The Effectiveness of *Project Lead the Way* Curricula in Developing Pre-engineering Competencies as Perceived by Indiana Teachers

George E. Rogers

High school teachers from across the nation are realizing that their schools could provide pre-engineering programs that allow students to explore their strengths and interests in engineering and engineering technology (Thilmany, 2003). According to Dearing and Daugherty (2004), leaders from both secondary technology education and college-level engineering have called for changes in the high school curriculum to address the need to adequately prepare high school graduates related to engineering and technology. To address this need, school districts across the nation are implementing pre-engineering courses into their curriculum. As schools infuse these pre-engineering programs, leaders and teachers in technology education are debating the merits of pre-engineering education (Lewis, 2004).

Research in Indiana has indicated that "technology education teachers have embraced pre-engineering education as a very valuable component of technology education" (Rogers, 2005, p. 18). Rogers went on to note that technology education teachers from Indiana also view the pre-engineering curriculum as beneficial in developing technological literacy. Rogers and Rogers (2005) concluded that the forward provided by William A. Wulf, president of the National Academy of Engineering, in the *Standards for Technological Literacy: Content for the Study of Technology* (International Technology Education Association, 2000) provides clear evidence that pre-engineering has become a component of the technology education discipline.

During the past decade, according to Pearson (2003), engineering associations, curriculum developers, and the technology education profession have devoted numerous resources toward developing instructional materials, initiating projects, and producing media programs to revise the curriculum to include engineering concepts. Schroll (2002) noted that there was concern in the profession about whether the discipline was creating appropriate pre-engineering curricula that aligned with the knowledge base required by secondary education graduates for today's workplace. Grimsley (2002) added that the national

---

George E. Rogers (rogersg@purdue.edu) is an Associate Professor in the Department of Industrial Technology at Purdue Unversity, West Lafayette, Indiana.

educational focus is now on student accountability and student achievement, and that educators are being held accountable for their students' performance. If this is the case, how does the push for inclusion of pre-engineering curriculum affect students' development of identified competencies?

According to McVearry (2003), Project Lead The Way (PLTW) is the nation's premier program in providing high schools with pre-engineering curriculum and linkages to college-level engineering and engineering technology programs. PLTW (2005) described its curriculum as a four-year sequence of courses which, when combined with college preparatory mathematics and science courses, introduces students to the scope, rigor, and discipline of engineering and engineering technology. PLTW has grown from 11 high schools, mostly in upstate New York, in 1997 to a current total of over 1600 schools in 46 states, plus Great Britain (McVearry; PLTW). Bottoms and Anthony (2005) noted that the PLTW curriculum contains effective educational learning activities that positively affect students' learning of pre-engineering competencies. Grimsley (2002) went on to note "the primary difference in pre-engineering courses taught at most schools . . . is that students are held accountable for a more in-depth knowledge" (p. 3).

Is there evidence that school pre-engineering programs, such as PLTW, can make a difference for today's high school student? Does the claim of Bottoms and Anthony (2005) that "PLTW stresses the importance of engaging students in challenging assignments that require them to apply academic and technical knowledge and skills to complete real-world projects" (p. 12) affect the development of students' competencies in engineering and technology? Bottoms and Anthony continued by noting that the achievement of PLTW students was significantly higher than other high school students with similar backgrounds. Do classroom PLTW teachers support this claim?

Bottoms and Anthony (2005) noted that "analyses of PLTW students suggest that to improve the quality of high school career/technical studies" schools must "invest in developing high-quality instructional and curriculum guides that define course objectives, outline the content to be covered, and provide challenging, authentic projects – projects that require students to apply academic and technical knowledge" (p. 14)). Dearing and Daugherty (2004) called for the profession to carefully develop curriculum materials related to pre-engineering education. Bottoms and Anthony concluded that the PLTW curriculum provides students with quality learning experiences. Again, one must ask if there is any research to support these assertions.

Research Questions

The following research questions were addressed by this study.

1. Do high school teachers perceive PLTW learning activities as effective in developing pre-engineering competencies for their students?
2. Are there differences between high school teachers' perceptions regarding the effectiveness of various PLTW curricula in developing high school students' pre-engineering competencies?

Methodology

In order to address these research questions, this study used a survey technique to ascertain the perceptions of Indiana's technology education teachers who currently teach PLTW courses. The State of Indiana was selected to serve as the base for this research since the PLTW curriculum is included in the State's technology education curriculum, requires PLTW teachers to hold a technology education teaching license, and has the highest per capita inclusion of PLTW in the nation.

Instrument

These PLTW teachers were first asked to provide demographic data: PLTW courses taught, highest degree earned, age group, and professional association membership. A survey instrument was developed that listed 14 pre-engineering competencies addressed by the PLTW high school courses of Introduction to Engineering Design (IED), Principles of Engineering (POE), Engineering Design and Development (EDD), Civil Engineering and Architecture (CEA), Computer Integrated Manufacturing (CIM), and Digital Electronics (DE). Competencies were considered to be the general descriptions of student abilities needed to succeed in a post-secondary engineering or engineering technology program (PLTW, 2005). The competencies were selected as representative of the PLTW curriculum by a team of PLTW affiliate professors and PLTW curriculum consultants.

The IED course provides students with an application of the engineering design process based on parametric modeling techniques. POE provides high school students with a broad overview of the engineering field including statics, vector diagrams, tensile testing, and problem-solving. The DE course is focused on circuit design, logic gates, and microprocessors. CEA is concerned with developing knowledge and skills related to commercial site preparation, structure design, and building requirements. CIM is a course that allows students to develop skills in transferring design models to machining programs and then applying manufacturing automation. The PLTW capstone course, EDD, teams students with a practicing engineer to examine a real-world problem, explore design solutions, build a prototype, and conduct product testing.

PLTW teachers were asked to rate their perception of the effectiveness of PLTW course learning activities in developing pre-engineering competencies in their students. The ratings were on a five-point Likert-type scale: very effective (5), somewhat effective (4), no effect (3), somewhat ineffective (2), and very ineffective (1). The Likert-type scale was suggested for this type of study by both Zargari (1996) and McCall (2001). McCall noted that "the words of the Likert scale are converted in a meaningful way to an interval scale that gives the researcher the ability to use totals or to calculate numerical averages" (p. 2). Construct validity was determined by three pre-engineering education professionals (Borg & Gall, 2002).

Population and Sample

The population and sample for this study consisted of technology education teachers who had completed the PLTW professional development institute at Purdue University and were currently teaching PLTW courses in Indiana. The group was comprised of 76 technology education teachers. To the sample was mailed a cover letter, the survey instrument, and a postage-paid return envelope. The response was 44.7% (n = 34). The demographic description of the respondents can be viewed in Table 1.

A master's degree or higher had been earned by 21 teachers (61.8%); 21 respondents (61.8%) were over 40 years of age; and 24 teachers (70.6%) were members of a professional association. Professional associations noted included: the International Technology Education Association (ITEA), the Technology Education Division of the Association for Career and Technical Education (ACTE/TED), and the American Society for Engineering Education (ASEE).

As noted in Table 2, IED was taught by 26 PLTW teachers (76.5%); 12 teachers (35.3%) taught POE; and 17 teachers (50.0%) taught more than one PLTW course. DE and CEA both had six teachers (17.6%) who indicated that they taught those PLTW courses; CIM was taught by five respondents (14.7%); and EDD and GTT were taught by four of these PLTW teachers (11.8%). Teachers who taught only Gateway to Technology, PLTW's middle school course, were not utilized for this study's data analysis beyond the overall effectiveness rating.

Table 1
Demographic Descriptions of Respondents

Variable	*n*	%
Highest degree earned		
Bachelor's	13	38.2
Master's	21	61.8
Years of age		
Less than 31	6	17.6
31-40	7	20.6
41-50	9	26.5
Over 50	12	35.3
Professional association membership		
ITEA	21	61.8
ACTE/TED	2	5.9
ASEE	1	2.9

Table 2
PLTW Courses Taught

Course	*n*	%
Introduction to Engineering Design	26	76.5%
Principles of Engineering	12	35.3%
Digital Electronics	6	17.6%
Civil Engineering and Architecture	6	17.6%
Computer Integrated Manufacturing	5	14.7%
Engineering Design and Development	4	11.8%
Gateway to Technology	4	11.8%

Note: Seventeen teachers taught more than one course.

Findings

The teachers' ratings of the overall effectiveness of the PLTW curricula in developing pre-engineering competencies in students are reported in Table 3. Overall, the respondents indicated that the PLTW curriculum is effective in developing student competency in pre-engineering. The PLTW curriculum was perceived as very effective ($M = 4.50$ or higher) for developing over one half of the competencies noted. Those competencies included "construct electronic circuits ($M = 4.67$, $SD = 0.492$), "apply geometric constraints" ($M = 4.65$, $SD = 0.485$), and "apply the engineering design process" ($M = 4.65$, $SD = 0.485$). "Design logic gates" ($M = 4.62$, $SD = 0.506$), "design electronic circuits" ($M = 4.62$, $SD = 0.506$), "design automated manufacturing systems" ($M= 4.56$, $SD = 0.512$), and "perform parametric modeling" ($M = 4.50$, $SD =0.508$) were also perceived as very effective by this sample of PLTW teachers. Even the lowest perceived item, "perform CIM processes", supported the effectiveness of the PLTW curriculum ($M = 4.00$, $SD = 1.130$).

Table 3
Overall Effectiveness of the PLTW Curriculum

Competency	*M*	*SD*	*n*
Construct electronic circuits	4.67	0.492	12
Apply geometric constraints	4.65	0.485	34
Apply the engineering design process	4.65	0.485	34
Design logic gates	4.62	0.506	13
Design electronic circuits	4.62	0.506	13
Design automated manufacturing systems	4.56	0.512	16
Perform parametric modeling	4.50	0.508	32
Design and prototype solutions	4.39	0.497	28
Design CIM processes	4.33	0.492	12
Construct automated manufacturing systems	4.31	0.793	16
Conduct structural analyses	4.26	0.733	19
Perform materials testing	4.21	0.713	19
Design commercial structures	4.19	0.981	16
Perform CIM processes	4.00	1.130	15

Table 4 presents the teachers' effectiveness ratings of the PLTW curriculum divided by the PLTW courses taught. The competency ratings reported in Table 4 were calculated for only the PLTW teachers who indicated they taught that PLTW course. As previously noted, 17 teachers taught more than one PLTW course. IED teachers indicated that the IED curriculum was very effective in developing student competencies related to "applying the engineering design process" ($M = 4.73$, $SD = 0.452$), "applying geometric constraints" ($M = 4.62$, $SD = 0.496$), and "performing parametric modeling" ($M = 4.46$, $SD = 0.647$). POE teachers did not perceive the POE learning activities as effective as the IED activities, but still perceived the POE curriculum overall as effective ($M = 4.33$ to $M = 4.00$).

Table 4
Effectiveness of the PLTW Curriculum by Course

Course Competency	***M***	***SD***	***n***
Introduction to Engineering Design			
Apply the engineering design process	4.73	0.452	26
Apply geometric constraints	4.62	0.496	26
Perform parametric modeling	4.46	0.647	26
Principles of Engineering			
Design automated manufacturing systems	4.33	0.651	12
Construct automated manufacturing systems	4.33	0.651	12
Perform materials testing	4.00	0.853	12
Digital Electronics			
Design electronic circuits	4.17	0.753	6
Construct electronic circuits	4.17	0.753	6
Design logic gates	3.83	0.983	6
Civil Engineering and Architecture			
Design commercial structures	4.17	0.753	6
Conducting structural analyses	4.17	1.17	6
Computer Integrated Manufacturing			
Design CIM processes	4.40	0.548	5
Perform CIM processes	4.40	0.894	5
Engineering Design and Development			
Design and prototype solutions	4.50	0.577	4

DE teachers perceived the PLTW learning activities focused on developing students' competency to "design logic gates" as the lowest overall item ($M = 3.83$, $SD = 0.983$). DE activities related to "design" and "construct electronic circuits" were noted as effective for students ($M = 4.17$, $SD = 0.753$). The perceptions of the DE teachers related to their DE learning activities were lower than the overall perception of these activities (see Table 3) that included the input from non-DE teachers. CEA instructors indicated that their curriculum was effective for two competencies included in this survey, "design commercial structures" and "conduct structural analyses" ($M = 4.17$). CIM teachers perceived the PLTW CIM curriculum effective ($M = 4.40$) in developing skills related to "design and perform CIM processes," while EDD teachers noted that their curriculum was approaching very effective in developing students' competency to "design and prototype design solutions" (*M* = 4.50, *SD* = 0.577).

Further analysis was conducted only on the responses of the IED teachers and the POE teachers, since the IED teachers comprised 76.5% of the respondents (*n* = 26), and the next largest group was the 12 POE teachers (35.3%). Statistical analyses of the IED and POE teacher groups were conducted using the t-test to compare the teachers by highest degree earned and membership in professional associations. The one-way analysis of variance (ANOVA) was utilized to statistically compare the perceptions of these PLTW teachers related to age group.

In comparing perceptions of the IED teachers (*n* = 26) by highest educational degree earned, bachelor's degree and master's degree, no significant differences were found. However, the IED teachers with a bachelor's degree perceived the PLTW curriculum as being very effective (*M* = 4.89, *SD* = 0.333) in developing student competencies related to "applying the engineering design process" (see Table 5).

Table 5
Introduction to Engineering Design Course Effectiveness by Highest Degree Earned

	Bachelor's			Master's					
Competency	***M***	***SD***	***n***	***M***	***SD***	***n***	***df***	***t***	***p***
Apply the engineering design process	4.89	0.333	9	4.71	0.470	17	24	1.030	0.311
Apply geometric constraints	4.56	0.527	9	4.65	0.493	17	24	0.440	0.664
Perform parametric modeling	4.22	0.667	9	4.59	0.618	17	24	1.400	0.175

The results of examining the IED respondents' perceptions related to their membership in a professional association (ITEA, ACTE/TED, or ASEE) are presented in Table 6. There were no significant differences indicated between professional association members (*n* = 16) and non-members (*n* = 10) related to their perception of the effectiveness of the IED curriculum.

Curricular effectiveness examined by IED teachers' age group is presented in Table 7. It must be noted that younger PLTW teachers (less than 40 years of age) and older PLTW teachers (over 50 years of age) perceived the effectiveness of the IED curriculum as more effective than middle-aged teachers (41 to 50 years of age). All of the younger IED teachers (*n* = 9) perceived the IED learning activities in developing student competencies in "apply the engineering design process" as very effective (*M* = 5.00, *SD* = 0.000). An ANOVA related to this competency noted a significant difference between the IED teachers related to

Table 6
Introduction to Engineering Design Course Effectiveness by Professional Association Membership

	Member			Non-Member					
Competency	***M***	***SD***	***n***	***M***	***SD***	***n***	***df***	***t***	***p***
Apply the engineering design process	4.75	0.447	16	4.70	0.483	10	24	0.269	0.790
Apply geometric constraints	4.56	0.512	16	4.70	0.483	10	24	0.680	0.503
Perform parametric modeling	4.44	0.727	16	4.50	0.527	10	24	0.235	0.816

Table 7
Introduction to Engineering Design Course Effectiveness Design by Age Group

	Age Ranges					
	< 40 (*n* = 9)		41-50 (*n* = 7)		> 50 (*n* = 10)	
Competency	***M***	***SD***	***M***	***SD***	***M***	***SD***
Apply the engineering design process	5.00	0.00	4.29	0.488	4.80	0.422
Apply geometric constraints	4.67	0.50	4.43	0.535	4.70	0.483
Perform parametric modeling	4.56	0.527	4.29	0.756	4.50	0.707

Table 7a
Apply the Engineering Design Process Effectiveness by Age Group

Source of Variance	***SS***	***df***	***MS***	***F***	***p***
Between	2.087	2	1.043	7.924	0.002*
Error	3.029	23	0.1317		
Total	5.115	25			

Table 7b
Apply Geometric Constraints Effectiveness by Age Group

Source of Variance	*SS*	*df*	*MS*	*F*	*p*
Between	0.3107	2	0.1554	0.3520	0.707
Error	10.15	23	0.4413		
Total	10.46	25			

Table 7c
Perform Parametric Modeling Effectiveness by Age Group

Source of Variance	*SS*	*df*	*MS*	*F*	*p*
Between	0.3396	2	0.1698	0.6716	0.521
Error	5.814	23	0.2528		
Total	6.154	25			

age (F = 7.924, p = 0.002, df = 25). The ANOVA related to "apply geometric constraints" and "perform parametric modeling" did not indicate any significant differences between age groups.

The comparisons of the POE teachers (n = 12) in relationship to their highest degree earned are reported in Table 8. While PLTW teachers with a master's degree did perceive "design and construct automated manufacturing systems" higher (M = 4.44, SD = 0.527) than teachers with a bachelor's degree (M = 3.67, SD = 1.15), no significant difference was indicated. Both educational levels perceived activities as effective for the competency of "perform materials testing" (M = 4.00). POE teachers' membership in a professional association did not indicate any differences in their perception of the effectiveness of the POE curriculum (see Table 9).

Table 10 presents the POE teachers' perception of POE learning activities grouped by their age. Overall, no significant difference was indicated related to "design automated manufacturing systems" and "design and construct automated manufacturing systems." The older teachers (over 50 years of age) did perceive the POE activities higher in regard to "perform materials testing" (M = 4.50, SD = 0.577) than the middle-aged POE teachers (41 to 50 years of age) (M = 3.60, SD 0.894). However, the ANOVA did not indicate any significant difference between the age groups related to this activity.

Table 8
Principles of Engineering Course Effectiveness by Highest Degree Earned

	B.S. (n = 3)		M.S. (n = 9)				
	M	*SD*	*M*	*SD*	*df*	*t*	*p*
Design auto manufacturing systems	3.67	1.15	4.44	0.527	10	1.670	0.126
Construct auto	3.67	1.15	4.44	0.527	10	1.670	0.126

manufacturing systems							
Perform materials testing	4.00	0.00	4.00	1.00	10	0.000	1.000

Table 9
Principles of Engineering Course Effectiveness by Professional Association Membership

	Member (*n* = 7)		**Non-Member** (*n* = 5)				
	M	***SD***	***M***	***SD***	***df***	***t***	***p***
Design auto manufacturing systems	4.29	0.756	4.20	0.837	10	0.185	0.857
Construct auto manufacturing systems	4.29	0.756	4.20	0.837	10	0.185	0.857
Perform materials testing	4.29	0.756	3.60	0.894	10	1.440	0.181

Conclusions

The results of this study indicated that Indiana's PLTW teachers perceive the PLTW curriculum as being "effective" to "very effective" in developing pre-engineering competencies in their high school students. This positive perception was true across all PLTW courses: IED, POE, DE, CIM, CEA, and EDD. This finding concurs with an article by Bottoms and Anthony (2005) that noted the PLTW curriculum contains effective educational learning activities and that these activities have a positive effect on students' learning the PLTW pre-engineering competencies.

Data indicated that one half of the respondents were teaching more than one PLTW course and that three fourths of the PLTW teachers were teaching the IED class. Since IED is the initial high school course, this was to be expected. Demographically, the majority of these technology education teachers were over 40 years of age (61.8%), held a master's degree (61.8%), and were members of a professional association (70.6%).

These technology education teachers indicated that overall, the learning activities included in the IED, CIM, and EDD curricula were perceived as the most effective. Examination of the effectiveness of the IED curriculum by the highest degree earned and professional

Table 10
Principles of Engineering Course Effectiveness Design by Age Group

	Age Ranges

	< 40 (*n* = 3)		41-50 (*n* = 5)		> 50 (*n* = 4)	
Competency	***M***	***SD***	***M***	***SD***	***M***	***SD***
Design auto manufacturing systems	4.33	1.15	4.20	0.837	4.25	0.500
Construct auto manufacturing systems	4.33	1.15	4.20	0.837	4.25	0.500
Perform materials testing	4.00	1.00	3.60	0.894	4.50	0.577

Table 10a
Design Automated Manufacturing Systems Effectiveness by Age Group

Source of Variance	*SS*	*df*	MS	*F*	*p*
Between	3.333	2	1.6667	2.413	0.976
Error	6.217	9	0.6907		
Total	6.250	1			

Table 10b
Construct Automated Manufacturing Systems Effectiveness by Age Group

Source of Variance	*SS*	*df*	*MS*	*F*	*p*
Between	3.333	2	1.6667	2.413	0.976
Error	6.217	9	0.6907		
Total	6.250	11			

Table 10c
Perform Materials Testing Effectiveness by Age Group

Source of Variance	*SS*	*df*	*MS*	*F*	*p*
Between	1.800	2	0.9000	1.306	0.318
Error	6.200	9	0.6889		
Total	8.000	11			

association membership categories indicated no significant differences. However, it was noted that the middle-aged IED teachers (41 - 50 years of age) perceived the IED learning activities lower than their younger or older IED counterparts. This difference tested significant by an ANOVA (F = 7.924, p = 0.002, df = 25). The fact that the older IED PLTW teachers (51 years of age and older) perceived the curriculum higher may indicate that this group views the PLTW IED curriculum as meeting the needs of their students and has accepted this new pre-engineering curriculum (Rogers, 1992).

The findings of this study must not be generalized beyond the sample of Indiana teachers. Furthermore, the reader is reminded that that data are based principally on the perceptions of teachers. However, this study does support the report of Bottoms and Anthony (2005) that indicated that PLTW students were receiving effective high school instruction based on effective curriculum and engaging learning activities. As noted by Rogers (2005), Indiana technology education teachers have adopted the PLTW pre-engineering curriculum and perceive this new curriculum as effective in addressing their students' needs.

References

Borg, W. R., & Gall, M. D. (2002). *Educational research: An introduction*. New York: Longman.

Bottoms, G., & Anthony, K. (2005). *Project Lead the Way: A pre-engineering curriculum that works*. Atlanta, GA: Southern Regional Educational Board.

Dearing, B. M., & Daugherty, M. K. (2004). Delivering engineering content in technology education. *The Technology Teacher, 64*(3), 8-11.

Grimsley. R. (2002). *Engineering and technology education*. Paper presented at the annual meeting of the Mississippi Valley Technology Teacher Education Conference, St. Louis, MO.

Lewis, T. (2004). A turn to engineering: The continuing struggle of technology education for legitimization as a school subject. *Journal of Technology Education, 16*(1), 21-39.

McCall, C. H. (2001). *An empirical examination of the Likert scale: Some assumptions, development and cautions*. Paper presented at the annual meeting of the CERA Conference, South Lake Tahoe, CA.

McVearry, R. D. (2003, April). High-tech high schools build bridges to college. *Engineering Times*. Alexandria, VA: National Society of Professional Engineers. Retrieved from http://www.nspe.org

Pearson, G. (2003). *Engineering and technology education: Collaboration conundrum*. Paper presented at the annual meeting of the Mississippi Valley Technology Teacher Education Conference, Nashville, TN.

Project Lead The Way. (2005). *About Project Lead The Way: An overview*. Clifton Park, NY: Author. Retrieved on June 18, 2006 from http://www.pltw.org

Rogers, G.E. (2005). Pre-engineering's place in technology education and its effect on technological literacy as perceived by technology education teachers. *Journal of Industrial Teacher Education, 41*(3), 6-22.

Rogers, S., & Rogers, G.E. (2005). Technology education benefits from the inclusion of pre-engineering education. *Journal of Industrial Teacher Education, 41*(3), 88-95.

Rogers, G. E. (1992). Industrial arts/technology education: Have Omaha teachers accepted the change? *Journal of Industrial Teacher Education, 30(*1), 46-58.

Schroll, M. (2002). *Pre-engineering at the high school level: A teacher's perspective*. Paper presented at the annual meeting of the Mississippi Valley Technology Teacher Education Conference, St. Louis, MO.

Thilmany, J. (2003, May). Catching them younger. *Mechanical Engineering*. New York, NY:

Zargari, A. (1996). Survey results guide total quality management (TQM) course development in industrial technology. *Journal of Technological Studies, 22*(1), 60-61.