A Study of the Impact of a National Project Based Learning Curriculum (PLTW) on Student Continuation to Postsecondary Institutions

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Abstract

Project based learning (PBL) has increasingly been promoted as a way to increase student interest in the STEM related fields. One such curriculum, Project Lead The Way (PLTW), has gained increasing popularity in middle schools and high schools. A key objective of the PLTW engineering curriculum is to create a more seamless transition for students from secondary school into science, technology, engineering, and mathematics post-secondary programs. PLTW has been implemented in all fifty states; however, there has been sparse research to-date that has rigorously measured the impact of PLTW or other PBL curricula on the student's choice to persist into postsecondary education We used Iowa's statewide longitudinal data system to follow multiple cohorts of PLTW participants and nonparticipants from 8th grade into secondary education. We derived a comparable treatment and control group by matching students based on their propensity to enter PLTW, permitting a stronger interpretation of the program's impact than prior studies. Specifically, the students were matched based on 8th grade standardized test math and science scores, gender, ethnicity, and SES information. We found statistically significant evidence that PLTW increases the odds of a student attending a 2-year college by 64% ($p = 0.007$) and increases the odds that they attend a 4-year college or university by 52% ($p = 0.024$). Further studies are being carried out to examine the majors selected by these students and their persistence in post-secondary education. This study has implications for researchers, practitioners, and policy makers regarding the comprehensive evaluation design and the critical role that PBL curricula can play to increase the participation, both generally and within non-traditional groups, in postsecondary STEM education in the U.S.

Introduction

During the past decade, improvement of science, technology, engineering, and mathematics (STEM) education has received attention from policy makers, educators, and researchers to sustain America's competitive position in the global economy. In response to the nation's "talent crisis," a number of educational programs have been designed and implemented at secondary education level to expand the proportion of students who persist in STEM-related fields at post-secondary level. Among such programs, Project Lead The Way (PLTW) aims to provide a seamless path to college and career success in STEM-related fields for middle school and high school students (Blais, 2003). PLTW has been implemented in every U.S. state since the late 1990s, and was first introduced to the state of Iowa in 2005. Since then Iowa PLTW experienced a fast, steady growth from only about 200 students in 2005 to more than 4,000 in 2012. The increase in Iowa's enrollment coincided with growth of PLTW nationwide (e.g., Brandt, 2009; Cech, 2007; Spellman, 2007).

The PLTW program is a sequence of year-long courses designed to teach engineering and problem solving concepts to high school students. Each course involves a series of hands on projects that emphasize open-ended problem solving, design contents, and 21st century skills. While these courses provide the possibility of college credit for students who achieve an appropriate score on the end-of-course assessment and some schools provide weighted grading for PLTW courses. However, unlike typical AP courses, PLTW indicates that the hands-on nature of the PLTW courses makes them accessible to 80% of secondary students. So there can be a broad range of students in these courses. The curriculum is divided into two strata (Taylor, Foster, & Ratcliff, 2006)—foundation courses (Introduction to Engineering Design and Principles of Engineering) and specialization courses (Aerospace Engineering; Biotechnical Engineering; Civil Engineering and Architecture; Computer Integrated Manufacturing; and Digital Electronics). The sequence of courses ends with a capstone course (Engineering Design and Development) that requires students to take their own idea from design through development. In addition, Gateway to Technology is offered in middle school in selected school districts and is intended to maintain and increase middle students' interest in STEM fields and to encourage the students to take the high school courses.

Based on the results from the five-year assessment of PLTW strategic objectives, 80% of the PLTW students intended to pursue a postsecondary education (Walcerz, 2007). Further, Bottoms and Anthony (2005) found that the PLTW students were more likely to plan to pursue a bachelor's degree than those who enroll in Career and Technical Education (CTE) programs. While students' intent to pursue postsecondary education may indicate as the evidence of the PLTW program success, there still is critical information that is unknown –whether those PLTW students actually attend college. Thus, the purpose of this study is to measure transition rates of PLTW and non-PLTW students into postsecondary institutions. More specifically, this study employs propensity score matching to generate treatment (PLTW students) and control (non-PLTW students) groups to estimate the PLTW impact on students' immediate entry to college with a comprehensive data set. Emphasizing the postsecondary portion of the data set, this study addresses the following research questions:

1. To what extent do PLTW and non-PLTW students persist to 2- and 4-year institutions?
2. What demographic and achievement factors (e.g., ethnicity, gender, social economic status, PLTW participation, ITED math and science scores, etc.) predict PLTW and non-PLTW students' immediate entry to 2- and 4-year institutions after high school graduation?

Literature Review

Several studies have attempted to explore the impact of PLTW on various educational outcomes (Blais & Adelson, 1998; Bottoms & Anthony, 2005; Walcerz, 2007), a serious limitation of these studies is the lack of control for pre-existing ability. However, some researchers have begun to address this issue. A research brief by the Southern Regional

Education Board (SREB) matched PLTW participants with career and technical education students with similar demographics and fields of study. SREB found that PLTW students who enrolled in two or more PLTW courses did significantly better in mathematics and science on the High Schools that Work (HSTW) assessment than career/technical students in comparable fields (Bottoms & Anthony, 2005). Differences between PLTW students and similar career/technical students were also found for subsequent course-taking behavior, with PLTW students more likely to complete the four years of mathematics and science (Bottoms & Uhn, 2007). However, this may not have been an appropriate control group since the PLTW courses can all result in college credit. In addition, SREB's study was limited to matching on students' race and gender.

A study by Rethwisch, et al. (Rethwisch, 2011) examined the impact of PLTW participation on performance on high stakes science and math examinations. The study matched PLTW participants with nonparticipants using results of prior achievement scores in mathematics and science, gender, ethnicity, and free and reduced lunch eligibility. They reported that students who had participated in PLTW scored an average of a half grade level higher on the Iowa Test of Educational Development (ITED). There was also a measurable increase in science scores.

College student persistence has been a topic of interest to researchers, educators, administrators, parents, and students in the past decades. A body of existing literature suggests that educational experiences, motivations, and academic performance at multiple educational levels can predict student persistence (Tinto, 1975; 1993, Astin, 1993). Furthermore, students' demographic characteristics, such as age, race, and gender influence their persistence (Astin, 1972; Leppel, 2001; Spady, 1970).

Much of earlier research on persistence in education was focused on the institutional level. Over the past decade, there has been a surge in research from a system perspective (Reason, 2009). System persistence (Hagedorn, Cypers & Lester, 2008) looks at persistence toward completion of the academic degree which includes the transfer from community college to a four-year institution. Research on that transition from community college to the four-year institution has generally focused on institutional and individual factors that help or hinder in the transfer process. (Helm & Cohen, 2001) Other variations of system persistence includes reverse transfers (Po, 2006; Townsend, 2000), who are students attending community college after attending or while attending a four-year institution, as well as transfers who transfer from one community college to the next.

Maltese and Tai (2011) used the research of Adelman (2006), who constructed who built a multi-step model of persistence using variables that impacted college completion, as a framework for their study in the association of educational experiences in high school with their choice to complete a STEM major. Their findings indicate that students make their choice to pursue a STEM major during high school and that choice is based on a growing interest in mathematics and science and not necessarily related directly to high achievement in mathematics and science.

Conceptual Framework

To answer the research questions, this study adopts Pascarella's model of student learning and cognitive development (1985) and Hagedorn's conceptualization of student retention (2004, 2006, 2008). Pascarella's model suggests that students' development is a function of the direct and indirect effects of variables in five major areas, including 1) student background and precollege characteristics, 2) structural and organization characteristics of the institution, 3) institutional environment, 4) interactions with socializing agents, and 5) quality of student effort. Based on transcript analysis of transfer student retention, Hagedorn and colleagues (Hagedorn & Cepeda, 2004; Hagedorn, Moon, Cypers, Maxwell & Lester, 2006; Hagedorn, 2006; Hagedorn, Cypers & Lester, 2008) affirmed that students' academic success lead to a likelihood of transfer from a community college to a four-year institution, which measured as the positive outcome of students. Conceptually, students' transfer from a community college to a four-year institution was conceived as student persistence in postsecondary education. This concept is also known as system retention. The intent of this study is to examine students' pre-college experiences with or without PLTW and determine the effectiveness of PLTW in a student's entry to college immediately after graduating from high school and their subsequent path through higher education. With this cohort of students we are able to follow these students into their second year following high school graduation.

Methodology

Participants

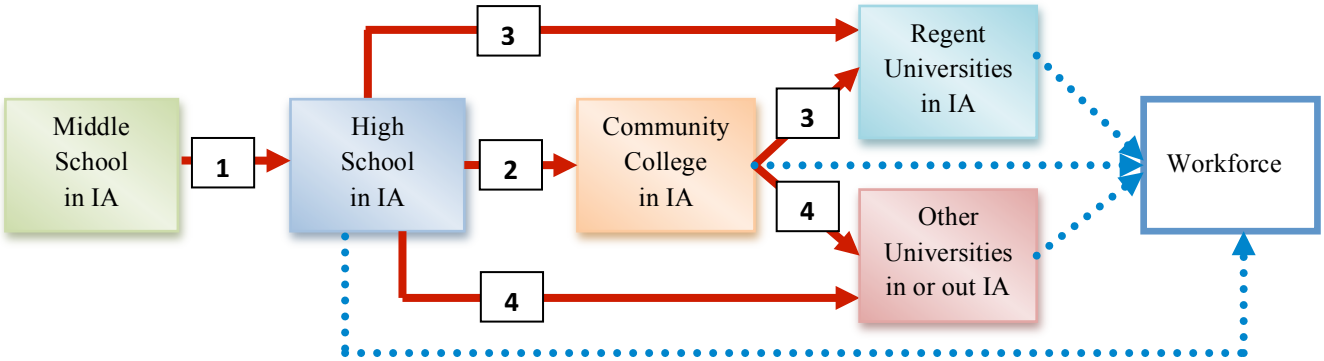
This study advances the knowledge of PLTW students' transition to higher education, as this study measures college transition rate using a comprehensive statewide dataset, including variables from Project EASIER, the Community College MIS, the Regent transcripts, and the National Student Clearinghouse. This analysis is a part of a large-scale research project regarding Iowa PLTW and only focuses on approximately 1,000 PLTW students and 15,000 non-PLTW students who graduated from Iowa high schools in 2009. Students who were enrolled in at least one PLTW course during high school were identified and denoted as a PLTW participant. A control cohort was chosen from students who were enrolled a school which offered PLTW, but were not actually enrolled in any PLTW courses.

Data Sources

Four data sources were merged to form the PLTW dataset. Figure 1 shows the capability of the researchers to follow students from 8th grade through college. Project EASIER contains data on K-12 students starting in 2000 and includes information on which students enrolled in PLTW courses, their academic performance, standardized test scores (Iowa Test of Basic Skills, ITBS and Iowa Test of Educational Development, ITED), and other demographic information. The State of Iowa also maintains a comprehensive database of students enrolled in Iowa's 15 community colleges. The database contains demographic information, the courses in which the student is enrolled, their course program, and other educational and demographic data. The

National Student Clearinghouse provides data on student enrollment at both 2-year and 4-year institutions along with major selection and degree completion data that may be provided through that source.

Figure 1. PLTW data set for tracking PLTW students



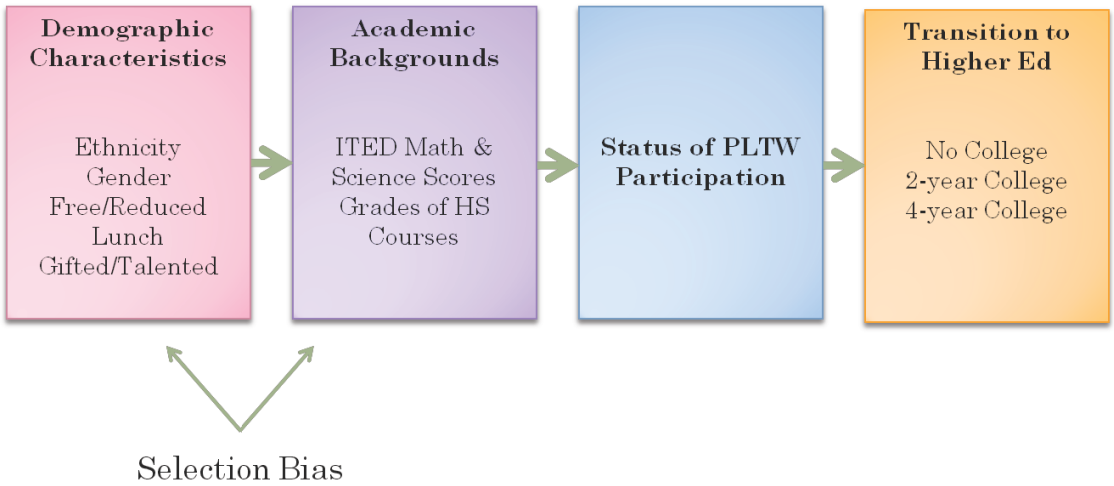
1: Project EASIER (K-12)

2: Community College MIS

3: Regent University Partnership

4: National Student Clearinghouse

Figure 2. Demographics of PLTW and Non-PLTW Students in 8th Grade (before high school)



Data Analysis

Propensity score matching – control group selection.

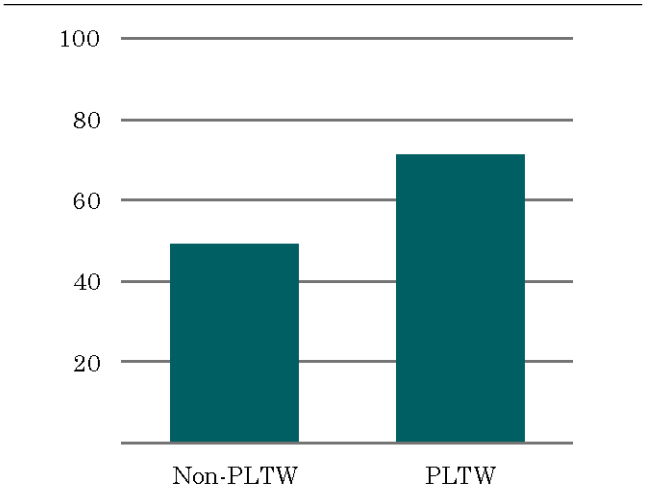
This evaluation draws on the counterfactual framework (Haavelmo 1943; Holland, 1986) to estimate the program's impact. This framework permits researchers to compare the outcomes of individuals that have taken a PLTW course with a control group that have not. The control was selected using a 2 to 1 genetic algorithm (p. 296, Rosenbaum, 2002) with students matched based

on the 8th grade performance on the Iowa Test of Basic skills math and science sections (note: this is before they had taken any PLTW courses), gender, ethnicity, and socioeconomic status (using free and reduced lunch status as a proxy). Genetic algorithms are a class of "learning algorithms" used to seek optimal solutions through numerical iterative techniques. These algorithms use selection, recombination, and mutation of estimates to derive optimal solutions. Once an optimal solution is derived, the matched students and corresponding regression weights are used in the subsequent analysis. We used the genetic algorithms implemented in a software package developed by Ho, Imai, King, & Stuart (2011). To estimate the effect of PLTW on postsecondary enrollment, a multinomial logit regression was conducted with the matched data. In particular, we estimate the impact of enrolling in 2-year college to no postsecondary enrollment and enrolling in 4-year universities to no postsecondary enrollment. See Figure 2.

Results

Approximately 70% of PLTW students in the 2009 graduating class immediately transitioned into higher education, while only about 50% of non-PLTW students transitioned to college (Figure 3). A student is considered to have immediately transitioned if that student began college in the fall of the same year as he or she graduated from high school, and maintained enrollment at that college for at least 30 days and did not withdraw from the college in the fall semester. Among those who immediately transitioned to higher education, more than half of the non-PLTW college students (55%) went to 2-year institutions with the remaining 45% choosing 4-year institutions was 10% lower (Figure 4). The majority of PLTW and non-PLTW students attended public colleges or universities, with the percentage of PLTW students being slightly higher.

Figure 3. Transition to higher education for PLTW and non-PLTW students: 2009 cohort



Note: Includes all PLTW and non-PTLW students, is not limited to the "matched" cohort.

Figure 4. Transition of PLTW and Non-PLTW Students to Higher Education

Postsecondary Enrollment	**PLTW Participation**				**Total**
	Non-PLTW		PLTW		
	n	%	n	%	
4-year	4,132	28.74	295	33.33	**4,427**
2-year	3,299	22.95	336	37.97	**3,635**
No College	6,944	48.31	254	28.70	**7,198**
Total	**14,375**	100.00	**885**	100.00	**15,260**

The descriptive data on higher education transition is, at least, partly attributable to the differences between participants and non-participants before entering PLTW. We used the "matched" set of students to estimate the impact from PLTW while controlling for other variables. Our findings indicate that PLTW participation increased the probability of immediately attending a two-year college, but had minimal or no impact on attending a 4-year university. The odds of a PLTW student attending college compared to not attending college rose 58 percent compared to similar non-participants (Figure 5). The marginal effect—the increase in probability by participating in PLTW—was nearly 11 percent. However, the odds of attending a four-year college compared to not attending college did not significantly change with PLTW participation.

Although males comprise most of the matched sample, they were less likely to enroll in college than their female counterparts. Eighth-grade mathematics ITBS achievement scores were a strong predictor for college entry, while reading was also a significant predictor. Students who were eligible for free lunch were less likely to immediately enrolling in college and students with reduced lunch eligibility were also less likely to enroll, but only significant at the 10 percent level.

Our initial regression did not include other mathematics and science courses. Yet, researchers have documented the importance of these classes which predict entry into college (Aldeman, 2006; Harvill, 2010). We included additional mathematics and science courses in the regression to account for their role. Including additional coursework greatly diminishes PLTW

estimates impact (Figure 6). While the coefficient is positive, the estimates are no longer statistically significant, regardless of our matching algorithms.

Figure 5. Estimates of PLTW Impact on Higher Education Transition

Fixed Effects	Odds Ratio	Standard Error	
PLTW	1.59	0.16	***
Black / African-American	1.25	0.49	
Asian / Pacific-Islander	0.94	0.48	
Hispanic	1.26	0.45	
Male	0.58	0.22	**
Free Lunch Eligible	0.30	0.24	***
Reduced Lunch Eligible	0.60	0.31	*
Individualized Education Plan	0.53	0.47	
Section 504	1.14	0.67	
Gifted & Talented	1.12	0.25	
Homeless	0.62	1.08	
Science	1.00	0.00	
Mathematics	1.01	0.00	***
Reading	1.01	0.00	*
Intercept	0.02	0.95	***
Random Effects	Variance	Standard Error	
School District (intercept)	0.10	-0.08	
Model Information			
Students (Level 1)		999	
School Districts (Level 2)		35	
Log Likelihood		-562.54	

Conclusions

The ultimate aim of Project Lead The Way is to increase the supply of students in the STEM pipeline. After accounting for selection biases, both in terms of student demographics as well as academic background, the data indicates that PLTW participants immediately transitioned at a higher rate to higher education than non-participants. PLTW participation increases the probability of transitioning into higher education by nearly 11 percent.

Although PLTW attracts students who perform very well in mathematics and science, the program seems to increase enrollment in 2-year and 4-year colleges. The odds of attending a 2-year college increases by 63 percent, while the odds of attending a 4-year college increases by 52 percent.

Figure 6. Estimates of PLTW Impact on Higher Education Transition with Cumulative Mathematics and Science Carnegie Units

	Odds Ratio	Standard Error	
Fixed Effects			
PLTW	1.27	0.18	
Sciences			
Earth Sciences	1.17	0.13	
Biology	1.03	0.13	
			**
Chemistry	1.72	0.16	*
Physics	1.38	0.16	**
Engineering/Technology	1.67	0.29	*
Mathematics			
Algebra 1	1.01	0.15	
Algebra 2	0.85	0.17	
			**
Algebra 3/Trigonometry	1.75	0.21	*
Precalculus	1.36	0.25	
			**
Calculus	3.72	0.27	*
Probability & Statistics	0.90	0.23	
IB Mathematics	1.79	0.30	*
Business/Technical	0.63	0.24	*
Other	0.78	0.30	
	Variance	Standard Error	
Random Effects			
School District (intercept)	0.08	-0.08	
Model Information			
Students (Level 1)		999	
School District (Level 2)		35	
Loglikelihood		-519.58	

Most PLTW students in college enrolled in local community colleges and universities. Iowa's community colleges are open-access institutions, which guarantees all students are able to enroll in coursework. The only practical limitation, however, is students may not be able to

enroll in a particular major due to space limitations or minimum requirements. Iowa's public universities, meanwhile, agreed to enroll students based on a computer algorithm. Iowa's Regent Admission Index includes ACT scores, high school rank, grade-point average, and completion of core courses as the deciding factors.

While PLTW does increase postsecondary enrollment, we cannot rule out that PLTW impact is masking the impact from additional mathematics and science coursework. But what does the correlation between PLTW, mathematics, and science mean? Several further hypotheses remain for further analysis.

The first is PLTW encourages, inspires, or motivates students to participate in mathematics and science courses, independent of PLTW. Indeed, many PLTW teachers hope to motivate high school kids by using PLTW as a gateway course.

Second, minimum enrollment requirements set forth by PLTW or school administrators may force students to take additional mathematics and science coursework. PLTW does recommend pre- and co-requisites for several courses. For instance, Introduction to Engineering Design requires students to enroll in algebra 1 course. Subsequent courses often require algebra 2 as a co-requisite.

Finally, we may have failed to account for a latent variable that predicts entry into PLTW and additional mathematics and science courses. Propensity score matching—unlike randomized studies—are unable to balance samples on unobserved data. Several factors may push students to enroll in a STEM curriculum that are unobserved to us, such as latent interests; parental pressure; parental occupations; relationship with teachers[1]; or students perceived return on investment in the coursework.

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