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Board 152: An Analysis of School District Adoption of K-12 Engineering Curriculum (Evaluation) (DEI)

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ABSTRACT

Historically the STEM disciplines have not been inclusive. Workforce projections indicate that there is a growing need for STEM professionals and STEM degree programs are not keeping up with demand to meet labor force needs. Efforts to broaden interest in the STEM disciplines have been ongoing with considerable investment from government agencies and private sector organizations. However, participation in the STEM workforce still does not reflect population demographics. The research literature provides an evidence-base that early STEM experiences can impact K-12 students intention to enroll in STEM degree programs. Over the last two decades pre-college engineering programs and pathways have been developed to prepare K-12 students for engineering degree programs at the post-secondary level. A secondary goal of these pathways was to broaden interest in engineering professions and diversify the engineering pipeline. Pre-college programs that provide a positive STEM experience may increase the pipeline and diversity of students interested in pursuing STEM at the postsecondary level. The Project Lead the Way Program (PLTW) is one example of a pre-college engineering program implemented in all 50 states in the US in over 12,000 schools. This study examined adoption patterns of PLTW using the lens of Diffusion of Innovation Theory of engineering curriculum using a 12-year data set from Texas. Researchers across Texas. Factors that may influence adoption were examined including school size, expenditures, student demographics, and standardized test scores. Findings suggest that school size based on enrollment and socio-economic status have a significant impact on adoption of the PLTW engineering curriculum. It was also found that adopting districts enroll more students from underrepresented groups which may lead to broader participation in engineering.

Keywords: STEM education, engineering education, diffusion of innovation, panel logit model (Poster, Work in Progress)

Introduction

Workforce projections indicate that opportunities in Science, Technology, Engineering and Mathematics (STEM) fields will grow considerably in upcoming years (BLS, 2014). Engineering fields in particular are experiencing a shortage of qualified workers in spite of being high paid positions compared to many professions. There is a concern that this shortage is in part due to a pipeline crisis within the educational field. Specifically, review of higher education retention data highlight that post-secondary institutions are not recruiting and graduating a sufficient number of high-quality students to fill STEM workforce vacancies (Fox & Hackerman, 2003; Marginson et al., 2013; National Academy of Sciences, 2007; Suzuki & Collins, 2009).

Multiple studies have provided evidence of the importance of early educational experiences to students' eventual decision to study in a STEM-related discipline during their post-secondary education. Involvement in educational activities that offer positive experiences in engineering and other STEM areas increase the likelihood students will pursue a STEM-focused degree and enter the workforce (Cassady et al., 2020; Maltese & Tai, 2011; Sadler et al., 2012). In response, educators have begun implementing structured curriculum designed with the explicit purpose of developing students' STEM understanding and interest through the use of innovative teaching practices (Bottoms & Uhn, 2007).

There are several precollege curriculum programs that are implemented in Texas to prepare students for post-secondary engineering degree programs. One of the most widely used curriculum interventions with potential to support positive higher education and employment outcomes is Project Lead the Way (PLTW). PLTW utilizes a problem-based pedagogical approach to support the development of skills and knowledge needed for college and career readiness (Project Lead the Way, 2020; Starobin et al., 2013). Although there is some evidence of the short and long-term benefits of Project Lead the Way (Hess et al., 2016), the contextual factors that influence PLTW adoption are not well understood. This research investigates the school and district characteristics that are predictive of PLTW adoption to better understand the contextual factors may help identify factors and barriers to adopting innovative engineering curricula such as PLTW.

As part of this study, the researchers examined longitudinal student data maintained by state designated Educational Research Centers (ERC) that serve as repositories for P-16 and workforce data to address the following research questions:

1. How many schools across Texas have adopted the PLTW model?
2. What are the general characteristics of the adopting school districts? Are there statistical differences between adopting school districts and non-adopting school districts in terms of district size, district expenditure, student demographics, and standardized test scores?
3. What district characteristics predict the school districts' decision to adopt the PLTW model?

Background

For the purposes of this study, the researchers focused on middle school Gateway and high school Engineering curriculum. Project Lead the Way is a national program known throughout the education community for providing K – 12 STEM-focused educational programing. The curriculum is designed to support STEM knowledge development, engagement, interest, and motivation using problem-based learning techniques (Project Lead the Way, 2020; Tai, 2012). Problem-based learning (PBL) is an instructional approach derived from the constructivist tradition that emphasizes the importance of active knowledge construction in the development of transferable skills and knowledge (Chi, 2009; Hmelo-Silver, 2004). In PBL, educators support students to construct their own understanding of content through the presentation of real-world problems that require 21st century skills (De Graff & Kolmos, 2003; Hmelo-Silver, 2004).

PLTW also includes a comprehensive professional development component to ensure educators can implement innovative instructional practices with fidelity (Project Lead the Way, 2020). More specifically, educators have access to intensive training modules and supportive materials (e.g., curriculum guides) designed to challenge misconceptions regarding effective teaching and provide the skills needed to effectively implement student-centered teaching practices that reduce passivity and allow learners to become an active participant in the learning process (Project Lead the Way, 2020). The alignment of innovative instruction, STEM community involvement, and professional development cultivates a "STEM ecosystem" in which learners are exposed to a variety of high-interest and impact learning experiences. These experiences are designed to provide academic preparation needed to overcome common barriers to STEM pipeline persistence (Reid & Feldhaus, 2007). Prior investigations of the overall efficacy of PLTW have repeatedly demonstrated the impact of the educational program on proximal academic outcomes (Hess et al., 2016; Van Overschelde, 2013; Tran & Nathan, 2010). For instance, students involved in the program are likely to pursue a STEM-focused degree after completing high-school, and are more likely to persist until degree completion than students who complete a more traditional K-12 experience (Bottoms & Uhn, 2007; Gottfried & Plasman, 2018; Lee et al., 2019; Rethwisch et al., 2012; Robbins et al., 2014; Sorge, 2014; Starobin et al., 2013; Van Overschelde, 2013).

Prior empirical investigations from the qualitative perspective have provided converging evidence that the primary barriers to PLTW implementation are costs associated with program implementation and a lack appropriate facilities to support the "problem-based" curriculum (Reid & Feldhaus, 2007; Shields, 2007). This study goes beyond the qualitative findings and uses a quantitative approach to determine key predictors of adoption with the goal of identifying resources to better support implementation efforts.

Theoretical Framework

Diffusion of Innovation (DOI) Theory purports that novel ideas are spread through social networks through a process that involves (a) awareness of the need for a novel approach to address an issue, problem, or situation, (b) a decision by individuals to adopt the novel idea, (c) the testing of the idea in relation to one's own particular circumstance, and (d) the continued use of the innovation (Rogers, 1962). Adopters of a novel idea can be organized into five distinct categories – innovators, early adopters, early majority, late majority, and laggards. Although research suggests that the majority of adopters (approximately 68%) fall within the early majority and late majority categories. There are a number of factors that predict adoption of the new idea into a social network. These include the degree to which the idea is perceived as an improvement upon existing ideas, the compatibility of the idea with the values, needs, and experiences of the individuals involved, and the complexity of the new idea in relation to the idea that it is being replaced.

PLTW involves innovative instructional techniques and professional development opportunities that allow adopting schools to develop an ecosystem. This ecosystem is characterized by high-impact learning experiences that allow learners to overcome known barriers to pursuing (and persisting in) STEM careers. DOI Theory can be used to help understand and predict how PLTW is initially adopted and spread.

Data

This research utilized two different datasets to examine PLTW schools in Texas. The first data set housed school roster data collected by the former PLTW State Affiliate. The data cover a twelve-year period from the 2007-08 school year to 2018-2019 school year. This dataset allows the identification of adoption trends over time and across different school districts. The second dataset comes from the Texas Smart School project at the ERC. This dataset combines data from the Texas Education Agency, the U.S. Census Bureau, and the Texas Comptroller of Public Accounts to provide a comparison across schools and school districts in the state. It covers elementary, middle, and secondary schools across the state of Texas. It contains students' math and reading test score information, school district expenditure, school/district enrollment, student demographics, and Career and Technical Education enrollment. This study uses the most recent six years of data that are available, i.e., 2013-14 to 2018-2019.

Researchers matched the PLTW school roster data with the Texas Smart School data which constitutes the main analysis sample for our study. The main analysis sample is a six-year panel dataset containing all public schools and charter schools and their supervising districts. There are 1077 school districts (5162 school district year observations) number of PLTW schools in 2014-2019 and 182 school districts (926 school district year observations) number of non-PLTW schools.

Methodology

For the state of Texas data, PLTW schools were linked by school roster data with the Texas Smart data. The final analysis sample consists of all K-12 schools in state of Texas of which 182 schools implemented PLTW. The researchers answer the research question two by comparing the PLTW schools and non-PLTW schools using a series of independent samples t-test.

To address the last research question modeling the school and school district adoption decision by estimating the following panel logit model.

$$P(PLTW_{it} = 1) = \alpha + \beta_1 * S_{it} + \beta_2 * D_{it} + \beta_3 * T_i + \varepsilon$$

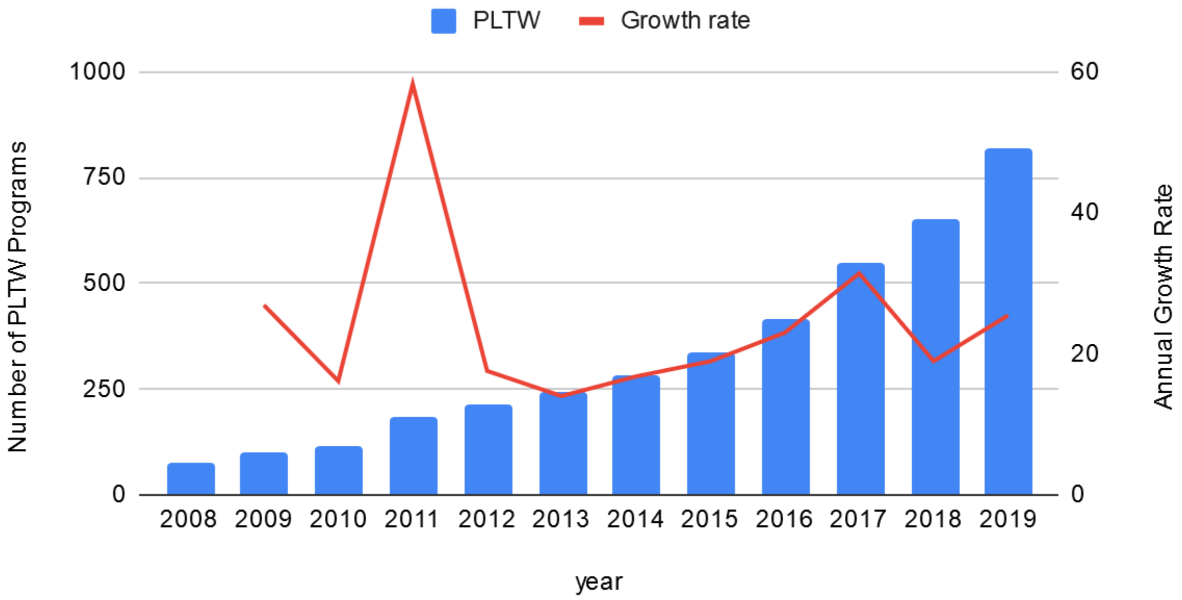
The PLTW program adoption variable for school district (i) and time (t) is the dependent variable of interests. For those PLTW schools, this variable is defined as one and zero for those non-PLTW schools. Since the dependent variable is binary, we used panel logit estimation. We also tested out a series of other model specifications such as Poisson regression, Zero-inflated negative binomial regression, logit regression. However, the best fitting model is the panel logit model that is presented here.

Independent variables include school district level student characteristics S_{it}. Specifically, we include a composite academic progress percentile. This measure combines math and reading progress and adjusts for differences in student demographics. Additional student characteristics include: percent of economically disadvantaged students, percent of Limited English Proficient students, percent of special education students, percent of transient students, percent of at-risk students, percent of Hispanic students, and percent of African-American students. School district level characteristics D were also included. The researchers used two measures of school district to measure school district size. The first one is district level student enrollment and another one is the square miles of the school district. School district wealth will also be captured by district level characteristics such as the total revenue per student from all sources local, state, and federal government.

Results

The initial trend analysis focused on the school and school districts that have ever adopted any PLTW program. In Figure 1, blue bar indicates the number of PLTW programs in a specific year. For example, there are 78 PLTW programs in 2008 school year and that number doubled in 2011. On the right axis, we also provided annual growth rate. The average growth rate for all PLTW programs is around 25% with one noted spike to almost 60% growth rate in 2011.

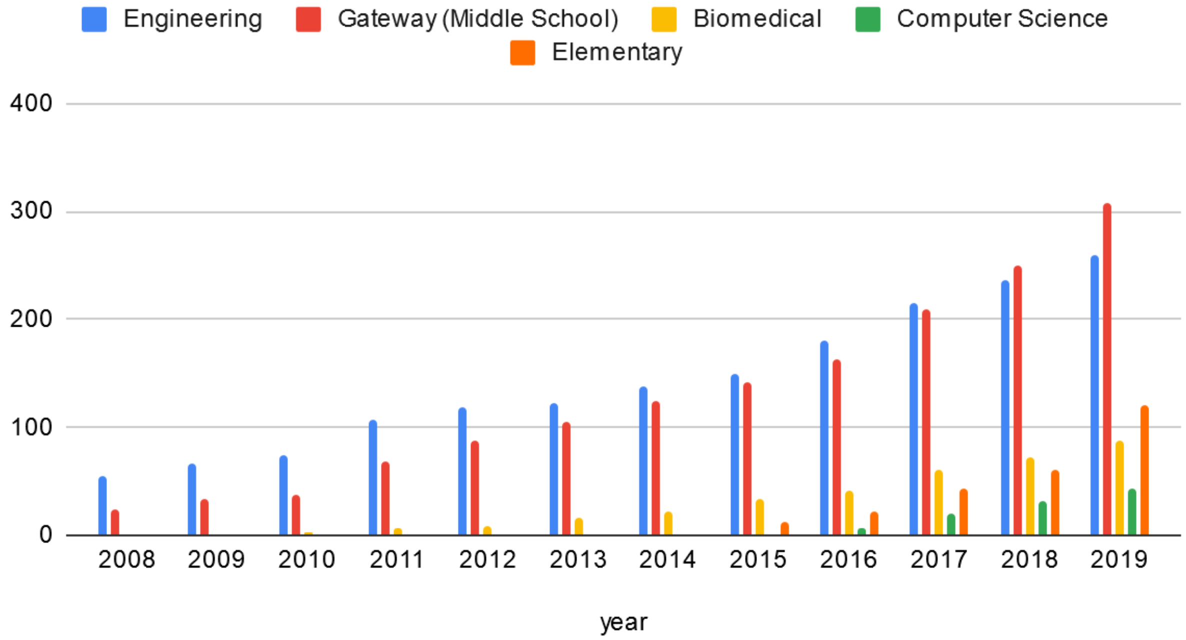
Figure 1. Texas PLTW Program Adoption and Growth Rate



PLTW programs have grown across Texas. There are some cases where growth may have been spurred by policy from the Texas Education Agency (TEA). In 2010, TEA initiated the Texas STEM Academy (T-STEM) Program. TEA provided districts and charter schools the opportunity to open T-STEM Academies. If TEA designation was granted, schools initially received additional funding per student to support the implementation of the T-STEM Academy Blueprint model. T-STEM Academies are open enrollment secondary schools and often enroll underserved, at-risk and economically disadvantaged students. Given T-STEM Academies' focus on STEM subjects, it is not surprising to see the growth of PLTW coincide with the establishment and growth of T-STEM Academies.

In Figure 2, the blue bar indicates the number of Engineering programs. The red bar indicates the number of Middle School Gateway program. The yellow bar indicates the average number of Bio-medical program. The green bar indicates the number of high school Computer Science program. The orange bar indicates the number of Elementary Launch program.

Figure 2. Texas PLTW Specific Program Adoption 2008-2019



During the period examined, high school PLTW Engineering programs have had steady annual growth rate of 15% and Gateway middle school programs seems to catch up with the Engineering program in 2018 and experienced faster growth rate (27%) than the Engineering program (15%). In 2019, there are 308 Gateway Programs in state of Texas and 259 Engineering programs.

There was significant growth in Engineering and Gateway adoptions during the initial-STEM program implementation. Also, from 2010-12, the PLTW affiliate received over $1.2 million in grants from TEA to support STEM Teacher Professional Development that subsidized training costs for schools.

A second policy decision that may impact future adoptions at the middle school level occurred in 2019-20. TEA Career and Technical Education (CTE) weighted funding was extended to the middle-school level as a result of the passage of House Bill 3. This could lead to more funding that allows more adoptions of PLTW Gateway programs. In the area of computer science, TEA passed rules in 2016 that allowed Computer Science to fulfill the foreign language requirement in High School. This policy freed up space in the high school curriculum for students to enroll in computer science. There was a significant increase in the number of computer science adoptions after this policy went into effect.

Table 3 provides summary statistics for PLTW adopting school district characteristics and those of non-PLTW school districts. A series of independent samples t-tests were calculated to investigate general differences in between these two samples. It was found that adopting districts are much larger in terms of enrollment size. The average enrollment is around 20,000 students in adopting districts versus only 2,000 students in non-adopting districts which was an indicator of a rural setting. In Texas, high schools are classified by enrollment primarily for athletic competitions as managed by the University Interscholastic League (UIL) with 6A High Schools (over 2,220 students) being the largest classification and 1A (less than 105 students) being the smallest. The researchers suspect larger districts probably have more resources to implement a relatively more expensive program like the PLTW.

An examination of district wealth differences found that the total revenue per student is higher in adopting districts. More interestingly, the local share of the revenue in non-adopting districts are much lower than adopting districts. Adopting districts tend to have higher share of African American (10.25% v.s. 5.9%) and Hispanic students (53% versus 37%), at-risk students (50% versus 43%), students with Limited English Proficiency (16% versus 8%). In both non-PLTW and PLTW school districts, there are roughly equal share of economically disadvantaged students. Moreover, we also examined the standardized test score differences between these school districts. PLTW school districts have significantly higher standardized math test performance than non-PLTW school districts.

In the panel logit analysis (Table 1), four different models are presented that gradually add additional control or explanatory variables that the DOI theory and earlier literature indicates as important. Model 1 include district size as measured in both number of students enrolled, and geographical areas of the district as measured in square miles. Model 2 added three district revenue related variables, i.e., district revenue per student in thousands of dollars, district revenue from state and federal government in thousands of dollars, and share of district revenue from local share or their property tax base. Model 3 added district level student characteristics such as percentage of Hispanic students, African American students, economically disadvantaged, Limited English Proficient students (LEP), special education students, student mobility, and students at-risk. Model 3 also controls for both math and reading progress Z-score. Model 4 add regional controls and year controls.

Table 1. Comparison of PLTW Adopting School Districts and non-PLTW School Districts and the T-Test of Sample Mean in 2014-2019

	Non-PLTW School Districts Mean (SD)	**PLTW School Districts Mean (SD)**	**T-Test of Means (PLTW mean-non-PLTW mean)**
District Enrollment Size (thousands of students)	2.266	19.94	15.80*
	(6.344)	(27.96)	(0.384)
District Size in thousands of square miles	0.267	0.255	-0.0132
	(0.330)	(0.523)	(0.0131)
Total Revenue per FTE (thousands of dollars)	13.08	11.58	-1.348*
	(4.968)	(2.637)	(0.164)
Total Revenue from State and Federal Government (thousands of dollars)	6.548	5.755	-0.852*

	(2.866)	(2.612)	(0.110)
% Revenue Local Share	47.44	49.44	2.851*
	(21.23)	(21.36)	(0.830)
% Students Hispanic	36.95	53.12	14.88*
	(25.84)	(27.87)	(0.898)
% Students African American	5.960	10.25	1.907*
	(9.929)	(12.15)	(0.513)
% Economically Disadvantaged	58.08	59.36	0.444
	(18.15)	(22.26)	(0.696)
% LEP	7.895	16.12	7.137*
	(9.054)	(13.06)	(0.415)
% Special Education	9.528	8.961	-0.817*
	(2.695)	(1.597)	(0.123)
% Student Mobility	14.71	15.18	-1.506*
	(5.457)	(4.605)	(0.381)
% Students At-Risk	42.54	50.19	4.915*
	(14.15)	(15.10)	(0.581)
Math Progress Z-Score	-0.00338	0.0296	0.0374*
	(0.128)	(0.107)	(0.00453)
Reading Progress Z-Score	-0.00400	-0.00668	0.00252
	(0.0765)	(0.0723)	(0.00281)
Observations	5162	926	

Note: * $p < .005$

Looking across all four models, district size based on enrollment, has a strong and statistically significant positive relationship with the adoption decision. Larger school district size is associated with PLTW program adoption in both Engineering program adoption and other program adoption. Square miles turn out to be not statistically significant. District wealth variables seems to point out some interesting findings. Per FTE total revenue is not statistically significant but the total revenue from state and Federal government is statistically significant and negative. This could potentially mean that high poverty school districts that receives a higher share of Title I funding from the Federal government may not be able to adopt programs such as PLTW.

Model 4, indicated that a higher share of Hispanic students, African-American students, and Limited English Proficient students are associated with more engineering program adoption. However, having more economically disadvantaged students is negatively correlated with program adoption. This could be reinforcing earlier findings that school districts receiving a higher share of Federal funding may be at a disadvantage in terms of new program adoption.

Statewide there are large variations within and across regions. As shown in Table 2, several regions such as region 4 in Houston area, region 10 Richardson area, region 11 Fort Worth area, region 13 Austin area, region 19 El Paso area had high levels of implementation. This may also be a result of school size based on enrollment. Schools with larger enrollments are more likely to adopt than smaller schools. ESC regions 4 (Houston), 10 (Dallas), 11 (Fort Worth), 13 (Austin), 19 (El Paso), and 20 (San Antonio) are home to large urban and suburban school districts. There may be a needed critical mass of students that impacts adoption.

Table 2: Panel Logit Results of Student Characteristics, District Size, and District Wealth on the Engineering Program Adoption in 2014-2019

	(1) Ever Adopted the PLTW Engineering Program Coef./Std. err.	(2) Ever Adopted the PLTW Engineering Program Coef./Std. err.	(3) Ever Adopted the PLTW Engineering Program Coef./Std. err.	(4) Ever Adopted the PLTW Engineering Program Coef./Std. err.
District Enrollment Size (thousands of students)	0.500^{***}	0.459^{***}	0.509^{***}	0.559^{***}
	(0.02)	(0.03)	(0.03)	(0.04)
District Size in thousands of square miles	-1.095	-0.265	-0.857	3.133
	(0.56)	(0.74)	(1.56)	(1.91)
Total Revenue per FTE (thousands of dollars)		-0.040	-0.041	0.006
		(0.10)	(0.16)	(0.14)
Total Revenue from State and Federal Government (thousands of dollars)		-0.294	-1.091^{*}	-1.444^{*}
		(0.32)	(0.50)	(0.64)
% Revenue Local Share		-0.026	-0.107	-0.165^{*}
		(0.04)	(0.07)	(0.08)

% Students Hispanic	0.176***	0.261***
	(0.03)	(0.05)
% Students African American	0.284***	0.245***
	(0.05)	(0.04)
% Economically Disadvantaged	-0.222***	-0.286***
	(0.06)	(0.06)
% LEP	0.244***	0.170*
	(0.06)	(0.08)
% Special Education	0.123	-0.050
	(0.21)	(0.26)
% Student Mobility	0.059	0.205
	(0.09)	(0.14)
% Students At-Risk	0.036	0.063
	(0.05)	(0.06)
Math Progress Z-Score	2.019	1.151
	(3.72)	(3.98)
Reading Progress Z-Score	-2.027	-2.173
	(7.01)	(7.07)
Region 1 Edinburg		7.373*
		(3.12)
Region 2 Corpus Christi		5.843
		(3.70)
Region 3 Victoria		0.000
		(.)
Region 4 Houston		16.567***
		(3.41)
Region 5 Beaumont		12.455**
		(4.76)
Region 6 Huntsville		8.975*
		(4.51)
Region 7 Kilgore		8.955*
		(3.93)
Region 8 Mount Pleasant		-0.292
		(7.89)

Region 9 Wichita Falls				10.863*
				(4.27)
Region 10 Richardson				18.160***
				(3.58)
Region 11 Fort Worth				13.423***
				(3.52)
Region 12 Waco				11.468*
				(4.45)
Region 13 Austin				12.803**
				(4.23)
Region 14 Abilene				5.111
				(3.92)
Region 15 San Angelo				-2.419
				(4.05)
Region 16 Amarillo				-2.638
				(4.01)
Region 17 Lubbock				1.901
				(3.64)
Region 18 Midland				-3.555
				(4.69)
Region 19 El Paso				9.349*
				(3.68)
Constant	-12.888***	-8.823**	-11.538	-20.561*
	(0.43)	(3.16)	(5.94)	(8.22)
Year fixed effects	No	No	No	Yes
# Of district-year observations	5903.000	5902.000	5882.000	5654.000
# Of district observations	988.000	988.000	986.000	948.000
Log Likelihood	-355.826	-358.847	-317.283	-290.110

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Conclusions and Recommendations

This research study focuses on one particular curriculum and program, but results have implications for both the education field as a whole and policy adoption and diffusion. For any innovative program, the knowledge and information barriers are strong initially and will be reduced as more and more innovators adopt such curriculum. Such can be said of the PLTW program. Prior to 2018, PLTW had a central location for teacher professional development. The two-week-long summer workshop created a network of teachers. Some of these teachers become trainers for future teachers and often help their school districts to carry out the implementation of these programs. The positive learning experience and exposure to like-minded teachers may have helped these teachers to bring their knowledge back to their middle or high schools. This process facilitated later PLTW program adoption in other schools within the same region and same school districts. In addition to state, regional, and local diffusion, we also noted that there are some important state policies that affect the growth of the PLTW program. For example, the launch of schoolwide program such as the Texas T-STEM Academies facilitated the adoption of the PLTW program in the state of Texas. Another important insight is that when program costs are offset by statewide professional development funding adoption rates increased. Finally, PLTW school districts in Texas tend to be demographically diverse. Given the prior literature on the effectiveness of the PLTW program in promoting student's achievement and future college choice of STEM majors, this may be an area for future research.

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