTW impacts on STEM major declaration may only generalize to the population of students who are similar to the current program participants. In this regard it

is useful to think about the intensive and extensive margins of program expansion. The estimates in this study are most informative regarding the extensive margin (i.e., more schools offering the program). They may be less informative regarding the intensive margin (i.e., program expansion in a given high school), which may induce more students to participate in the program, including students whose skills are weaker than the current participants. While our ITT estimates do suggest smaller effects for less prepared students, the future study may consider how the impact of program participation differ by students' STEM preparation levels as both course offering and student participation increase over time.

In response to the popularity of high school PLTW courses, both elementary and middle schools have begun offering new PLTW courses (“Launch” and “Gateway”, respectively) to stimulate STEM interest in early grades and increase the pool of prepared students in high school. Likewise, more high schools are adding Biomedical and Computer Sciences strands to their PLTW curriculum. The expansion of the Biomedical strand has increased female participation. While most students in this study were in the Engineering strand, it is important to investigate whether we can expect similar impacts for all strands. Nonetheless, the results of this study suggest that while rigorous STEM CTE programs are promising, it is also important to improve high school STEM readiness, so that more students can benefit from such opportunities.

¹ This is a composite measure of STEM readiness. The model is estimated using the 2010 cohort and applied to later cohorts to predict their scores.

² It is also unclear whether these multi-cohort studies removed cohort effects.

³ See Hong et al. (2012) for the benefit of using the outcome-based prognostic scores in the DiD analysis.

⁴ However, $\alpha_{3_G1S1} = 0$ does not guarantee that both assumptions are met since we can have $\alpha_{3_G1S1} = 0$ when the two effects are in the opposite direction with the same magnitude.

⁵ Of the 2010 cohort, 0.56 percent participated in PLTW (.18 percent in PLTW schools and .39 percent non-PLTW schools). This is explained by school mobility where PLTW was available in the new school.

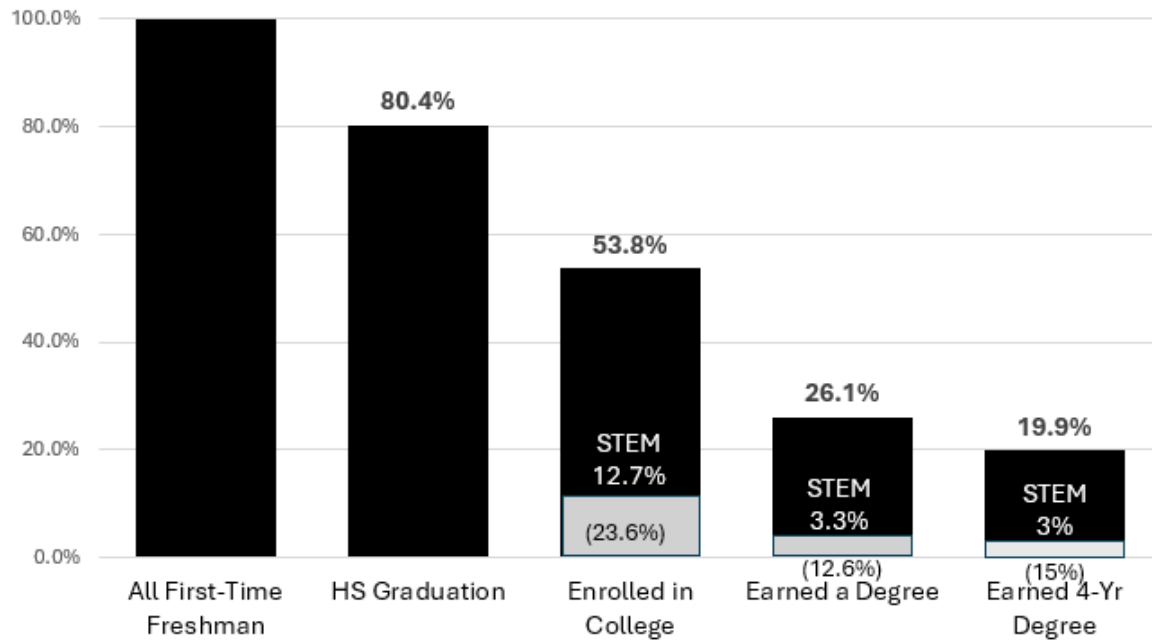
⁶ We also examined high school graduation and found little evidence PLTW impacts.

⁷ The average STEM enrollment rate from Model 2 is lower than that from Model 1 because Model 2 includes prognostic scores as covariates where the value of zero represents the average students in the analytic population, and PLTW participants have higher prognostic scores.

Figures and Tables

Figure 1

STEM Pipeline in Missouri

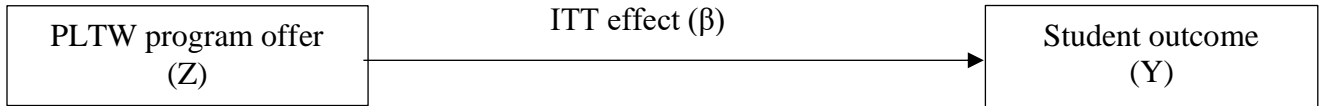


Note: The numbers in the parentheses indicate the STEM share among college enrollees (the third bar), those who earned any degree (the fourth bar), and those who earned a four-year degree (the fifth bar)

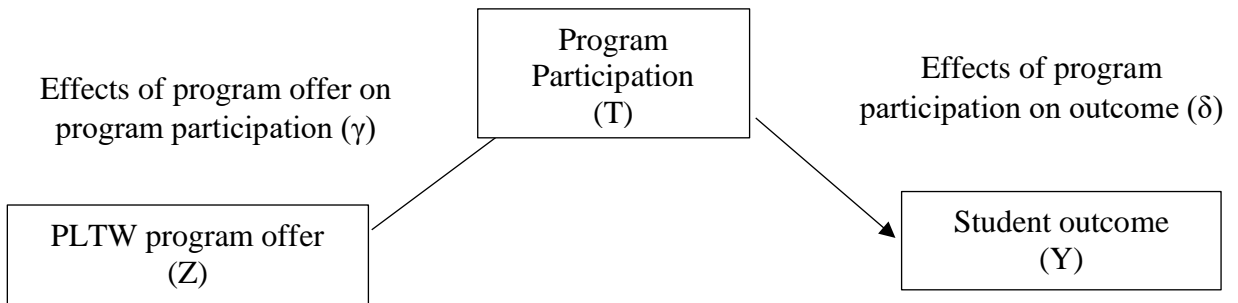
Figure 2

Graphical Representation of PLTW Impacts

a) Impact of PLTW program offer (ITT)



b) Impact of PLTW program offer fully mediated by program participation



c) Impact of PLTW program offer mediated by program participation and other factors

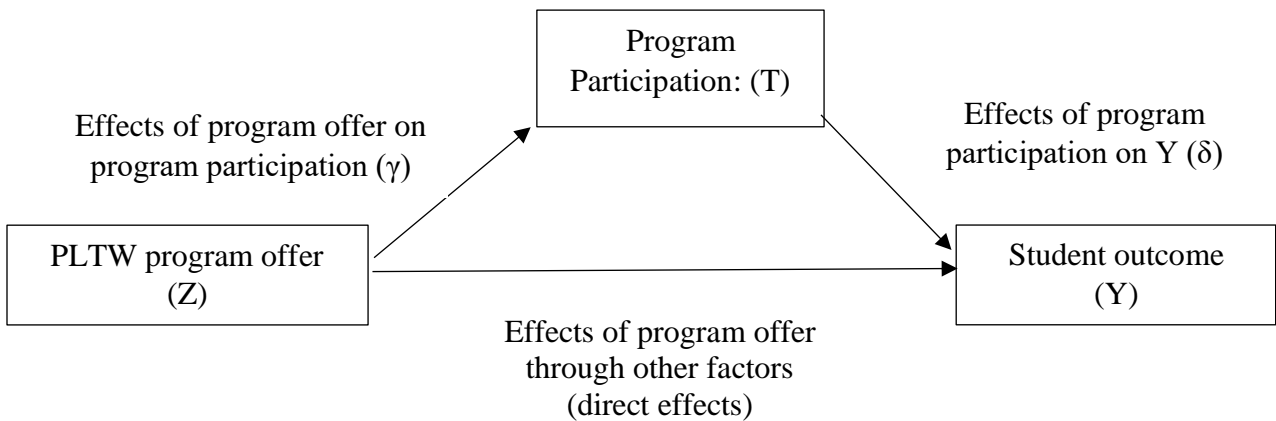


Table 1

Descriptive Statistics on Student Characteristics

	Missouri student population		Study population	
	Mean	SD	Mean	SD
Female	.485	.500	.485	.500
White	.751	.432	.826	.379
Black	.162	.368	.098	.298
Hispanic	.045	.207	.040	.197
Other	.042	.200	.035	.184
FRL	.530	.499	.570	.495
ELL	.018	.133	.017	.129
MAP ELA	.000	1.000	-.027	.977
MAP Math	.000	1.000	-.026	.959
MAP Science	.000	1.000	-.003	.960
Math / ELA	.000	1.000	-.039	.985
Completed Alg in Grade 8	.184	.387	.150	.357
GPA9	2.732	.949	2.774	.911
Attendance (G9)	93.834	8.384	93.913	8.098
N students	212,146		106,510	
N schools	523		380	

Note: 2010, 2013, and 2014 cohorts are pooled

Table 2

School Descriptive Statistics by School Type (Baseline 2010 Cohort)

	PLTW schools		Non-PLTW schools	
	Mean	SD	Mean	SD
% White	.793	.405	.885	.319
% Black	.135	.341	.062	.241
% Hispanic	.036	.187	.029	.169
% Other	.036	.185	.024	.153
Free/Reduced Lunch	.500	.500	.588	.492
English Language Learner	.012	.110	.010	.101
Avg. ELA scores	-.076	.997	-.110	.957
Avg. Math scores	-.099	.979	-.121	.929
Avg. Science scores	-.076	.982	-.095	.904
ELA / Math Ratio	-.066	.935	-.080	.918
% Completed Algebra in Grade 8	.137	.344	.132	.338
Mean GPA9	2.752	.352	2.830	.322
District Locale				
-City	.150	.359	.050	.218
-Suburban	.180	.386	.037	.188
-Town	.240	.429	.173	.379
-Rural	.430	.498	.711	.454
Average School Enrollment	649.280	600.885	287.246	326.104
Baseline (2010 cohort) Outcomes				
% College enrollment within 6 MO	.450	.498	.424	.494
%STEM major upon college entry	.058	.233	.060	.237
% Any degree	.231	.421	.220	.415
%STEM degree	.031	.174	.024	.153
	School N	96	284	

Table 3

Populations Before and After Weighting

Before Weighting

	2010 cohort	2013/2014 cohort
PLTW Schools (G=1)	A) (G=1, S=s, Z=0)	PLTW Takers (G=1, S=1, Z=1)
		Non-Takers (G=1, S=0, Z=1)
Non-PLTW Schools (G=0)	B) (G=0, S=s, Z=0)	C) (G=0, S=s, Z=0)

After weighting: Version 1

	2010 cohort	2013/2014 cohort
PLTW Schools (G=1)	<i>PLTW Takers</i> (G=1, S=1, Z=0)	PLTW Takers (G=1, S=1, Z=1)
	<i>Non-Takers</i> (G=1, S=0, Z=0)	Non-Takers (G=1, S=0, Z=1)
Non-PLTW Schools (G=0)	B) (G=0, S=s, Z=0)	C) (G=0, S=s, Z=0)

Note: Italics indicates the populations constructed through weighting

After weighting: Version 2

	2010 cohorts	2013/2014 cohort
PLTW Schools (G=1)	<i>PLTW Takers</i> (G=1, S=1, Z=0)	PLTW Takers (G=1, S=1, Z=1)
	<i>Non-Takers</i> (G=1, S=0, Z=0)	Non-Takers (G=1, S=0, Z=1)
Non-PLTW Schools (G=0)	<i>PLTW Takers</i> (G=0, S=1, Z=0)	<i>PLTW Takers</i> (G=0, S=1, Z=0)
	<i>Non-Takers</i> (G=0, S=0, Z=0)	<i>Non-Takers</i> (G=0, S=0, Z=0)

Note: Italics indicates the populations constructed through weighting

Table 4

Student Characteristics by PLTW Participation Status (2013 and 2014 Cohorts in PLTW Schools)

	2013				2014			
	Participants	Non-Participants	Diff	T-Value	Participants	Non-Participants	Diff	T-Value
	Mean	Mean			Mean	Mean		
Female	.299	.494	-.195	-11.09***	.307	.512	-.206	-17.35***
White	.709	.764	-.056	-3.23**	.796	.767	.029	2.83*
Black	.158	.140	.018	1.26	.087	.134	-.047	-6.35***
Hispanic	.057	.051	.006	.70	.051	.050	.001	.16
Other	.077	.045	.032	3.19**	.065	.049	.017	2.68*
FRL	.464	.543	-.079	-4.12***	.446	.542	-.096	-7.58***
ELL	.036	.026	.011	1.49***	.027	.024	.003	.74
MAP ELA	.338	-.018	.356	9.64***	.268	-.012	.281	12.21***
MAP Math	.540	-.001	.541	13.76***	.366	-.014	.380	16.25***
MAP Science	.477	.030	.447	11.94***	.396	.010	.385	16.80***
MAP Math / ELA	.257	-.044	.301	7.62***	.073	-.037	.110	4.77***
Completed Alg in G8	.312	.157	.155	8.84***	.295	.159	.136	11.93***
GPA9	3.070	2.773	.297	9.42***	3.023	2.759	.263	12.55***
Attendance G9	95.276	93.367	1.909	8.29***	95.381	93.965	1.417	9.08***
N students	717	15,880			1,715	15,149		

*<.05. **<.01. ***<.001

Table 5

Impact of PLTW Program Offer on Participation

	2013	2014
Overall	.036*** (.002)	.087*** (.002)
Deciles	By prognostic score deciles	
1	.008 (.006)	.033*** (.008)
2	.011 (.006)	.036*** (.008)
3	.014* (.006)	.052*** (.008)
4	.026*** (.006)	.058*** (.008)
5	.031*** (.006)	.081*** (.008)
6	.028*** (.006)	.09*** (.008)
7	.035*** (.006)	.109*** (.008)
8	.05*** (.006)	.119*** (.008)
9	.063*** (.006)	.126*** (.008)
10	.101*** (.006)	.171*** (.008)
Student N	52,190	54,320
School N	380	380

Standard errors are in parentheses.

* <.05. ** <.01. *** <.001

Table 6

Impact of PLTW Program Offer on College Enrollment and Initial STEM Major

	College Enrollment					STEM Major Declaration				
	Int (Coh10)	2013		2014		Int (Coh10)	2013		2014	
		M1	M2	M1	M2		M1	M2	M1	M2
Overall	.368*** (.004)	-.015* (.007)	-.01 (.007)	-.003 (.007)	-.001 (.007)	.07*** (.002)	.008* (.004)	.01** (0)	.013*** (.004)	.015*** (.004)
Impact by Prognostic Score Deciles										
Deciles	Int (Coh10)	2013		2014		Int (Coh10)	2013		2014	
		M1	M2	M1	M2		M1	M2	M1	M2
1	.051*** (.011)	-.018 (.021)	-.005 (.016)	-.018 (.021)	-.001 (.016)	.003 (.006)	-.002 (.012)	.004 (.009)	-.002 (.012)	.006 (.009)
2	.114*** (.01)	-.008 (.021)	.004 (.015)	-.028 (.021)	-.013 (.015)	.005 (.006)	-.001 (.011)	.009 (.008)	-.009 (.012)	.004 (.009)
3	.196*** (.01)	-.015 (.02)	.006 (.015)	-.029 (.02)	-.005 (.015)	.014** (.005)	.006 (.011)	.008 (.008)	.004 (.011)	.007 (.008)
4	.282*** (.01)	.02 (.02)	.001 (.014)	.027 (.02)	.008 (.015)	.022*** (.005)	.017 (.011)	.008 (.008)	.015 (.011)	.006 (.008)
5	.37*** (.01)	-.023 (.02)	-.014 (.014)	.002 (.02)	.01 (.015)	.03*** (.005)	.007 (.011)	.003 (.008)	.004 (.011)	.001 (.008)
6	.464*** (.01)	-.042* (.02)	-.016 (.015)	-.021 (.02)	-.003 (.015)	.044*** (.005)	.01 (.011)	.003 (.008)	.014 (.011)	.009 (.008)
7	.55*** (.01)	-.041* (.02)	-.032* (.014)	.02 (.02)	.022 (.015)	.056*** (.005)	0 (.011)	.008 (.008)	-.001 (.011)	.006 (.008)
8	.646*** (.01)	-.024 (.02)	-.023 (.015)	-.005 (.02)	-.015 (.015)	.089*** (.005)	.015 (.011)	.018* (.008)	.023* (.011)	.024** (.008)
9	.713*** (.01)	-.034 (.02)	-.03* (.015)	-.011 (.02)	-.015 (.015)	.128*** (.005)	.012 (.011)	.012 (.008)	.023* (.011)	.022** (.008)
10	.829*** (.011)	.038 (.021)	-.008 (.016)	.038 (.022)	-.01 (.016)	.221*** (.006)	.017 (.012)	.022* (.009)	.051*** (.012)	.056*** (.009)

Note: Intercept represents the average outcome of the 2010 cohort in non-PLTW schools M1 controls for STEM prognostic scores and student demographics. M2 adds the outcome prognostic scores and school fixed effects. Standard errors are in parentheses. * <.05. ** <.01. *** <.001

Table 7

PLTW Participation Impacts, using PLTW Schools Only

(1) Within-school comparison with the untreated students as a comparison group (Treated and untreated weights applied to the 2010 students)								
	College Enrollment				STEM Major Declaration			
	2013		2014		2013		2014	
	M1	M2	M1	M2	M1	M2	M1	M2
Int(Coh10_S0)	.44*** (.014)	N/A	.439*** (.014)	N/A	.056*** (.003)	N/A	.056*** (.003)	N/A
Coh10(S1)	.074*** (.006)	-.009 (.006)	.056*** (.006)	-.004 (.004)	.041*** (.004)	-.004 (.004)	.035*** (.004)	-.01** (.003)
Post(S0)	-.016 (.009)	-.015 (.008)	-.012 (.008)	-.013 (.007)	.006 (.003)	.009*** (.002)	.016*** (.004)	.02*** (.003)
TOT	.075* (.03)	.064** (.022)	.07* (.031)	.062*** (.015)	.055*** (.015)	.062*** (.014)	.092*** (.023)	.106*** (.018)

(2) Modified within-school comparison with the “would be treated” students as a comparison group (Treated weights applied to the 2010 students and 2013/2014 non-participants)								
	College Enrollment				STEM Major Declaration			
	2013		2014		2013		2014	
	M1	M2	M1	M2	M1	M2	M1	M2
Int(Coh10_S1)	.514*** (.016)	N/A	.495*** (.016)	N/A	.098*** (.007)	N/A	.091*** (.006)	N/A
Post(S1)	-.005 (.013)	-.015 (.012)	.008 (.013)	-.011 (.011)	.003 (.007)	.013* (.006)	.027*** (.008)	.035*** (.008)
TOT	.063* (.031)	.07** (.021)	.049 (.031)	.067*** (.014)	.058*** (.015)	.065*** (.016)	.08*** (.023)	.107*** (.015)

Note: M1 controls for STEM prognostic scores and student demographics. M2 adds the outcome prognostic scores and school fixed effects. For the top panel, intercept represents the average outcome of the 2010 “would-be-untreated” students in PLTW schools. For the bottom panel, intercept represents the average outcome of the 2010 “would-be-treated in PLTW schools.

Standard errors are in parentheses.

* <.05. ** <.01. *** <.001

Table 8

PLTW Participation Impacts, using PLTW and Non-PLTW Schools

(3) Between-school comparison with students in non-PLTW schools as a comparison group (Treated and untreated weights applied to the 2010 students in PLTW schools)								
	College Enrollment				STEM Major Declaration			
	2013		2014		2013		2014	
	M1	M2	M1	M2	M1	M2	M1	M2
Int (Coh10_G0)	.424*** (.007)	.431*** (.005)	.424*** (.007)	.431*** (.005)	.06*** (.003)	.062*** (.002)	.06*** (.003)	.062*** (.002)
Coh10_G1S0	.016 (.016)	.011 (.011)	.015 (.016)	.011 (.011)	-.003 (.004)	-.007* (.003)	-.004 (.004)	-.007* (.003)
Coh10_G1S1	.09*** (.017)	-.001 (.012)	.071*** (.017)	.005 (.011)	.038*** (.007)	-.012* (.006)	.031*** (.007)	-.017** (.006)
Post_G0	.006 (.006)	0 (.006)	-.005 (.006)	-.007 (.008)	.004 (.003)	.003 (.003)	.015*** (.003)	.014*** (.003)
TOUT	-.006 (.019)	-.006 (.012)	.008 (.018)	.005 (.013)	-.001 (.004)	-.001 (.003)	-.003 (.005)	-.003 (.004)
TOT	.053 (.032)	.051 (.026)	.062 (.032)	.047* (.02)	.057*** (.014)	.067*** (.013)	.092*** (.024)	.101*** (.021)

Note: M1 controls for STEM prognostic scores and student demographics. M2 adds the outcome prognostic scores and school fixed effects. Intercept represents the average outcome of the 2010 cohort in non-PLTW schools. Standard errors are in parentheses.

* < .05. ** < .01. *** < .001

Table 9

PLTW Participation Impacts, using PLTW and Non-PLTW Schools with Treated Weights

(4) Modified between-school comparison with the “would-be treated students” in non-PLTW schools as a comparison group (Treated weights applied to the 2010 students in PLTW schools and the 2010 and 2013/14 students in non-PLTW schools)

	College Enrollment				STEM Major Declaration			
	2013		2014		2013		2014	
	M1	M2	M1	M2	M1	M2	M1	M2
Int (Coh10_G0S1)	.515*** (.013)	.434*** (.008)	.495*** (.012)	.434*** (.007)	.099*** (.006)	.058*** (.005)	.096*** (.005)	.052*** (.005)
Coh10_G1S1	-.001 (.021)	.003 (.014)	0 (.02)	.005 (.012)	-.002 (.009)	.001 (.009)	-.005 (.008)	-.001 (.009)
Post_G0S1	.002 (.012)	-.003 (.01)	.002 (.011)	-.014 (.012)	.008 (.006)	.016* (.008)	.029*** (.006)	.034*** (.008)
TOT	.057 (.033)	.053 (.028)	.055 (.034)	.053* (.023)	.053*** (.015)	.051** (.016)	.078** (.024)	.079*** (.023)

(5) Extended between-school comparison with untreated students in PLTW schools receiving treated weights as an additional comparison group

	College Enrollment				STEM Major Declaration			
	2013		2014		2013		2014	
	M1	M2	M1	M2	M1	M2	M1	M2
Int (Coh10_G0S1)	.515*** (.013)	.433*** (.008)	.495*** (.012)	.434*** (.007)	.099*** (.006)	.058*** (.006)	.096*** (.005)	.05*** (.006)
Coh10_G1S1	-.001 (.021)	.003 (.014)	0 (.02)	.005 (.012)	-.002 (.009)	.001 (.009)	-.005 (.008)	-.001 (.009)
Post_G0S1	.002 (.012)	-.002 (.01)	.002 (.011)	-.013 (.012)	.008 (.006)	.017* (.008)	.029*** (.006)	.035*** (.008)
Post*Untreat_w1	-.007 (.018)	-.008 (.016)	.006 (.017)	.005 (.016)	-.005 (.009)	-.006 (.011)	-.001 (.01)	-.003 (.011)
TOT	.063* (.031)	.061* (.025)	.049 (.031)	.048** (.018)	.058*** (.015)	.057*** (.013)	.08*** (.023)	.082*** (.018)

Note: M1 controls for STEM prognostic scores and student demographics. M2 adds the outcome prognostic scores and school fixed effects. Intercept represents the average outcome of the 2010 “would be treated” students in non-PLTW schools.

Standard errors are in parentheses.

* <.05. ** <.01. *** <.001

Table 10

Impact of PLTW Offer on Non-Participants

(6) Between-school comparison with students in non-PLTW schools as a comparison group
(Untreated weights applied to the 2010 students in PLTW schools and students in non-PLTW schools)

	College Enrollment				STEM Major Declaration			
	2013		2014		2013		2014	
	M1	M2	M1	M2	M1	M2	M1	M2
Int (Coh10_G0S0)	.432*** (.009)	.431*** (.006)	.431*** (.009)	.43*** (.006)	.062*** (.003)	.062*** (.003)	.06*** (.003)	.062*** (.003)
Coh10_G1S0	0 (.007)	-.002 (.007)	0 (.008)	-.003 (.01)	.003 (.003)	.002 (.003)	.017*** (.003)	.016*** (.003)
Cohort_G0S0	.018 (.017)	.011 (.011)	.02 (.017)	.011 (.011)	-.004 (.005)	-.007 (.004)	-.003 (.005)	-.007* (.004)
TOUT	-.027* (.012)	-.014 (.01)	-.022 (.012)	-.01 (.013)	.002 (.004)	.006 (.004)	-.003 (.005)	.002 (.005)

Note: M1 controls for STEM prognostic scores and student demographics. M2 adds the outcome prognostic scores and school fixed effects. Intercept represents the average outcome of the 2010 “would be untreated” students in non-PLTW schools.

Standard errors are in parentheses.

* <.05. ** <.01. *** <.001

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Appendix A

Table A1

Covariate Balance Between PLTW Participants and Non-Participants in PLTW Schools Before and After Weighting

	Unadjusted Difference		Difference after Weighting		Unadjusted Difference		Difference after Weighting	
	Diff	T-Value	Diff	T-Value	Diff	T-Value	Diff	T-Value
Female	.195	11.09***	-.0004	-.02	.206	17.35***	.0000	.00
White	.056	3.23**	.0000	.00	-.029	-2.83*	-.0008	-.08
Black	-.018	-1.26	-.0013	-.09	.047	6.35***	.0006	.08
Hispanic	-.006	-.70	.0006	.07	-.001	-.16	.0005	.09
Other	-.032	-3.19**	.0007	.07	-.017	-2.68*	-.0003	-.04
FRL	.079	4.12***	.0011	.06	.096	7.58***	-.0012	-.10
ELL	-.011	-1.49***	.0003	.04	-.003	-.74	-.0001	-.03
ELA	-.356	-9.64***	.0011	.03	-.281	-12.21***	.0042	.18
Math	-.541	-13.76***	.0091	.23	-.380	-16.25***	.0025	.11
Science	-.447	-11.94***	.0053	.14	-.385	-16.80***	.0033	.15
Math / ELA	-.301	-7.62***	.0078	.20	-.110	-4.77***	-.0003	-.01
Taking Alg 8th	-.155	-8.84***	.0030	.17	-.136	-11.93***	.0009	.08
GPA9	-.297	-9.42***	-.0002	-.01	-.263	-12.55***	.0008	.04
Attendance G9	-1.909	-8.29***	.0021	.08	-1.417	-9.08***	-.0001	-.01

Table A2

Covariate Balance Between Program Participants in PLTW Schools (G=1, Z=1, S=1) and Three Comparison Groups Before and After Weighting

A) The 2010 students in PLTW schools as the comparison group

	2013				2014			
	Before Weighting		After Weighting		Before Weighting		After Weighting	
	STD Diff	Variance ratio	STD Diff	Variance ratio	STD Diff	Variance ratio	STD Diff	Variance ratio
Prop Score	.679	12.377	.121	1.103	.736	5.028	.15	1.095
Female	-.375	.842	.002	1.002	-.36	.852	0	1
Black	.065	1.141	.007	1.012	-.151	.685	-.021	.936
Hispanic	.098	1.536	0	.999	.072	1.386	-.006	.98
Other	.179	2.062	-.023	.938	.136	1.776	-.004	.988
FRL	-.072	.996	-.003	1	-.109	.989	-.021	.996
ELL	.156	2.884	.006	1.024	.105	2.152	-.013	.939
MAP ELA	.322	.929	.004	.791	.258	.807	.086	.596
MAP Math	.492	1.036	-.004	.543	.373	.901	.106	.43
MAP Science	.422	.937	-.013	.842	.38	.785	.088	.629
Math / ELA	.256	.927	.008	.517	.097	.864	.068	.445
Taking Alg 8th	.429	1.817	.008	1.006	.391	1.758	.045	1.039
GPA G9	.308	.801	.005	.853	.261	.781	.042	.799
Attendance G9	.235	.475	.005	.874	.187	.552	.027	.82

B) The 2010 students in non-PLTW schools as the comparison group

	2013				2014			
	Before Weighting		After Weighting		Before Weighting		After Weighting	
	STD Diff	Variance ratio	STD Diff	Variance ratio	STD Diff	Variance ratio	STD Diff	Variance ratio
Prop Score	.748	13.554	-.025	.665	.784	5.799	.043	.784
Female	-.373	.842	.015	1.014	-.358	.853	.01	1.009
Black	.31	2.29	.008	1.013	.097	1.375	-.049	.885
Hispanic	.137	1.897	-.004	.986	.112	1.712	-.016	.945
Other	.243	3.044	-.051	.883	.202	2.622	-.02	.944
FRL	-.249	1.028	.008	1.001	-.287	1.02	-.022	.996
ELL	.172	3.398	-.011	.959	.122	2.536	-.031	.87
MAP ELA	.363	1.009	-.001	.85	.3	.877	.074	.643
MAP Math	.529	1.152	-.052	.494	.408	1.002	.073	.4
MAP Science	.459	1.104	-.035	.903	.419	.925	.077	.673
Math / ELA	.274	.963	-.045	.415	.114	.898	.029	.371
Taking Alg 8th	.445	1.878	-.038	.975	.406	1.817	.018	1.014
GPA G9	.299	.902	-.01	.894	.25	.879	.037	.815
Attendance G9	.152	.582	.003	.705	.102	.676	.031	.621

C) The 2013 & 2014 students in non-PLTW schools as the comparison group

	2013				2014			
	Before Weighting		After Weighting		Before Weighting		After Weighting	
	STD Diff	Variance ratio	STD Diff	Variance ratio	STD Diff	Variance ratio	STD Diff	Variance ratio
Prop Score	.745	3.353	-.061	.746	.68	2.101	-.019	.922
Female	-.388	.842	.001	1.001	-.371	.852	.002	1.002
Black	.288	2.113	.001	1.002	.064	1.222	-.006	.984
Hispanic	.091	1.482	-.003	.991	.062	1.314	.001	1.002
Other	.212	2.486	-.004	.989	.17	2.145	0	.999
FRL	-.308	1.053	-.001	1	-.361	1.053	.004	1.001
ELL	.139	2.468	-.008	.967	.082	1.758	.005	1.024
MAP ELA	.343	1.028	-.002	1.074	.291	.869	-.009	.926
MAP Math	.518	1.172	-.01	.961	.417	1.007	-.005	1.025
MAP Science	.449	1.071	-.005	1.083	.43	.901	-.005	.987
Math / ELA	.259	.954	-.008	.859	.106	.884	-.002	1.096
Taking Alg 8th	.383	1.657	-.011	.992	.378	1.713	-.003	.998
GPA G9	.279	.885	0	.948	.235	.827	0	.869
Attendance G9	.139	.74	.002	.848	.101	.759	.002	.759

Table A3.

Covariate Balance for Program Non-Participants in PLTW Schools (G=1, Z=1, S=0) and Three Comparison Groups Before and After Weighting

A) The 2010 students in PLTW schools as the comparison group

	2013				2014			
	Before Weighting		After Weighting		Before Weighting		After Weighting	
	STD Diff	Variance ratio	STD Diff	Variance ratio	STD Diff	Variance ratio	STD Diff	Variance ratio
Prop Score	.168	1.324	-.003	.997	.184	1.245	.001	1.029
Female	.03	1.002	-.001	1	.065	1.001	-.002	1
Black	.014	1.029	.001	1.002	-.001	.998	.001	1.002
Hispanic	.071	1.376	-.004	.986	.069	1.364	-.002	.991
Other	.046	1.239	.002	1.009	.065	1.346	.001	1.006
FRL	.086	.993	-.001	1	.085	.993	-.002	1
ELL	.098	2.056	-.006	.97	.087	1.917	-.002	.991
MAP ELA	-.04	1.02	.003	.953	-.038	1.002	.001	.948
MAP Math	-.038	1.006	0	.95	-.031	.999	-.002	.966
MAP Science	-.027	.964	.002	.919	-.025	.979	.002	.947
Math / ELA	-.029	.99	-.001	.942	-.02	.995	-.006	.968
Taking Alg 8th	.057	1.12	.001	1.002	.062	1.13	.003	1.006
GPA G9	-.026	.96	-.003	.949	-.036	.928	-.002	.909
Attendance G9	-.004	.915	-.002	.953	0	.887	-.001	.943

B) The 2010 students in non-PLTW schools as the comparison group

	2013				2014			
	Before Weighting		After Weighting		Before Weighting		After Weighting	
	STD Diff	Variance ratio	STD Diff	Variance ratio	STD Diff	Variance ratio	STD Diff	Variance ratio
Prop Score	.395	1.56	.008	1.034	.395	1.535	.01	1.051
Female	.032	1.002	.005	1	.067	1.001	.005	1
Black	.26	2.065	.004	1.007	.245	2.002	.004	1.008
Hispanic	.11	1.7	0	.998	.108	1.685	0	1
Other	.114	1.829	0	.998	.133	1.987	.003	1.009
FRL	-.09	1.024	.001	1	-.091	1.024	0	1
ELL	.115	2.423	.005	1.024	.104	2.259	.004	1.02
MAP ELA	-.006	1.108	-.002	1.064	-.004	1.089	0	1.058
MAP Math	-.015	1.118	-.008	1.071	-.008	1.111	-.004	1.076
MAP Science	-.008	1.137	0	1.07	-.006	1.154	.002	1.105
Math / ELA	-.014	1.028	-.014	.999	-.005	1.034	-.009	1.015
Taking Alg 8th	.072	1.158	.005	1.009	.077	1.169	.012	1.022
GPA G9	-.046	1.082	-.011	.998	-.056	1.045	-.003	.953
Attendance G9	-.09	1.121	-.002	.772	-.087	1.087	-.004	.781

C) The 2013 and 2014 students in non-PLTW schools as the comparison group

	2013				2014			
	Before Weighting		After Weighting		Before Weighting		After Weighting	
	STD Diff	Variance ratio	STD Diff	Variance ratio	STD Diff	Variance ratio	STD Diff	Variance ratio
Prop Score	.386	1.388	.012	1.061	.385	1.261	.004	1.014
Female	.018	1.001	.003	1	.055	1	.001	1
Black	.238	1.906	.01	1.018	.212	1.779	.002	1.004
Hispanic	.064	1.328	.002	1.008	.058	1.293	0	1.002
Other	.081	1.494	-.001	.994	.1	1.625	.001	1.005
FRL	-.148	1.049	0	1	-.164	1.057	0	1
ELL	.08	1.76	.013	1.074	.063	1.566	.009	1.053
MAP ELA	-.027	1.128	-.006	1.084	-.012	1.078	.001	1.041
MAP Math	-.028	1.137	-.008	1.066	0	1.116	-.002	1.081
MAP Science	-.015	1.103	-.005	1.069	.007	1.125	.003	1.086
Math / ELA	-.029	1.019	-.008	1.023	-.012	1.018	-.009	1.046
Taking Alg 8th	.011	1.022	.004	1.008	.049	1.101	.009	1.017
GPA G9	-.063	1.061	-.007	.952	-.066	.983	.007	.875
Attendance G9	-.116	1.424	-.005	.878	-.093	1.22	-.002	.822