2012

Measuring Undergraduate Student Perceptions of the Impact of Project Lead The Way

Noah Salzman
Purdue University

Eric L. Mann
Purdue University

Matthew Ohland
Purdue University, ohland@purdue.edu

AC 2012-3692: MEASURING UNDERGRADUATE STUDENT PERCEPTIONS OF THE IMPACT OF PROJECT LEAD THE WAY

Mr. Noah Salzman, Purdue University

Noah Salzman is a graduate student in engineering education and mechanical engineering at Purdue University. He received his B.S. in engineering from Swarthmore College, and his M.Ed. in secondary science education from University of Massachusetts, Amherst. He has work experience as both an engineer and taught science, technology, engineering, and mathematics at the high school level. His research focuses on the intersection of pre-college and undergraduate engineering programs.

Dr. Eric L. Mann, Purdue University, West Lafayette

Eric L. Mann is an Assistant Professor of educational studies and a faculty member of both the Istitute for P-12 Engineering Research and Learning (INSPIRE) and the Gifted Education Resource Institute (GERI) at Purdue University. After a military career involving the the design and operation of space systems and several years teaching middle science and mathematics, Mann earned his Ph.D. in educational psychology from University of Connecticut. Mann's research interests center on creativity and talent development within science, technology, mathematics, and engineering (STEM) disciplines.

Dr. Matthew W. Ohland, Purdue University, West Lafayette

Matthew W. Ohland is Associate Professor of engineering education at Purdue University. He has degrees from Swarthmore College, Rensselaer Polytechnic Institute, and the University of Florida. His research on the longitudinal study of engineering students, team assignment, peer evaluation, and active and collaborative teaching methods has been supported by more than $11.6 million from the National Science Foundation and the Sloan Foundation and his team received the William Elgin Wickenden Award for the Best Paper in the Journal of Engineering Education in 2008 and multiple conference Best Paper awards. Ohland is Past Chair of ASEE's Educational Research and Methods division and an At-large member the Administrative Committee of the IEEE Education Society. He was the 2002-2006 President of Tau Beta Pi.

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Introduction

Numerous reports and studies have identified K-12 engineering programs as a means of addressing the "pipeline" issue by increasing interest in pursuing engineering as a career and preparing K-12 students for further study in engineering at the university level[1]. Project Lead The Way (PLTW) is the most prevalent high school engineering program, and is often cited as a model for including engineering in the K-12 curriculum. PLTW can trace its roots to the Shenendehowa Central School District in upstate New York. The success achieved there in encouraging students' interest in engineering lead to the creation of PLTW and, in 1997, the adoption by 12 New York State high schools of PLTW's Pathway to Engineering Curriculum. The curriculum consists of two introductory courses, five elective courses in a variety of engineering disciplines, and a capstone design class. PLTW programs are now offered in all 50 states and more than 4,200 schools with an enrollment of over 400,000 students[2].

As programs like PLTW continue to expand, undergraduate engineering programs should expect increasing numbers of alumni from these programs to matriculate at their institutions. However, there is currently very little research on what happens to PLTW alumni when they reach college. The present study seeks to address this gap through a survey administered to all undergraduate students at a large Research I university to collect demographic information on a random sample of PLTW alumni and their impressions of PLTW classes.

Literature Review

Early research on PLTW tended to be more descriptive than empirical, providing overviews of the program and making the case for its implementation or describing the establishment of PLTW K-12 programs and university partnerships[3–5]. As the program grew, formal research studies emerged. These include formal evaluation reports commissioned by PLTW; explorations of the achievement of PLTW students compared to their peers; parents, teachers, guidance counselors and principals' impressions of PLTW, and studies of the lasting effects of PLTW on university students.

For several years, PLTW has commissioned evaluations of their programs and students through TrueOutcomes, and has published some of this research in publicly released reports[6,7]. A full summary of these reports is beyond the scope of this paper, but they generally found that students had positive experiences with PLTW, performed slightly better on some assessments than matched groups of peers, and achieved representation of underrepresented minorities and females at rates proportional to their presence in PLTW schools and undergraduate engineering programs, respectively.

Independent studies of PLTW have found both positive and negative effects of participation in PLTW programs. Rethswich, Laanan, Haynes, and Starobin[8] found that PLTW participants were more likely to be white, male, enroll in math and science courses, and have higher standardized test scores. Another study[9] found that PLTW students showed smaller gains in math

achievement and no measurable difference in science achievement than a matched group of peers. Consensus on the impact of PLTW participation on achievement remains an open area of research.

Various studies have focused on the impressions of PLTW of parents and school personnel. Werner[10] found that parents generally had a positive impression of PLTW and thought that it was a good experience for their children, but found frequent misperceptions of the ability to use PLTW courses to receive university credit. A pair of studies of teachers' perceptions of PLTW[11,12] found that teachers generally felt that PLTW effectively developed pre-engineering competencies. High school principals shared similar beliefs on the value and efficacy of PLTW programs[13]. Guidance counselors in PLTW schools perceived greater availability of school resources for engineering education, and greater likelihood that college preparatory skills and concepts in math and science were effectively integrated with engineering activities than guidance counselors in non-PLTW schools[14]. All of these studies show considerable support for PLTW among parents and school personnel.

Across all of these studies, very little research exists on the long-term effects of participation in PLTW. Tracking of the post-graduate experiences of alumni by PLTW found that they were much more likely to pursue majors in STEM fields than a matched group, and a very limited sample of PLTW students at one institution found that students who participated in PLTW showed greater persistence in engineering and slightly higher GPAs than students that did not[7]. However, virtually nothing is known about how university students perceive the benefits of participation in PLTW. This study seeks to address this gap with the following research questions:

1. What are the demographics of PLTW students at Purdue University?
2. How do these students perceive their PLTW experiences, and how do these experiences vary between different subgroups?

Method

A survey was created to explore the PLTW experiences of students at Purdue University. In addition to demographic information, participants also indicated the PLTW classes they had taken. Participants also provided the college that they were studying in, and students in the College of Technology and College of Engineering indicated which school they were in within the college. Finally, the participants rated six aspects of their PLTW experience using a five point Likert-type scale, and had the opportunity to write a brief open response about their experience with PLTW.

The survey was administered using the Qualtrics online survey system. An email was sent to the entire undergraduate student body with an invitation to complete the survey. Approximately 240 students who had taken PLTW classes in high school responded. The data were analyzed using both Microsoft Excel for basic explanatory statistics, and T-tests were performed using SPSS to examine differences in the Likert-type responses between various subgroups of respondents.

The open responses were also analyzed qualitatively. The responses were first open-coded to capture the breadth of the responses, and these were then reduced to a final set of codes that the researchers felt captured the important aspects of the responses[15].

It is important to recognize that this was a self-selected sample of students who chose to complete the survey, and not a constructed sample. Because of this limitation, these results provide a useful picture of the demographics and experiences of PLTW alumni at Purdue University but no attempt should be made to extrapolate these results to the entire student body and their experiences with PLTW or to other universities. The work is exploratory in nature, but is still informative.

Results

Table 1 shows the gender of the survey respondents. The percentage of female respondents is somewhat higher than the percentage of female participants reported by PLTW, which is approximately 18%[6]. This is consistent with the fact that women are more likely to respond to volunteer surveys[16]. Table 2 shows the race reported by survey respondents along with the demographic composition of the entire undergraduate population, the undergraduate engineering population, and the undergraduate technology population. Students are represented in the study similar to their representation in the larger populations, and discrepancies may be due to the lack of foreign students in the study (approximately 6% of Purdue's undergraduate population). No statistics are readily available regarding racial/ethnic representation in PLTW participation.

Table 3 shows the class year of the survey respondents. Almost half of the respondents were freshmen, 30% were sophomores, 13% were juniors, and 8% were seniors. The large number of freshmen responses could be due to the recent rapid growth of PLTW[6], decreased interest or memory of high school experiences by older students, or possibly lack of persistence of PLTW alumni.

Table 1: Gender of survey respondents (n=239) and other populations at Purdue

Gender	Study	All Undergraduates	All Engineering Undergraduates	All Technology Undergraduates
Male	74%	58%	79%	89%
Female	26%	42%	21%	11%

Table 2: Race of survey respondents (n=241) and other populations at Purdue

Race or Ethnicity	Study	All Undergraduates	All Engineering Undergraduates	All Technology Undergraduates
White/Caucasian	89%	85%	79%	83%
African American	2%	3%	3%	7%
Hispanic	3%	2%	2%	3%
Asian	4%	3%	8%	4%

Table 3: Class year of survey respondents (n=243)

Class year	Count	Percentage
Freshman	119	49%
Sophomore	74	30%
Junior	31	13%
Senior	19	8%

Table 4 shows the participation of the participants in various advanced study opportunities available in high school. The vast majority of respondents participated in one or more of these opportunities, indicating that the sample is composed of students that were highly academically motivated in high school. This could also simply be indicative of the competitiveness of the admissions process at Purdue University.

Table 4: Advanced study in high school reported by survey respondents

Advanced Study Opportunity	Count	Percentage
AP Courses	173	71%
Academic Honors diploma.	167	69%
College courses for dual credit.	52	21%
Other	14	6%
None	18	7%

Tables 5, 6, and 7 show the respondents' affiliations with the various colleges and schools at Purdue University. Over half of the respondents are students in the College of Engineering, with students in the Colleges of Engineering and Technology making up almost 80% of the sample. Within the College of Engineering, PLTW alumni are represented among all of the schools of engineering at Purdue University, with Mechanical Engineering, Electrical and Computer Engineering, Civil Engineering, and Aeronautics and Astronautics as the most common majors. Within the College of Technology, Mechanical Engineering Technology, Electrical and Computer Engineering Technology, and Computer Graphics Technology are the most popular choices of major. This could be indicative of PLTW influencing the respondents' choices of major, as the most popular majors align closely with the PLTW curriculum.

Table 5: College of survey respondents

College	Count	Percentage
Engineering	129	53%
Technology	64	26%
Agriculture	12	5%
Consumer and Family Sciences	3	1%
Education	3	1%
Liberal Arts	7	3%
Science	16	7%
Pharmacy, Nursing and Health Services	5	2%
Veterinary Medicine	0	0%
Management	4	2%
Total	243	100%

Table 6: School of engineering reported by respondents in the College of Engineering

School of Engineering	Count	Percentage
Aeronautics and Astronautics	19	13%
Agricultural and Biological	4	3%
Biomedical	4	3%
Chemical	9	6%
Civil	21	14%
Construction and Engineering Management	2	1%
Electrical and Computer	26	17%
Engineering Education	2	1%
Industrial	6	4%
Materials	1	1%
Mechanical	38	25%
Nuclear	1	1%
Undecided	17	11%
Total	150	100%

Table 7: School of technology reported by respondents in the College of Technology

School of Technology	Count	Percentage
Aviation Technology	7	10%
Building and Construction Management	8	12%
Computer Graphics Technology	11	16%
Computer Information Technology	4	6%
Electrical and Computer Engineering Technology	11	16%
Industrial Technology	3	4%
Mechanical Engineering Technology	18	26%
Manufacturing Engineering Technology	3	4%
Organizational Leadership and Supervision	1	1%
Undecided	3	4%
Total	69	100%

Table 8 shows the mean value of the responses to the six Likert-type questions among various subgroups of survey respondents. Multiple t-tests were used to measure significant differences in the responses between the groups. Statistically significant differences ($p<.01$) are indicated in bold. In general, most of the respondents indicated that they had positive experiences with PLTW. The table shows minimal differences between male and female responses, with female respondents indicating that PLTW classes challenged them to do their best slightly more than male participants. The table also shows no statistically significant differences between students in the College of Engineering and the College of Technology.

Table 8: Mean scores of the responses of various subgroups and t-tests to compare responses of pairs of subgroups

	Gender		College		College		Number of PLTW Classes	
	Male (n=160)	Female (n=51)	Eng (n=115)	Tech (n=59)	Eng & Tech (n=174)	Other (n=41)	2 or more (n=150)	1 (n=65)
I was better prepared for college because I participated in PLTW.	2.16	2.16	2.10	1.95	**2.05**	**2.71**	**1.95**	**2.65**
I looked forward to my PLTW classes.	1.52	1.52	1.56	1.42	1.51	1.57	**1.39**	**1.71**
PLTW challenged me to do my best	**2.06**	**1.69**	2.06	1.90	2.01	1.85	1.91	2.03
PLTW gave me an appreciation for technology and engineering.	1.75	1.72	1.77	1.58	1.71	1.95	**1.59**	**1.97**
PLTW influenced my choice of major at Purdue.	2.15	2.04	2.07	1.81	**1.98**	**2.73**	**1.87**	**2.62**
I believe all students would benefit from participating in PLTW.	2.13	1.86	2.10	1.88	2.02	2.24	**1.88**	**2.38**

Bold =difference between pairs significant at $p<.01$ 1=Strongly Agree 2=Agree 3=Neither Agree nor Disagree 4=Disagree 5=Strongly Disagree

Table 9 shows the results of the qualitative analysis of students' open responses. The most common response was that the PLTW classes were "fun" or enjoyable, which is consistent with most of the respondents indicating that they looked forward to their PLTW classes as shown in Table 8. The respondents also indicated that PLTW helped to prepare them for college, influenced their decision to major in engineering, or helped them learn to think like an engineer. Another common theme was students' experiences with their PLTW teachers, both positive and negative. Numerous respondents felt that their teachers were very knowledgeable and had a strong positive influence, while similar numbers reported that their teachers were unprepared or did not seem to understand the material. Several respondents also described learning specific technologies, generally CAD software, that was helpful to them in their undergraduate studies. A common complaint was the lack of course credit at Purdue University for their PLTW coursework. Although numerous institutions do have agreements with PLTW to grant college course credit, Purdue is not one of them and this may not have been clear to the respondents. A final theme revealed in the analysis of the open responses were respondents feeling that PLTW better prepares students for technology programs than engineering programs. Although Table 8 does show that students in the College of Technology responded slightly more positively than students in the College of Engineering, these differences were not statistically significant.

Table 9: Qualitative codes and frequencies of open responses (n=92)

Code	Description	Frequency
FUN	Described PLTW as fun or enjoyable	29
EMD	Engineering Major Decision-ascribed decision to major or not major in engineering to PLTW experience	19
PREP	Felt better prepared for university studies as a result of PLTW	19
LST	Learned Specific Technology-mentioned learning a particular software package or technology that proved useful	8
NCC	No Course Credit-expressed frustration at expecting university credit for work with PLTW but had no way of getting it at this university	8
GT	Good teaching-teacher was very knowledgeable or had a large positive influence	7
PT	Poor teaching-teacher was not knowledgeable or prepared	6
EDT	Engineering Design Thinking-specific mentions of learning engineering design or how to think like an engineer	5
LE	Left engineering	4
TNE	Technology Not Engineering: PLTW better prepares students for technology programs than engineering	3

Conclusions

The students sampled in this survey generally felt that their experiences with PLTW were positive and did a good job preparing them for undergraduate studies in engineering and engineering technology. While not necessarily representative of all PLTW alumni at Purdue University, the respondents of this survey were mostly Caucasian, majority male, and generally participated in advanced study opportunities in their high schools. Respondents who took two or more PLTW classes responded more positively about their experiences than respondents who had taken only one PLTW class. This suggests that more research is needed to understand why

students leave PLTW, and if PLTW experiences both encourage and dissuade students from further study in STEM fields.

Frustration or lack of understanding about receiving college credit was one of the themes that emerged in the qualitative analysis, and echoes similar misconceptions of parents described by Werner[10]. This suggests that there is a need for greater transparency in the PLTW credit granting process, and more effort needs to be put into educating students, parents, and school personnel on this matter.

This study represents the beginning of a larger research agenda to explore the effects of PLTW on university students. Future work will combine the results of this survey with transcript analyses of the participants to look for patterns in university achievement related to PLTW experiences and perceptions. We will also administer a redesigned survey to examine if the responses have changed over time, and look at ways of constructing a sample representative of the entire undergraduate community to make these results more generalizable. Based on the results of this survey, we will include additional questions on perceived quality of PLTW teaching, receiving college credit for PLTW courses, clarification of why the classes were "fun" and what that means to the participants, and how PLTW classes influenced the decision to major in a STEM field. As the numbers of students with K-12 engineering experience continue to increase, the importance of understanding the effects of these programs on university students will continue to grow.

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