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ABSTRACT

The Southern Regional Education Board partnered with the not-for-profit organization Project Lead the Way (PLTW) to develop a program connecting challenging academic courses with a pre-engineering program of study. The programs goal is to increase the number and quality of engineers and engineering technologists by providing the following items: (1) a fully developed curriculum for high schools; (2) a middle grades technology program; (3) extensive training for teachers; (4) training for school counselors; (5) access to affordable equipment; and (6) college-level certification and course credit. The program's middle grades component combines challenging academic courses with courses devoted to design and modeling, the "magic" of electrons, the science of technology, and automation and robotics. The high school component consists of a challenging standards-based pre-engineering curriculum that requires students to apply their knowledge and skills in mathematics, science, and technology to solving real-world engineering problems in five hands-on pre-engineering courses. The program's teacher and counselor preparation component includes preassessment, a summer training institute, and ongoing training. The estimated costs of 1 middle grades laboratory with 26 student stations and the high school component for a class of 20 students are estimated at \$54,147 and \$95,508, respectively. Students who have participated in the program have spoken of it very highly. (MN)

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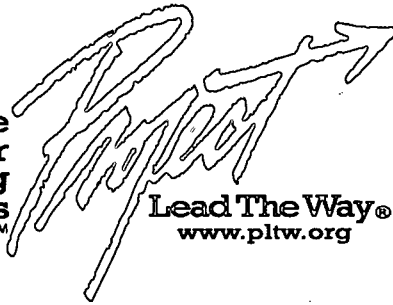


SREB

HSTW Presents a Pre-engineering Program of Study

in partnership with

National Alliance
For
Pre-Engineering
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Lead The Way®
www.pltw.org

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The Southern Regional Education Board's *High Schools That Work* is a national school-improvement initiative. More than 1,100 schools in 26 states are using the *HSTW* framework of goals and key practices to make whole-school changes aimed at raising students' academic, technical and intellectual achievement.

Support for Project Lead The Way is provided by a not-for-profit charitable foundation.

High Schools That Work Presents a Pre-engineering Program of Study

The need for engineers and engineering technologists ---

Engineering is a part of everything around us. Engineers and engineering technologists create the systems that purify our water, protect our environment and monitor our food and drugs. They develop medical instruments and artificial organs that save and improve lives. They design robotic components, space stations, cellular phones and high-speed trains.

The work of engineers and engineering technologists is vital, stimulating, profitable, creative and abundant. U.S. Department of Labor statistics reveal that 20 percent more engineers will be needed by the end of this decade. Many positions in engineering and related technology are vacant because of the lack of qualified candidates. Why? The number of students enrolled in engineering programs hit a 17-year low in 1999, according to the National Society of Professional Engineers. Enrollment in engineering technology programs in 2000 was about half what it was in 1990. The problem is compounded further by the fact that more than half of the students in postsecondary engineering and engineering technology programs drop out or change majors.

The world of technology requires strong mathematics and science skills, plus the abilities to read and write well, to think and reason, and to explain complex concepts. Sadly, too many students lack the rigorous academic background or the reasoning and problem-solving skills to pursue further study or to work in engineering and engineering-related fields. As a result, technical industries suffer, even though the job opportunities, salaries and benefits in these fields are very desirable.

"It is disconcerting to see technical jobs, particularly in manufacturing, migrating out of the country. This phenomenon will ultimately undermine our standard of living in the United States. Project Lead The Way is proving to be a program which addresses the causes of that migration at their base: the motivation of our talented youth and the quality of their education in technology."

Frank D. Zaffino, Senior Vice President (retired)
Worldwide Manufacturing Division
Eastman Kodak

The Southern Regional Education Board recognizes that many opportunities await young people who complete an upgraded academic core and a career/technical concentration. For this reason, SREB's *High Schools That Work* has formed a partnership with Project Lead The Way to connect challenging academic courses with a pre-engineering program of study.

Project Lead The Way Inc. is a not-for-profit organization that works with public schools, the private sector and higher education to increase the quantity and quality of engineers and engineering technologists by providing high school students with engaging pre-engineering studies. The program complements the major goals of the *High Schools That Work* school-improvement design:

- to increase the percentage of high school students who complete college-preparatory studies and perform at the proficient level in reading, mathematics and science; and
- to blend the essential content of traditional college-preparatory studies with challenging career and technical studies.

Increasing opportunities for students ---

Students who are introduced to engineering and engineering technology in the middle grades and high school can decide — prior to college — whether they are interested in engineering-related careers. A challenging academic and pre-engineering program of study equips students to move easily from high school into high-tech jobs, further training at community or technical colleges, or programs of study at four-year colleges. Students who have been well-prepared in high school are less likely to drop out of college programs.

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;
- a middle grades technology curriculum;
- extensive training for teachers;
- training for school counselors;
- access to affordable equipment; and
- college-level certification and course credit.

“Project Lead The Way represents what new high school career/technical programs must become. The pre-engineering curriculum is to high school career/technical studies what Advanced Placement courses are to academic studies. It provides instructional materials for teachers, a professional development program to prepare them to teach and end-of-course exams to determine if students mastered the content.”

James R. (Bob) Couch, Director
Office of Career and Technology Education
South Carolina Department of Education

The middle grades program

Project Lead The Way offers a middle grades curriculum — Gateway to Technology. This project-based, cutting-edge program introduces students in grades six through eight to the broad field of technology. It is “activity-oriented” to show students how technology is used in engineering to solve everyday problems.

Gateway to Technology consists of four independent units that should be taught in conjunction with a rigorous academic curriculum. The units are designed to challenge and engage the exploratory minds of middle grades students. Each 10-week unit contains performance objectives and suggested assessment methods. In sequence, the units are:

- **Design and Modeling** — This unit uses solid modeling (a very sophisticated mathematical technique for representing solid objects) to introduce students to the design process and to show them how this technology has influenced their lives. Using design briefs or abstracts, students create models and documentation to solve problems.
- **The Magic of Electrons** — Students see the wonders of electricity and electronics, design simple circuits and explore the impact of electricity on our lives.
- **The Science of Technology** — This unit traces how science has affected technology throughout history. Students learn about the mechanics of motion, the conversion of energy and the use of science to improve communication.
- **Automation and Robotics** — Students trace the history and development of automation and robotics. They learn about structures, energy transfer and machine automation. They also find out what they need to study in high school and beyond to prepare for careers in engineering.

Each school district decides how to schedule these units into the curriculum. Schools are encouraged to offer the first unit to sixth-graders, but they may decide to teach all four units in the eighth grade. For maximum impact on student achievement, the Gateway to Technology curriculum should be combined with a challenging academic curriculum in which:

- students complete Algebra I successfully or pass a pre-algebra proficiency test and use algebra concepts to reason and solve problems;
- students use laboratory and technology experiences to learn scientific concepts in physical, life and earth/space sciences;
- reading instruction is included in the academic core curriculum through grade eight;
- students use language correctly and effectively to find, organize and report on information through reading, writing, speaking and listening; and
- students describe their heritage, their government, their world and economic principles through the study of key issues of the past, present and future.

The high school program

The PLTW standards-based pre-engineering curriculum challenges students to solve real-world engineering problems by applying their knowledge and skills in mathematics, science and technology. Students who complete the curriculum and challenging academic studies:

- understand technology as a problem-solving tool;
- understand the scientific process, engineering problem-solving and the application of technology;
- understand how technological systems work with other systems;
- use mathematics knowledge and skills in solving problems;
- communicate effectively through reading, writing, listening and speaking; and
- work effectively with others.

The four-year pre-engineering sequence consists of five hands-on courses:

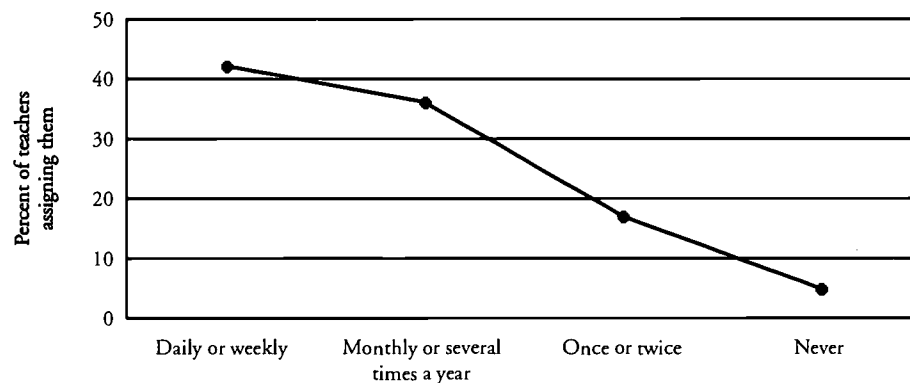
- **Principles of Engineering** provides an overview of engineering and engineering technology. Students develop problem-solving skills by tackling real-world engineering problems. Through theory and practical hands-on experiences, students address the emerging social and political consequences of technological change. The course outline includes:
 - *Overview and Perspective of Engineering.* Students learn about engineers' contributions to society and examine careers in engineering.
 - *Communications in Engineering.* Students make written and oral presentations, graphic representations and computer-aided designs.
 - *The Process of Engineering.* Students learn to solve problems, work in teams and explore career opportunities in engineering and engineering technology.
 - *Engineering Systems.* Students learn about mechanical, electrical/mechanical, hydraulic, pneumatic and control systems, motors and generators.
 - *Quality-control systems.* Students learn about quality-control systems, including precision measurement, quality assurance and process control, production processes and computer-aided manufacturing.
 - *Materials and Materials Testing in Engineering.* Students learn the categories and properties of materials, the materials testing process and the suitability and applications of different materials.

■ **Introduction to Engineering Design** emphasizes the development of a design. Students use 3-D computer software to produce, analyze and evaluate models of project solutions. They study the design concepts of form and function, then use state-of-the-art technology to translate conceptual designs into reproducible products. This course teaches students to:

- understand and apply the design process to solve various problems in a team setting;
- apply adaptive design concepts in developing sketches, features, parts and assemblies;
- interpret their own sketches in using computer software to design models;
- understand mass property calculations — such as volume, density, mass, surface area, moment of inertia, products of inertia, radii of gyration, principal axes and principal moments — and how they are used to elevate a parametric model;
- understand cost analysis, quality control, staffing needs, packaging and product marketing;
- explore career opportunities in design engineering and understand what skills and education these jobs require; and
- develop portfolios to display their designs and present them properly to peers, instructors and professionals.

Students in the *High Schools That Work* network have higher achievement when their career/technical teachers frequently make assignments that require advanced skills in reading, mathematics and science. Students in the Project Lead The Way Year Two Evaluation said most PLTW teachers emphasize technical assignments that involve mathematics.

Frequency of Technical Assignments That Require Mathematics

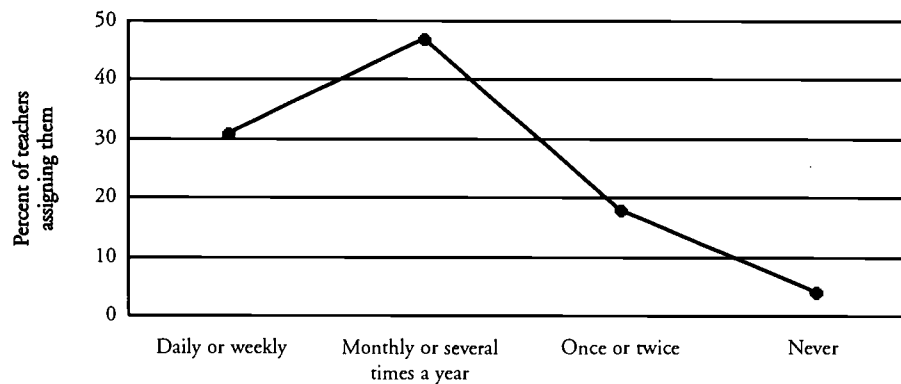


Source: Project Lead The Way Year Two (2000-2001) Evaluation Report prepared by Hezel Associates

- **Digital Electronics** introduces students to applied digital logic, a key element of careers in engineering and engineering technology. This course explores the smart circuits found in watches, calculators, video games and computers. Students use industry-standard computer software in testing and analyzing digital circuitry. They design circuits to solve problems, export their designs to a printed circuit auto-routing program that generates printed circuit boards, and use appropriate components to build their designs. Students use mathematics and science in solving real-world engineering problems. This course covers several topics, including analog and digital fundamentals; number systems and binary addition; logic gates and functions; Boolean algebra and circuit design; and decoders, multiplexers and de-multiplexers.
- **Engineering Design and Development** lets students apply what they have learned in academic and pre-engineering courses as they complete challenging, self-directed projects. Students work in teams to design and build solutions to authentic engineering problems. Their projects may include a robotic mascot for the school, a remote-controlled hovercraft or a solar-powered device. Students keep journals of notes, sketches, mathematical calculations and scientific research. Student teams make progress reports to their peers and the instructor and exchange constructive criticism and consultation. At the end of the course, teams defend their projects to a panel of engineers, business leaders and educators for professional review and feedback. This course equips students with the independent study skills that they will need in postsecondary education and careers in engineering and engineering technology.

Forty percent of students in the PLTW Year Two Evaluation said high school classes in general were not challenging. Yet, according to these same students, PLTW teachers frequently challenged them to work hard.

Frequency of Challenging Assignments in PLTW Classes
(as reported by students)

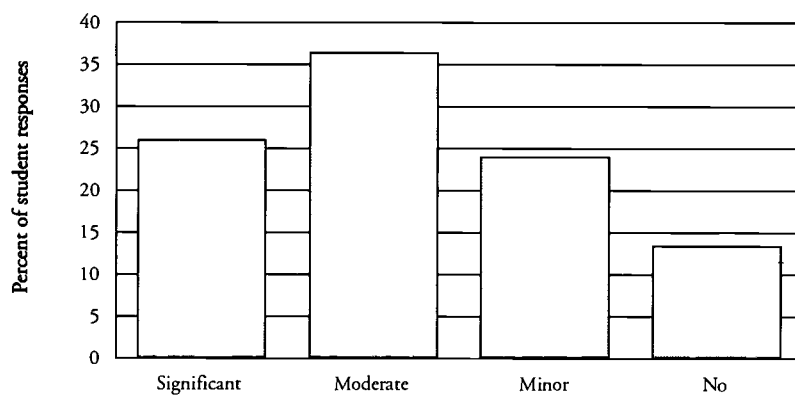


Source: Project Lead The Way Year Two (2000-2001) Evaluation Report prepared by Hezel Associates

- **Computer Integrated Manufacturing** teaches the fundamentals of computerized manufacturing technology. It builds on the solid-modeling skills developed in the Introduction to Engineering Design unit. Students use 3-D computer software to solve design problems. They assess their solutions through mass property analysis (the relationships of design, function and materials), modify their designs, and use prototyping equipment to produce 3-D models. The course includes these integrated concepts:
 - *Computer Modeling.* Students use 3-D software for mass property analysis.
 - *Computer Numerical Control (CNC) Equipment.* Students develop an understanding of the operating procedures and programming capabilities of machine tools.
 - *Computer-aided Manufacturing (CAM) Software.* Students convert computer-generated geometry into a program to direct the operation of CNC machine tools.
 - *Robotics.* Students program robots to handle materials in assembly-line operations.
 - *Flexible Manufacturing Systems.* Teams of students design manufacturing work cells and tabletop factories to solve complex problems that arise in integrating multiple pieces of computer-controlled equipment.

While Project Lead The Way raised students' confidence in science, engineering and technology, more than half of the students in the PLTW Year Two Evaluation said the program also improved their confidence in other academic areas and increased their overall academic performance.

Extent of PLTW's Effect on Overall Academic Achievement
(as reported by students)



Source: Project Lead The Way Year Two (2000-2001) Evaluation Report prepared by Hezel Associates

Recommended academic sequence

The *High Schools That Work* Assessment shows that students who combine challenging academic studies with quality career/technical studies achieve at higher levels. Students in the PLTW pre-engineering program complete:

- four credits in college-preparatory English;
- four credits in college-preparatory mathematics (Algebra I, geometry, Algebra II and a higher-level mathematics course);
- four credits in lab-based college-preparatory science (physical science, biology, chemistry, and physics or applied physics); and
- three credits in college-preparatory social studies.

Aligning academic courses with pre-engineering courses

The pre-engineering sequence and the academic courses in the PLTW curriculum provide many opportunities for students to practice academic skills in the context of technical studies. Both academic and career/technical teachers can use this natural alignment of content to integrate the curriculum. For example, teachers can integrate geometry with Introduction to Engineering Design and physical science with Principles of Engineering. School leaders can support teachers in integrating curricula by:

- getting teachers to work in teams or pairs to align the curriculum by identifying key concepts taught in each course and determining when these concepts will be introduced;
- asking teachers to work together to develop instructional plans that integrate specific content with the key concepts;

Recommended Pre-engineering Program of Study

PLTW unit	English	Mathematics	Science	Social Studies
Principles of Engineering	Academic/Honors English I	Algebra I	Physical Science	
Introduction to Engineering Design	Academic/Honors English II	Geometry	Biology	World History
Digital Electronics; Engineering Design and Development	Academic/Honors English III	Algebra II	Chemistry	American History
Computer Integrated Manufacturing	Academic/Honors English IV	Trigonometry or Pre-calculus	Physics	Government/Economics

- scheduling back-to-back courses so that teachers can plan together, teach in teams and conduct joint activities; and
- offering professional development on applied learning, integrated academic and technical learning, and other effective instructional practices.

Receiving college credit ---

Students who take pre-engineering courses in high school can receive college credit from Rochester Institute of Technology¹ in New York. After RIT reviews a program and certifies that it meets standards (curriculum, teacher training, equipment, guidance, etc.), students in that program can earn college credit if they make grades of 85 percent or higher in Introduction to Engineering Design,² Digital Electronics or Computer Integrated Manufacturing and if they score at least 70 percent on the RIT final exams for these courses.

There are many reasons to take RIT exams. These exams are open to any qualifying student in the program and indicate how students will perform on college tests. Students who meet the grade requirements may apply for RIT college credit at a charge of \$200 per course — substantially less than regular college tuition. The student's grade is the one he or she received on the RIT exam. Students who attend RIT receive full credit for their high school pre-engineering courses.

Other colleges may accept RIT credit if it meets their requirements. Many parents have praised the PLTW pre-engineering program for helping their children gain admission to other postsecondary institutions. RIT college credit clearly is an asset to any student's admissions portfolio.

Professional development for teachers and counselors ---

Teachers — Teacher preparation is an essential component of any new instructional program. Project Lead The Way has developed a comprehensive, intensive training program to prepare teachers to use the cutting-edge technology that is integral to the curriculum. This training consists of three phases:

- **Pre-assessment** — Teachers use an online assessment instrument to measure their readiness for training. They analyze the results and, if needed, engage in activities to gear up for the summer institute.
- **Summer training institute** — Teachers attend a two-week institute to earn certification for each new course they will teach in the fall. Rochester Institute of Technology offers graduate credit.

¹ Rochester Institute of Technology is a coeducational, privately endowed institution with more than 14,600 undergraduate and graduate students preparing for technical and professional careers. Located in Rochester, New York, the school was founded in 1829. It is accredited by the Middle States Association of Colleges and Schools.

² In New York, Introduction to Engineering Design is called Design and Drawing for Production.

- **Ongoing training** — Teachers receive ongoing support and instruction as they implement the program. Instruction may be conducted face-to-face or through a variety of distance-learning options. A strong support network is in place to share information and solve problems via electronic communication.

Any middle grades or high school teacher who plans to teach the courses must complete the 75-hour, two-week summer institute, which meets college standards. Teachers may earn graduate credit from Rochester Institute of Technology by demonstrating that they have met the standards and by developing portfolios, passing written exams or writing papers.

The institutes are offered at several national training centers: Rochester Institute of Technology (New York), Colorado Institute of Technology, Ferris State University (Michigan), New Hampshire Technical Institute, Purdue University (Indiana), the University of Houston (Texas) and the University of South Florida. Travel, room/board and other costs vary by location. Additional centers are expected to open soon in other parts of the country. For more information, visit the PLTW Web site at www.pltw.org or contact Guy Johnson, director of the National Technology Training Center at Rochester Institute of Technology, 137 Lomb Memorial Drive, Rochester, NY 14623. He can be reached by phone at (585) 475-2161 or by e-mail at gnjics@rit.edu.

Counselors — School counselors are vital to the pre-engineering program's success. PLTW makes a concerted effort to inform school counselors about the benefits of the program and the various careers available in the field. Participating school districts are invited to send middle grades and high school counselors to an annual conference. By sending different counselors each year, schools can ensure that all counselors have the opportunity to attend a conference. All counselors need to understand the program and its sequence of academic and pre-engineering courses so that they can help students and parents make important decisions about high school programs of study. Each counselor receives brochures, videotapes and other items to introduce PLTW to students and their parents.

Building local, state and industry partnerships ---

Project Lead The Way leaders work closely with business, education and professional organizations nationwide. These partnerships have resulted in a model curriculum, teacher training and development, and a national network of consultants. In addition, leaders from many state departments of education work with PLTW and with local school districts to support the program.

Schools that participate in PLTW are required to establish teams of postsecondary educators, parents and representatives of the private sector who will focus on implementing and sustaining a quality pre-engineering program. School leaders and teachers ask team members to:

- organize field trips to support classroom instruction;
- serve as mentors for students;
- provide guest speakers;

- handle public relations;
- provide expertise in specific engineering areas;
- suggest real-world projects that will engage students;
- consult with students working on projects;
- serve on panels to evaluate students' work; and
- provide advice and support for program implementation.

The partnership team also can support the program by arranging summer internships for high school juniors. A well-planned summer internship can improve academic, intellectual, technical and personal skills. The *High Schools That Work* guide *Planning and Conducting Student Summer Internship Experiences* contains step-by-step procedures, fact sheets and forms for use by students, parents, teachers, school coordinators and employers. The 76-page booklet is available from SREB for \$7.50 — or \$5 each for 10 or more copies.

Starting a new technical program

Although each district or school has its own procedure for implementing a new program, there are certain uniform requirements for Project Lead The Way. For example, the program must have the support of the district, the school, parents and the business community. A district or school can designate one or two people on the partnership team to help develop the awareness plan.

Key Dates in Implementing PLTW

March 1	First day to order from the PLTW national equipment bid list
March 15	Deadline for districts and schools to apply to offer the curriculum
May 1	Teacher self-assessment deadline
May 15	Last day to register for summer training institutes (online at www.pltw.org)
June 1	Deadline to submit the PLTW and School Agreement
June - August	Summer training institutes
Sept. 30	Last day to order from the PLTW national equipment bid list.
October	Annual conference for guidance counselors, Location A (online registration at www.pltw.org)
November	Annual conference for guidance counselors, Location B (online registration at www.pltw.org)

To implement the PLTW pre-engineering curriculum, each district must complete a district application and each school must complete a school application. These applications, which must be completed by March 15, are available online at www.pltw.org. When both applications are received, PLTW staff will send out a written agreement that must be approved by the school board and signed by the superintendent.

The PLTW and School Agreement

Effective long-term partnerships require clear expectations, open communication and loyalty to obligations. To facilitate strong partnerships with schools and districts, the PLTW and School Agreement outlines what each entity will provide.

PLTW provides:

- curriculum and resource guides for students;
- lesson plans, resources and teaching tools;
- curriculum review, revision and distribution;
- an online self-assessment for teachers;
- summer institutes for teachers (including classrooms, instructors, a curriculum and learning materials);
- ongoing teacher training (instruction only);
- a conference for guidance counselors (including facilities, materials and accommodations);
- increased purchasing power (coordinated bidding on and purchasing of furniture, hardware, software and supplies);
- information and support for schools and teachers;
- public relations materials for students and parents;
- national leadership (a board of directors and a national oversight committee); and
- independent evaluation of the national program.

Schools provide:

- equipment and software (must meet PLTW specifications);
- a laptop computer and software for each teacher in the program (must meet PLTW specifications);
- readiness training (as needed) before the summer institute;
- support for teachers to attend summer training institutes (stipends, travel, room/board and incidentals — these costs vary, depending on the training center);

- travel costs for guidance counselors to attend conferences;
- lab expansion when needed;
- annual budgets for materials and supplies;
- support to implement all five PLTW high school courses in four years or less and/or all four units of the Gateway to Technology program in three years or less; and
- community-based partnership teams.

High school programs must earn certification from Rochester Institute of Technology by the end of the second year of implementation, and all schools must participate in the evaluation component of the program.

Estimating program costs

Each participating school will develop a budget that includes the cost of equipment as each new course is introduced. Most schools add one or two courses per year and distribute the equipment costs over four years. During the first year, a school must purchase equipment for both the Principles of Engineering and the Introduction to Engineering Design courses. The budget also needs to include supplies and renewal fees for software licenses.

PLTW offers the program to schools at a low cost through a negotiated, national bid process. Schools may purchase equipment, furniture, tools and supplies from the bid list. They may use other suppliers, as long as the equipment meets PLTW specifications.

The following cost estimates are based on the 2001-2002 PLTW purchasing manual. Actual costs may vary. For up-to-date prices, check the PLTW Web site at www.pltw.org.

Middle School Costs

Computers	Equipment	Supplies	Furniture	Additional software	Consumables	Total
\$31,239	\$11,050	\$3,057	\$6,347	\$1,952	\$502	\$54,147

Notes: The costs are based on 26 students per class.
 The furniture costs are based on a "bare-walls" lab.
 Consumables are based on a class size of 26 students and should be multiplied by the number of sections taught.
 Resource materials (textbooks, laboratory manuals, instructional software, etc.) are not included.

The total cost for one middle grades Gateway to Technology lab with 26 student stations is about \$54,000. The cost will be less if the school already has equipment and/or computers that meet PLTW specifications.

High School Costs

Course	Computers	Equipment	Supplies	Furniture	Additional software	Consumables	Total
Principles of Engineering	\$0	\$15,045	\$458	\$0	\$0	\$139	\$15,642
Introduction to Engineering Design	\$24,117	\$8,943	\$167	\$5,420	\$1,251	\$567	\$40,465
Digital Electronics	\$0	\$1,961	\$2,975	\$0	\$0	\$120	\$5,056
Computer Integrated Manufacturing	\$0	\$32,810	\$212	\$1,323	\$0	\$0	\$34,345
Total	\$24,117	\$58,759	\$3,812	\$6,743	\$1,251	\$826	\$95,508

Notes: The costs are based on 20 students per class.
 The furniture costs are based on a "bare-walls" lab.
 Consumables are based on a class size of 20 students and should be multiplied by the number of sections taught.
 Resource materials (textbooks, laboratory manuals, instructional software, etc.) are not included.
 There are no specified items for Engineering Design and Development.

The total cost for one high school lab with 20 student stations — equipped for all five courses — is approximately \$95,500. The cost will be less if the school already has equipment and/or computers that meet PLTW specifications.

Annual Software Leases

Software description	Course	Seats	Annual cost
High school software:			\$3,500
Autodesk Inventor R4	Introduction to Engineering Design; Computer Integrated Manufacturing	100	
Circuit Maker	Digital Electronics	25	
Mastercam	Computer Integrated Manufacturing	100	
Eshed Robotec Robocell	Computer Integrated Manufacturing	30	
Middle school software:			\$1,800
Autodesk Inventor R4		100	

Software licenses (or seats) are districtwide. A district that has a high school and a middle school will need to purchase only the high school bundle unless it plans to load Autodesk Inventor on more than 100 seats.

What Students Say About PLTW Pre-engineering Classes

“I’ve learned engineering strategies, and my math and science skills have improved.”

“I had been struggling in math, and now I understand math better — especially geometry.”

“I have learned to budget my time better and solve problems accurately and cooperatively.”

“It has given me a head start on college to get my computer science degree.”

“Project Lead The Way exposed me to engineering. I learned about research, oral presentations and real-life business proposals.”

For more information on the Project Lead The Way pre-engineering programs, contact:

Northern Region	Western and Southwestern Regions	Southern Region
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Or visit these Web sites: www.sreb.org and www.pltw.org

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