

Articulation Agreements With High Schools Implementing Project Lead The Way (PLTW)

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Background:

Recently, the American Society for Engineering Education (ASEE) has embarked on an ambitious effort to promote and improve K-12 engineering and engineering technology education. Since 2003, the ASEE has created a new K-12 division dedicated to K-12 engineering education, created a guidebook for high school students called *Engineering, Go for It!* that was distributed to almost 350,000 secondary students, created an e-newsletter that reaches 10,000 secondary teachers, guidance counselors, and outreach program leaders, and created a survey to understand what secondary teachers think of engineering as an academic and career pathway for their students. Finally, ASEE brought together leaders from industry and higher education along with K-12 teachers for a Leadership Workshop on K-12 Engineering Outreach, held just before the ASEE 2004 Annual Conference and Exposition in Salt Lake City, Utah. A recent paper detailing the results of that conference and delineating guidelines for how K-12 engineering education works best and defines key challenges confronting the field was recently published. (1)

Clearly, there is a movement by the engineering and engineering technology communities to gain a better understanding of the K-12 issues that impact enrollment at post-secondary institutions, and to generate research to answer the question of how stakeholders from many levels – K-12 teachers, university professors, industry, and government representatives – can advance the state of engineering and engineering technology education. Coupled with the information from the aforementioned surveys, the ideas and suggestions from conference attendees and current research in the field of K-12 education, Dougless, Iversen and Kalyandurg (2004) have developed a set of six guidelines for improving K-12 engineering education and outreach:

1. *Hands-on learning:* Make K-12 science curriculum less theory-based and more context-based, emphasizing the social good of engineering and demonstrating how it is relevant to the real world
2. *Interdisciplinary approach:* Add a technological component to all subjects and lessons, and implement writing guidelines in math and science courses
3. *Standards:* Involve engineering in K-12 lessons that map to state standards for math and science. Further, states should follow Massachusetts and enact state standards for engineering
4. *Use/Improve K-12 Teachers:* Engage more K-12 teachers in outreach efforts and curriculum writing, and increase teacher salaries to attract the best technological minds to teaching

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5. *Make Engineers “Cool”*: Outreach to urban schools and females more aggressively, and create more mentors and role models to attract these constituencies
6. *Partnerships*: Create better incentives for all groups to engage in K-12 outreach (especially higher education and industry)

According to Dougless, Iverson and Kaylendurg (2004) there is no magical list of recommendations to promote and enhance engineering education in the K-12 world, but these six guidelines emerge from current outreach efforts and seek to move them a step further, offering a broader base for improving the quality, methodology, and reach of K-12 engineering education (1).

One program that seems related to nearly all of the aforementioned recommendations is Project Lead the Way (PLTW). PLTW is a high school curriculum in which students are introduced to engineering and engineering technology through a series of rigorous academic courses. Curriculum, textbooks, software and labs are standardized throughout the experience regardless of geographic location, and all PLTW teachers undergo extensive training in curriculum, pedagogy and delivery of the program. Project Lead the Way is a hands-on, contextual curriculum that uses an interdisciplinary approach and is based on national, state and local Science, Technology, Engineering and Math standards.

This paper will provide a brief description of Project Lead The Way initiative, the curriculum and courses offered in Project Lead The Way, discuss the Indiana Model for implementation of PLTW, requirements of successful secondary and post-secondary course articulation agreements and program replication considerations for Schools of Engineering and Technology interested in outreach.

Project Lead The Way: History, Values, Strategic Plan, Curriculum, and Training

According to the official website, Project Lead The Way Inc. (PLTW) is a national program forming partnerships among Public Schools, Higher Education Institutions and the Private Sector to increase the quantity and quality of engineers and engineering technologists graduating from the education system. First developed in the 1980's by Richard Blais who was then chairman of the Technology Department of an upstate New York school district, PLTW is now offered in over 42 states and the District of Columbia. (2)

Blais and members of the Technology Department were supported by a Technology Advisory Board that he established in order to gain the expertise of people in industry and to garner support for the changes that were to be implemented in the curriculum.

Over the first three years, it became apparent that the high school program was attracting an increasing number of students, many who would not have enrolled in any technology course until college. One of the members of the Advisory Board was an individual whose family formed the Charitable Venture Foundation. Through a grant from the Foundation and through ongoing funding, Project Lead The Way became a national program and

increased its rigorous, challenging, contextual, hands-on courses. Early on, PLTW became partners with the High Schools That Work initiative of the Southern Regional Educational Board (SREB) with schools in 30 states, and with Rochester Institute of Technology, its first national training center. Today, Project Lead The Way is the nation's leading pre-engineering middle school and high school program.

A comprehensive organizational structure has been created by PLTW to ensure continued participation and success. Key elements promote support at every level of the program. PLTW provides local, state and national organization for leadership and support, a model curriculum, teacher training and development through its affiliation with some of the nation's leading colleges and universities, and a network of consultants throughout the country. (2)

Project Lead the Way lists as its core values:

- Committing to diversity promotes opportunities for individuals, enhances creativity and strengthens organizations.
- Individuals and teams working in a culture of collaboration toward clear and common goals achieve greater satisfaction and superior results.
- The passionate and unwavering pursuit of continuous improvement is essential to high levels of achievement.
- All people are capable of achieving at higher levels and deserve the opportunity to achieve their full potential.
- All people have something to contribute.
- It is essential to know, listen to, and be responsive to our customers.
- Anticipating and managing change is critical to success.
- Learning is a lifelong process.
- Honesty, integrity and the highest ethical standards are essential attributes of an effective organization.

As with any quality, non-profit organization, Project Lead The Way has developed a comprehensive strategic plan in an effort to further its mission and vision.

- By the end of the second year of membership in PLTW each school will have an effective school partnership team.
- By 2005, 100% of PLTW students will meet college entrance requirements for engineering and engineering technology; of those students, at least 90% will successfully complete their first year of further study and at least 75 % will graduate from two or four year engineering and engineering technology programs.
- By 2005, the enrollment of females in PLTW courses will be 10 percentage points higher than the current female national enrollment in engineering and engineering technology programs.
- By 2005, the racial and ethnic minority student population in schools with PLTW courses will be collectively proportionate to the overall state population.

- By 2006, we will have at least 1000 schools in PLTW and additional, geographically located, university affiliates throughout the country.
- By 2006, we will increase by 20% the number of graduates from high school in PLTW who are accepted in engineering and engineering technology programs. (2)

Project Lead The Way has developed a comprehensive middle school and high school curriculum. For purposes of this research, the high school curriculum will be listed and described. The High School Program 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. The foundation courses consist of 1) Principles Of Engineering, 2) Introduction to Engineering Design, and 3) Digital Electronics. Specialization courses include, 1) Computer Integrated Manufacturing, 2) Biotechnical Engineering, 3) Civil Engineering and 4) Architectural, Aerospace Engineering. Finally, students complete the Capstone course titled Engineering Design and Development. Additionally, there are two new courses currently in the development stage, 1) Aerospace Engineering, and 2) Bio-Technical Engineering.

A description of each course follows:

- Principles of Engineering - A course that helps students understand the field of engineering/engineering technology. Exploring various technology systems and manufacturing processes help students learn how engineers and technicians use math, science and technology in an engineering problem solving process to benefit people. The course also includes concerns about social and political consequences of technological change.
- Digital Electronics - A course in applied logic that encompasses the application of electronic circuits and devices. Computer simulation software is used to design and test digital circuitry prior to the actual construction of circuits and devices.
- Introduction to Engineering Design - A course that teaches problem-solving skills using a design development process. Models of product solutions are created, analyzed and communicated using solid modeling computer design software. In NYS, the course is called Design and Drawing for Production and follows the syllabus developed by the State Education Department.
- Computer Integrated Manufacturing - A course that 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.
- Civil Engineering and Architecture - This course provides an overview of the fields of Civil Engineering and Architecture, while emphasizing the interrelationship and dependence of both fields on each other. Students use

state of the art software to solve real world problems and communicate solutions to hands-on projects and activities. This course covers topics such as: The Roles of Civil Engineers and Architects, Project Planning, Site Planning, Building Design, Project Documentation and Presentation

- Engineering Design and Development - An engineering research course in which students work in teams to research, design and construct a solution to an open-ended engineering problem. Students apply principles developed in the four preceding courses and are guided by a community mentor. They must 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.
- Aerospace Engineering - The Aerospace Engineering curriculum will be a systemic curriculum package that will introduce students to the world of aeronautics, flight, and engineering.
- Biotechnical Engineering - Biotechnical Engineering will be one of the specialty courses in the PLTW pre-engineering curriculum, which applies and concurrently develops secondary level knowledge and skills in biology, physics, technology, and mathematics. It includes experiences from the diverse fields of Bio-technology, Bio-engineering, Bio-medical engineering, and Bio-molecular engineering. (2)

According to Horn (1998), high school students who take a rigorous high school curriculum that has been specifically mapped during a consultation with high school counselors, parents/guardians and the high school student are much more likely to navigate the “pipeline” to college. Academic preparation is crucial to this matriculation and if a student, especially an underrepresented, at risk student, has not taken courses to prepare for university level work, the odds are striking that he/she will not be admitted into a four year program. (3) A clear pathway to university degree programs should begin during high school, and Project Lead The Way has developed a sample student schedule that helps high school students envision the four year course of study that they might take during their high school years (see table 1).

High school teachers in the PLTW program begin their training by completing an online assessment of skills self-test and questionnaire. The purpose of this assessment process is to assure that all teachers arrive for the summer institute training ready to prepare for their September teaching assignment. They then participate in a 2-week summer institute, where they are trained in the curriculum to be used in their PLTW course. These courses are two weeks, full time classes with homework, projects and exams. The courses are typically offered at a University within the teacher’s home state, and in some cases, can be taken for college credit. Each teacher must complete this course prior to starting a PLTW course. Other courses are offered after the initial training for enrichment. Instructors for these courses are also certified by PLTW, and attend training prior to being certified as an Affiliate Professor.

Sample Student Schedule			
Grade 9		Grade 10	
English 9	1 unit	English 10	1 unit
Social Studies 9	1 unit	Social Studies 10	1 unit
Math 9	1 unit	Math 10	1 unit
Science 9	1 unit	Science 10	1 unit
Foreign Language	1 unit	Foreign Language	1 unit
Principles of Engineering	1 unit	Intro To Engineering Design	1 unit
Physical Education	.5 unit	Physical Education	.5 unit
Grade 11		Grade 12	
English 11	1 unit	English 12	1 unit
Social Studies 11	1 unit	Social Studies 12	1 unit
Math 11	1 unit	Math 12	1 unit
Science 11	1 unit	Science 12	1 unit
Digital Electronics		Engineering Design and Development	1 unit
*Computer Integrated Manufacturing	1 unit	Health	.5 unit
*Civil Engineering and Architecture	1 unit	Physical Education	.5 unit
*Biotechnical Engineering	.5 unit		
*Aerospace Engineering			
Physical Education			

Table 1: Sample Student Schedule: Copyright; 1999 - 2004 Project Lead The Way Inc., Clifton Park NY. All rights reserved. <http://www.pltw.org/hsprogram.shtml> <accessed 12/26/04>

The Indiana Plan: Curriculum, Teacher Licensure, and Funding

The Indiana Department of Workforce Development and the Indiana Department of Education have recently partnered to provide service to the citizens of Indiana in the form of the Career Majors Academies. Indiana school corporations, area vocational schools and post-secondary institutions work together to form Indiana's career and technical education system and Project Lead The Way is an integral part of that system. Students are served through 48 area vocational districts, 353 high schools in 294 school corporations and seven state post-secondary institutions with 51 instructional sites across the state. Thanks to the partnership between education, business, government and labor, Indiana continues to prepare students and workers to compete in a global market place, attend advanced education programs through companies, enroll in post-secondary education, and upgrade their skills on the job.

Since 1997 nearly 800,000 secondary, postsecondary, and adult students have enrolled in technical education programs throughout the state, and more than 19,000 certificates of

technical achievement have been earned through various DWD administered training programs. (4)

For the 2002-03 program year

- 129, 250 students were enrolled in technical education.
- 4,207 certificates of technical achievement were earned.
- \$1.2 million were awarded to innovative youth programs.
- \$2.3 million were awarded to secondary/postsecondary partnerships to improve academic achievement and increase skills for high-wage, high-skill careers. (4)

In addition to the grant dollars awarded to secondary and post secondary partners by the Indiana Department of Workforce Development, the Indiana Department of Education has played a major role in the development of Project Lead The Way suggested curriculum pathways, teacher certification and reimbursement to schools and school corporations for students who complete Project Lead The Way courses. As of December, 2004, over 100 Indiana middle and high schools offered PLTW courses to nearly 14,000 students. (5) This significant number of schools and students enrolled in the Indiana Project Lead the Way programs/courses is due to many factors including the development of Career Pathways for Indiana students, the realignment of teacher licensure programs in both Career and Technical Education and Vocational Education, and the availability of Career Planning Grant dollars for all Indiana school corporations developing Career Pathways around the fourteen Indiana Career Clusters.

Indiana's Project Lead the Way (PLTW) program begins 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 are currently placed under the Technology Education umbrella while the remaining two courses, DE and EDD, are listed as part of the multidisciplinary course offerings. The positioning of courses under specific subject areas affects the certification needed for the teacher instructing the course. However, the Indiana State Board of Education has adopted rules regarding "Non-Standard Course Waivers" that have a provision allowing someone outside the assigned certification area to teach a specific course. Several schools have submitted waivers so that math and science teachers can be instructors for the classes.

In response to questions from schools looking for delivery options, a review of vocational education course titles and descriptions was conducted by the DOE. Based on this

review, the following vocational course titles under the Trade and Industrial Education program area may be used when offering four (4) of the five (5) PLTW courses:

Vocational Course Titles to be Used Under Trade and Industrial Education Program When Offering Project Lead The Way Courses	
1.	Introduction to Engineering Design and Principles of Engineering offered as ENGINEERING using Indiana Department of Education (DOE) Course Code #5644 and Career Information Process (CIP) Code #14.9999. Students' transcripts would have Engineering, 1st year and Engineering, 2nd year (or advanced) listed for the courses taken.
2.	Digital Electronics offered as ELECTRICAL/ELECTRONICS (DOE Course #5642 and CIP Code 47.0101 or 15.0303)
3.	Computer Integrated Manufacturing is expected to be added as a new Trade and Industrial Education course title by the beginning of school year 2003-04. Any school offering this PLTW course in the 2002-03 school year, under the vocational education umbrella, will need to submit a "Non-Standard Course Waiver" and possibly a new vocational program application. (See item #1 under Challenges and Issues to Consider.)

Table 2: Vocational Course Titles to be Used Under Trade and Industrial Education Program When Offering Project Lead The Way Courses

NOTE: No vocational course title corresponds to the PLTW course "Engineering Design and Development" and it is not anticipated that a new course title will be added. Supporting rationale for allowing the PLTW/vocational education option is based on Indiana's textbook adoption practices. Currently, schools have choices from different publishing companies when selecting a textbook for a specific course. When no textbook is adopted by the State Board of Education, local schools can determine what materials are used for instruction. Since textbooks are rarely, if ever, adopted for Trade and Industrial Education courses, use of the PLTW curriculum is acceptable so long as the materials address the description associated with the course title.

Challenges and Issues to Consider	
1.	The School District Agreement executed between the local school corporation and the national Project Lead the Way organization <i>requires</i> that any person assigned to teach PLTW courses will attend the training session(s) and have at least a <u>baccalaureate degree</u> . While this degree does not have to be in education, it would not be acceptable to use someone licensed as an Occupational Specialist if they did not have a four-year degree. For example, someone with a BS in Engineering, who could document the required work experience, could be hired to teach the Engineering course discussed in the previous section. <i>However</i> , someone with years of workplace experience in the electronic engineering technology field who lacked a baccalaureate degree, could not be hired to teach the PLTW Digital Electronics curriculum
2.	<p>The PLTW courses are offered for one credit each semester. When vocational programs are offered in some type of joint arrangement between school districts, the vocational courses are typically two or three hours in length to justify the transportation time and expense. Schools that want to consider joint operation of the PLTW program might explore offering the PLTW course in a block with the corresponding mathematics class. The example listed below (developed based on new student achievement information from the national PLTW organization) explains how this might work.</p> <p>9th Grade - Offer POE blocked with Algebra 1 10th Grade - Offer IED blocked with Geometry 11th Grade - Offer DE blocked with Algebra 2 OR block DE with CIM and have the students take Algebra 2 at their home high school. 12th Grade - Offer EDD at each home school with a supervising teacher and a method of electronic and face-to-face communication among the student/team and the business/industry mentors.</p>
3.	Schools with approved vocational courses can count the student enrollment and receive additional funding that would help to offset costs associated with PLTW. For school year 2002-03, schools are reimbursed for students enrolled in the vocational courses Engineering (CIP Code #14.9999) and Electrical/Electronics (CIP Code # 47.0101 or 15.0303) on the following formula basis: # of students X \$450.

Table 3: Challenges To Consider

Please Note: The newest version of the Assignment Code from the Professional Standards Board lists a Technology Education teacher with secondary emphasis, *who has received the PLTW training*, as an allowable licensing pattern to teach the vocational

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course titles described in this document. If passed, this will give additional flexibility to schools when staffing the PLTW programs.

All PLTW courses can be used to meet the directed elective or elective requirements of the Core 40 and Academic Honors Diploma programs. See Table 4 for a program of study.

PRE-ENGINEERING PROGRAM OF STUDY
Sample Course Sequence for Core 40

<p><u>9th Grade</u></p> <p>English 9 Algebra I Biology Physical Education Fine Arts Elective (Recommended) Principles of Engineering (PLTW) Additional Elective or Resource Period</p>	<p><u>10th Grade</u></p> <p>English 10 Geometry Chemistry Health/Computer Applications Fine Arts Elective (Recommended) Introduction to Engineering Design (PLTW) World Geography <i>(Foreign Language replaces Fine Arts elective for Honors Diploma)</i></p>
<p><u>11th Grade</u></p> <p>English 11 Algebra II Physics US History Foreign Language Elective (Recommended) Digital Electronics (PLTW) Computer Integrated Manufacturing (PLTW)</p>	<p><u>12th Grade</u></p> <p>English 12 Additional Mathematics Elective Additional Science Elective Government/Economics Foreign Language Elective (Recommended) Engineering Design & Development (PLTW) Additional Elective such as an Internship <i>(Pre-Calculus rep. Addl Math Elective for Honors diploma)</i></p>

Table #4: Sample Course Sequence for Core 40

Students interested in completing the Core 40 curriculum have the option (under the Directed Electives section) of taking “at least six credits in a logical sequence from a

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technical career area.” Students who started the PLTW program but did not complete three full classes (six credits) would count the credits earned from these courses simply as electives.

After completing the required courses in each subject area for the Academic Honors Diploma, students may complete the remaining 7 - 9 credits (for a total of 47) by taking courses from any subject area offered by the high school. This includes courses offered at the high school, the area vocational school affiliated with the high school, or a postsecondary institution offering a two or four year degree.

Articulation Agreements

Students completing the PLTW courses have the option of a final exam which can be used to demonstrate mastery of course content. Students passing the course with a sufficient score on this exam are eligible for credit from universities including Rochester Institute Of Technology, Purdue University and Indiana University Purdue University Indianapolis. Students scoring 85% or better plus a 70% or better on the exam receive credit from RIT. Students may receive three college credits in the Department of Industrial Technology at Purdue University by completing an eligible PLTW course with a ‘B’ or better from a PLTW certified school, scoring 70 or above on the college credit exam, and by enrolling in IT, ID, or Technology Education programs. IUPUI is currently establishing agreements with individual schools allowing credit which will count towards the student’s plan of study for PLTW courses. For example, students completing the Digital Electronics course with a ‘B’ or better, scoring a 70% or more on the final and with a ‘B’ or better in Advanced Algebra or higher will receive credit for ECET 109 (Digital Fundamentals) for students seeking degrees in Electrical Engineering Technology, Computer Engineering Technology or Biomedical Engineering Technology. These credits are offered at no cost to the student. Similar agreements are currently being developed for each other PLTW course.

Conclusions:

The Project Lead The Way program is quickly being implemented in middle schools and high schools nationwide, introducing many students to engineering and technology who may not otherwise be exposed to engineering or technology. With requirements for rigorous teacher training, counselor training, school certification, curriculum and required laboratory equipment, this program offers a standard of high quality and consistency. Students and parents have described the program as valuable and challenging, and industrial advisory board members have praised the program during visits.

PLTW and similar programs should increase the pool of students ready, willing and able to enter engineering and technology from high school. Students from the PLTW program who have passed the final exam should be excellent candidates to receive credit through articulation agreements.

Bibliography:

(1) Douglass, Iversen, & Kalyandurg, "Engineering in the K-12 Classroom: An Analysis of Current Practices & Guidelines for the Future," A Production of the ASEE Engineering K-12 Center, November, 2004. <http://www.engineeringk12.org>.

(2) Project Lead the Way, "Core Values, Strategic Objectives, Strategic Action Plan," <http://www.pltw.org>, accessed 12/26/04

(3) Horn, Laura, J., (1998). "Confronting the Odds: Students at Risk and the Pipeline to Higher Education." National Center for Educational Statistics Publication.

(4) Indiana Department of Workforce Development: Programs and Services. <http://www.in.gov/dwd/information/overview.html> <accessed 12/27/04>

(5) Indiana Department of Education: Office of Career and Technical Education Career Clusters. <http://www.doe.state.in.us/octe/facs/CrrClstrGrid.html>. <accessed 12/27/04>

Biography:

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