2006-1528: PREPARING TOMORROW'S ENGINEERS AND ENGINEERING TECHNOLOGISTS: AN EVALUATION OF THE PROJECT LEAD THE WAY OUTREACH PROGRAM FOR MIDDLE AND HIGH SCHOOL STUDENTS IN INDIANA

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Preparing Tomorrow's Engineers and Engineering Technologists: An Evaluation of the Project Lead The Way Outreach Program for Middle and High School Students in Indiana

Abstract

Project Lead The Way is a pre-engineering program designed to prepare students for postsecondary engineering and engineering technology courses. PLTW courses utilize project- and problem-based learning strategies that encourage students to apply what they learn to real-life situations. At the middle school level the program is called Gateway to Technology. Gateway to Technology is project-based and designed with all students in mind and addresses national standards in math, science and technology. One of the goals of the middle school curriculum is to increase interest and awareness of female and minority students in technology and related careers. Gateway to Technology also encourages increasing numbers of students to elect the high school program.

Over the past 6 years participation in PLTW in Indiana has risen to over 125 schools with over 14,000 students. The evaluation study sought to understand how PLTW programs are implemented and structured, as a means of identifying ways to increase the effectiveness of the PLTW programs in Indiana and sustaining them in the long term.

PROGRAM DESCRIPTION

Project Lead The Way (PLTW) is a national program in partnership with public schools, institutions of higher education and the private sector to increase the quantity and quality of engineers and engineering technologists graduating from the education system. It seeks dynamic collaborations with schools to prepare an increasing and more diverse group of students to be successful in engineering and engineering technology programs by providing them with an innovative and relevant high school pre-engineering curriculum; interactive, project-based middle school technology curriculum; comprehensive teacher training program; and continuous improvement in both curriculum and training. Quality assurance is maintained through systematic program evaluation, leadership and support to PLTW schools and students on the national and state/regional level[1].

Project Lead the Way introduces students to the scope, rigor and discipline of engineering and engineering technology prior to entering college. The goal of Project Lead the Way is to increase the number and quality of engineers and engineering technologists by providing a fully developed curriculum for high schools and extensive training for teachers and school counselors. The program not only attracts more students to engineering but it also allows them to determine if engineering is the career they desire. It is expected that students participating in the PLTW curriculum are better prepared for college engineering programs and more likely to be successful, thereby reducing the attrition rate in these college programs.

The high school Project Lead The Way program is a pre-engineering program taken in conjunction with college-preparatory level academics designed to prepare students for postsecondary engineering and engineering technology courses. PLTW courses utilize project-

and problem-based learning strategies that encourage students to apply what they learn to real-life situations providing students with opportunities.

Apart from a fully developed curriculum for high schools, PLTW also offers a Middle School Technology Curriculum - Gateway to Technology. This project based, cutting edge curriculum lasts 40 weeks and is designed to show students how technology is used in engineering to solve everyday problems. One of the goals is to increase interest and awareness of female and minority students in technology and related careers. It will also encourage students to enroll into the high school program.

Teacher preparation is an essential component of any new instructional program. With this in mind, PLTW has developed comprehensive and intensive training programs to prepare teachers to use the cutting-edge technology that is an integral part of the curriculum. This training is facilitated by a pre-assessment, Summer Training Institute. Ongoing training supports the teachers as they implement the program and provides for continuous improvement of skills. School counselors are also vital to the success of any pre-engineering program. PLTW informs counselors of the various benefits of the program and the various careers available in the field.

Over the past 6 years participation in PLTW in Indiana has risen to over 135 schools with over 14,000 students. The evaluation study seeks to understand how PLTW programs are implemented and structured, as a means of identifying ways to increase the effectiveness of the PLTW programs in Indiana and sustaining them in the long term. The program attracts more students to engineering and at the same time allowing them to determine if engineering is the career they desire. It is expected that students participating in PLTW courses are better prepared for college engineering programs and more likely to be successful, thus reducing the attrition rate in these college programs, which currently exceeds 50% nationally.

EVALUATION OF PROJECT LEAD THE WAY

Although an organization has been contracted to conduct the evaluation of PLTW at a national level, the focus and evaluation methodologies used will not adequately address the individual state evaluation needs and questions. Over the past 6 years participation in PLTW in Indiana has risen to over 125 schools with over 14,000 students.

Purpose of the Evaluation

The overall purpose of the evaluation is to determine the effectiveness of the program in terms of meeting its stated goals and objectives in the State of Indiana. The evaluation study seeks to understand how PLTW programs are implemented and structured, as a means of identifying ways to increase the effectiveness of the PLTW programs in Indiana and sustaining them in the long term. The evaluation will assess the effectiveness of the program based on the assessment of objective data, an established set of performance indicators, and scientifically-based research on helping students meet PLTW's high academic achievement standards. Upon completion of the evaluation project administrators will be able to use metrics an evaluation findings for continuous improvement of the project within Indiana and for broader dissemination of promising practices, and for the general information of the public.

Short and long terms goals of the evaluation include:

1. Understanding how PLTW programs are implemented and structured, as a means of identifying ways to increase the effectiveness of the PLTW programs in Indiana and sustaining them in the long term (formative evaluation).
2. Identifying ongoing assessment of PLTW programs' progress towards pre-established goals and objectives (performance measurement); and
3. Determining the impact of PLTW programs on academic achievement in general and achievement in mathematic in particular (summative evaluation).
4. Determining impact of PLTW programs on school and post-secondary success.

Evaluation Design

The basic evaluation design is an Outcomes-based evaluation (OBE). Outcomes-based evaluation focuses on the measurement of results or impact[2]. It identifies observations that demonstrate the impact the program has had on the participants. Data about the identified performance indicators is systematically collected and used to show the extent to which a program has achieved its goals. Outcomes based evaluation allows program administrator to become more accountable thereby increasing their likelihood of retaining or increase funding, develop and justify budgets. OBE allows administrators to focus attention on programmatic issues and garner support for innovative efforts. Positive outcomes allow the program to gain favorable public recognition in so doing attract new participants. Through OBE administrators are able to increase the program's internal efficiency by tracking its inputs and output and target effective services for expansion and prepare long-range plans. OBE is an effective way of demonstrating the program for replication[3].

Evaluation Questions

The evaluation seeks to answer the following questions:

1. What is the level of participation in PLTW at the high school level?
2. What is the level of participation at the middle school level?
3. What is the distribution of PLTW students in terms of gender, race/ethnicity, school type and geographic location?
4. What courses are being offered at the middle and high school levels?
5. Does participation in PLTW have an impact achievement in general and math in particular?
6. What courses do PLTW students enroll in college?
7. What impact does PLTW have on college success?
8. What impact does PLTW have on school success?

Formative Evaluation Plan

The formative evaluation will involve the assessing the extent to which the PLTW has been successful in meeting its originally stated objectives. This stage if the evaluation will be mainly descriptive.

Performance Indicators

The Project will undergo a formal assessment from October 2005 to September 2006. The main performance indicators are the following:

1. **Program Diversity**
    a. How are PLTW students distributed in terms of gender, race/ethnicity, school type and geographic location?
2. **Teacher involvement.**
    a. How many teachers are active in PLTW?
3. **Academic achievement.**
    a. What are the math scores and grades for PLTW students compared to non-PLTW students?
    b. What are the high school graduation rates?
    c. What the ISTEP scores for PLTW students?
    d. What is the grade point average for PLTW students
4. **Post-Secondary Education**
    a. What is the enrollment rate for PLTW students in post-secondary education
    b. How many dual-credits do PLTW students have upon enrolment into 2 or 4 year post secondary institutions?
    c. What degree programs are PLTW students enrolled in?
        – Engineering,
        – Engineering Technology, and
        – Other courses?
    d. What are the retention and persistence rates for PLTW students in chosen majors?
    e. What are the graduation rates from 2/4 year colleges for PLTW students?
5. **Middle-School**
    a. How many middle schools are involved with PLTW?
    b. How many middle school students are participating in PLTW?
    c. What subjects are being offered at this level?

Table 1: Performance Indicators and Assessment Strategies

Performance Indicator	**Metric**	**Assessment Strategy**
Statewide participation in PLTW	Number of students taking 3 or more PLTW courses number of students: - entering PLTW courses; - completing PLTW courses;	School data/DWD/IDOE data
Teacher participation	Number of teachers participating in PLTW	School Data Teacher Survey
Program diversity	Number/Percentage of female students Number/percent ethnic minorities	Disaggregation of enrollment figures DWD/IDOE databases
Academic achievement	ISTEP scores Grade point average Dual Credits High school graduation rates	School data/DWD/IDOE data

Developmental assets and interests	Attitudes toward school and engineering programs	Student Interest Inventory Survey
Transition into post-secondary further education	Percentages of PLTW high school graduates enrolling in 2/4 year college	
PLTW students enrolled in engineering or engineering-related course.	Number of students enrolled in Engineering, and Engineering Technology	
Retention	Percentage of students continuing 2nd year in college	
Persistence in major	Number of students continuing in the same major after 1st year in college	
College success	Graduation rates	
Middle school participation	Number of schools in PLTW Number students in PLTW Courses being offered at this level	School data

Summative Evaluation Plan

During the second phase of the evaluation, a summative evaluation will be conducted. The summative evaluation will involve the assessment of the project outcomes based on identified performance indicators using both qualitative and quantitative measures. A quasi-experimental design will be used to assess PTWL effectiveness and impact on the school curriculum. Other questions and/or factors that are of interest to program administrators will also be included.

Description of Stakeholders

The stakeholders for the PLTW Indiana program are PLTW national and state offices, technology teachers in particular the PLTW teachers, PLTW students, and the Indiana Department of Education.

PRELIMINARY FINDINGS

Participation in PLTW in Indiana

One hundred and thirty-five schools and other educational establishments were participating in PLTW by the early 2006, with the majority of schools initiating the program the same year (see Table 3). The majority of the schools, 64.2% were high schools. Other education establishments include area career centers, community colleges and universities offering PLTW on their campuses. Table 2 below shows the distribution of PLTW in educational institutions in Indiana.

Table 2: Distribution of PLTW in Indiana

	Frequency	Percent
High School	86	63.7
Middle School	31	23

Junior High School	9	6.7
Other	9	6.7
Total	135	100.0

The number of schools participating in project lead the way has been steadily rising since 2000 when PLTW was first introduced in Indiana.

Table 3: Year PLTW Initiated

Year Initiated	Frequency	Percent
2000	6	4.4
2001	18	13.3
2002	17	12.6
2003	20	14.8
2004	27	20.0
2005	41	30.4
2006	3	2.2
Not listed	3	2.2
Total	135	100.0

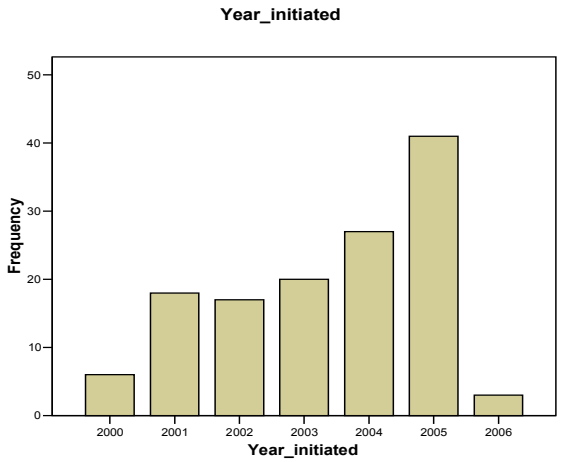

Figure 1: Year PLTW Initiated

Gender Diversity

A stated objective of PLTW is to increase the participation of girls in PLTW engineering and engineering technology programs. Table 4 shows the proportion of male and female students participating in PLTW courses. 37% of students participating in PLTW are female with the most equitable distribution being in middle school where 47% of the students are female.

Table 4: Proportion of male to Female Students in PLTW Programs

	Male	**Female**	**Total**
Introduction to Engineering Design (IED)	2437	361	2798
Principles of Engineering	687	69	756

(POE)			
Computer Integrated Manufacturing (CIM)	101	10	111
Civil Engineering & Architecture (CEA)	120	12	132
Engineering Design & Development (EDD)	62	5	67
Digital Electronics (DE)	842	8	850
Aerospace	28	2	30
Biotechnology	12	8	20
Gateway to Technology (Middle School)	2155	1902	4057
Total Enrollment	**6444**	**2377**	**8821**

Intended Course Outcomes Contents and Activities

The PLTW curricula have a strong emphasis on math and science and are designed to compliment existing curriculum within the classroom. All courses meet national and state math, science, and technology standards. PLTW courses use project-based learning. While taking PLTW students can earn up to six college credits.

Middle School Curriculum

The purpose of the middle school curriculum (Gateway to Technology) is to expose students to a broad overview of the field of technology and its related processes. The curriculum was designed to be "activity oriented" incorporating four units, each designed to be taught in a period of ten weeks. Each unit is an independent unit, developed specifically for the student's age and comprehension level. It is recommended that they be taught in the following order:

- Design and Modeling
- The Magic of Electrons
- The Science of Technology
- Automation and Robotics

High School Curriculum

This Pre-Engineering Curriculum is a four year sequence of courses which, when combined with traditional mathematics and science courses in high school, introduces students to the scope, rigor and discipline of engineering prior to entering college. However, those not intending to pursue further formal education will benefit greatly from the knowledge and logical thought processes that result from taking some or all of the courses provided in the curriculum. PLTW's flexible course sequences and our introduction of new courses recognize the importance of recruiting and retaining all students in our program, students' math and science sequences, and their career goals by dividing our courses into three groups: Foundation, Specialization, and Capstone.

Foundation Courses:

Introduction to Engineering Design – Students are introduced to problem-solving using design development processes. Models of product solutions are created, analyzed, and communicated using solid modeling computer design software.

Digital Electronics – Applied logic is the main focus of the course including the application of electronic circuits and devices. Computer simulation software are used to design and test digital circuitry prior to the actual construction of circuits and devices.

Principles of Engineering – Students gain an understanding of the field of engineering and engineering technology through the exploration of various technology systems and manufacturing processes. Students learn to apply math, science and technology in engineering problem solving processes. The course also addresses social and political consequences of technological change.

Specialization Courses:

Computer Integrated Manufacturing –applies principles of robotics and automation. The course builds on computer solid modeling skills developed in Introduction to Engineering Design, and Design and Drawing for Production. Students use CNC equipment to produce actual models of their three-dimensional designs. Fundamental concepts of robotics used in automated manufacturing, and design analysis are included. Other specialization courses include Civil Engineering and Architecture, Biotechnical Engineering, and Aerospace Engineering.

Capstone Course:

Engineering Design And Development Students work in teams to research, design and construct solutions to engineering problems. Students apply principles developed in the four preceding courses. Students present progress reports, submit a final written report and defend their solutions to a panel of outside reviewers at the end of the school year.

Table 5 shows the distribution of courses in Indiana schools. Indiana's Project Lead the Way (PLTW) program began with the following course sequence:

1. Introduction to Engineering Design (IED)
2. Digital Electronics (DE)
3. Principles of Engineering (POE)
4. Computer Integrated Manufacturing (CIM)
5. Engineering Design and Development (EDD)

IED, POE, and CIM were placed under the Technology Education umbrella while the remaining two courses, DE and EDD, were listed as part of the multidisciplinary course offerings. PLTW Indiana has succeeded in introducing all PLTW courses. The most commonly offered course in Indiana schools is Civil Engineering and Architecture.

Table 5: Distribution of Course in PLTW schools

Course	Number of School

Introduction to Engineering Design (IED)	60
Principles of Engineering (POE)	37
Computer Integrated Manufacturing (CIM)	9
Civil Engineering & Architecture (CEA)	120
Engineering Design & Development (EDD)	62
Digital Electronics (DE)	26
Aerospace Engineering	1
Biotechnology Engineering	1
Gateway to Technology (Middle School)	27

Outcomes Developmental and Academic Achievement

Students participating in PLTW have demonstrated high academic achievement. In the following PLTW courses student have received an average score of 91.3% (S.D. 6.64).

Table 6: Means of Student Scores in IED, POE and DE

	Number	**S.D.**
IED	153	6.92
POE	13	3.52
DE	10	4.25
Total	176	6.64

Another objective of PLTW is that PLTW students will meet college entrance requirements for engineering and engineering technology. At the end of the year students take college level examinations through the Rochester Institute of Technology. While students' scores are lower than their class grades, they were still impressively high. The average score was 82.5% (S.D.=7.25).

Table 7: RIT Examination Scores Means

PLTW Course	**Number of Students**	**RIT Exam Score (%)**	**S.D.**
IED	154	82.92	7.20
POE	13	86.65	6.56
DE	10	78.50	4.25
Total	177	82.94	7.25

Grades students earned in their PLTW courses correlated positively ($\rho = .51$) with scores on the RIT exam. PLTW are good indicators of success in college.

Table 8: Correlation of PLWT Course grades with RIT Examination

	RIT grade
PLTW course grade	.509**
N	176

**Correlation is significant at the 0.01 level (2-tailed).

Post-Secondary Outcomes

To ensure successful transition to post-secondary, PLTW has made articulation agreements with a number of colleges and universities in Indiana. The following is a list of course that have been approved for college credit at three institutions of higher education in Indiana.

Table 9: PLTW courses approved for College credit in Indiana

- PLTW Biotechnical Engineering
- PLTW Aerospace Engineering
- PLTW Civil Engineering & Architecture
- PLTW Introduction to Engineering Design
- PLTW Digital Electronics
- PLTW Principles of Engineering
- PLTW Computer Integrated Manufacturing

Students successfully completing the entire PLTW curriculum are offered 12 credit hours at the state community college level. 100% of the credit hours apply to the CIM associate of Applied Science degree, which requires 64 total credits. Following the completion of their PLTW career major program, students may choose from many national program options, or continue at the community college, complete their associate degree, 58 credits transfer toward a bachelor's degree.

Other articulation agreements are still in negation phases. Most institutions of higher education in Indiana are already available to accept PLTW credit for college credit on a case by case basis.

CONCLUSION

While these findings are still very preliminary and the evaluation is ongoing, these are observable and measurable "milestones" toward meeting the program goals and objectives. These outcomes suggest that the program is making significant progress toward the program goals.

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