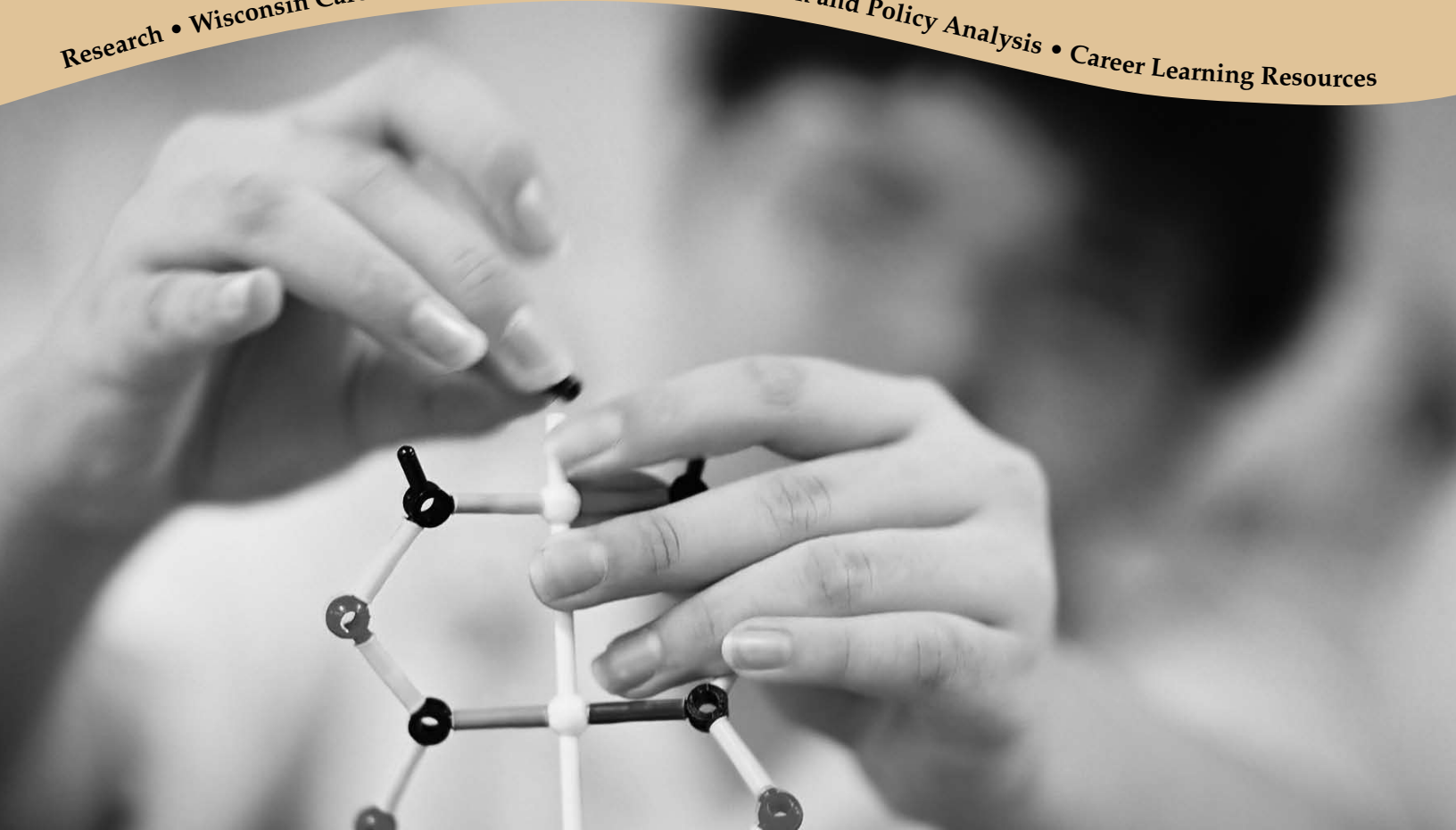




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PRE-ENGINEERING EDUCATION IN WISCONSIN: EARLY DEVELOPMENTS AND EMERGING PRIORITIES

February 2007

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SUMMARY

Without question, Wisconsin's economic future is increasingly dependent on the quality and relevance of the education students receive in our secondary schools, technical colleges and universities. Consider these promising economic development opportunities, yet highly problematic trends:

- Job openings requiring expertise in science, technology, engineering, and mathematics will increase by 18.3% through 2014, compared to 11.5% for all other occupations. Of these 13,800 annual openings, more than two-thirds (67.4%) will require an associate's or bachelor's degree.
- Currently, only 25% of Wisconsin's 9th graders complete a 2-year or 4-year college degree with six years of high school graduation, and only 21% of the degrees awarded by the UW System and the technical colleges focused on the fast growing science, technology, and engineering fields.
- Wisconsin's increasingly diverse 14-17 age youth population will decline by 11% over the next decade, which elevates the importance of enhancing the college and career readiness of all students.
- With a similar culture and business climate, Minnesota's 2005 per capita income (\$37,373) is well above the U.S. average (\$34,586). Moreover, the income gap between Minnesota and Wisconsin (\$33,315) is nearly \$4,000 per person and widening.
- Throughout the U.S. economy, high-tech firms represent 6.30% of all businesses, while they comprise only 4.98% of Wisconsin firms.
- The Wisconsin Technology Council notes that, "Wisconsin needs 150,000 more college graduates to *meet* the U.S. per capita income average... and another 150,000 workers with post-graduate degrees to *exceed* the U.S. per capita income average."

This report examines the challenges and promising recent developments on Wisconsin's pre-engineering and technology education landscape. We start by describing why attention to engineering and technology education is imperative for the state's secondary school and

college settings. The data on student achievement and engagement in secondary and postsecondary education inform the critical challenges which must be tackled by policymakers, educators, and community partners in developing and expanding the science, technology, engineering, and mathematics (STEM) education pipeline. Next, we consider how a nationally prominent pre-engineering education program—Project Lead the Way—is aligned with the emerging calls for high school redesign in Wisconsin, as well as nationally. Currently, 92 Wisconsin middle and high schools are implementing this standards-based curriculum, which makes extensive use of problem based learning. Student surveys, interviews, and focus groups in six schools (4 high schools, 2 middle schools) in the early stages of implementing PLTW courses and technology modules reveal some valuable insights about the benefits and challenges associated with implementing this problem and project-based curriculum. Finally, we outline four critical priorities for strengthening Wisconsin's pre-engineering and technology education initiatives and improving the STEM pipeline.

Critical Challenges

Over several decades, Wisconsin's educational system has provided high quality learning experiences for each generation of its future citizens. Among other indicators, high school graduation rates and average ACT scores rank Wisconsin among the highest performing states in the nation. However, the explosion of the knowledge-based global economy—along the changing workforce and other factors—create major questions about the state's economic future and the role of education: What major challenges must be addressed in preparing the state's future workforce to meet the rising demand for skills in the science, engineering, health care, and technology sectors? To what extent is a highly skilled workforce essential for maintaining the quality of life standards established over the past decade? Which program alignment policies and innovation incentives are needed to create STEM programs that address the global economic development priorities?

Several education and workforce development indicators reveal the complex challenges associated with addressing these questions.

- One of four Wisconsin 9th graders complete a 2-year or 4-year college degree within six years of completing high school, which ranks Wisconsin among the top 20 percent of states in educational attainment. However, of those graduates finishing an associate or bachelor degree, only 1 in 5 majors in science, engineering and technology, compared to the national benchmark of 32 percent. Nationwide, for every three college graduates prepared to enter the science and engineering workforce, Wisconsin prepares only two comparably trained scientists, technicians or engineers. When examining the STEM education pipeline, a significant shortage of graduates clearly limits the states' capacity to develop and retain high wage businesses in the STEM sector.
- Data from studies conducted by the Wisconsin Technology Council (2002) and Northstar Economics (2005), along with data from the National Science Foundation's 2006 Science and Engineering Indicators, suggest clearly that Wisconsin's economic future will depend heavily strengthening the credentials of the workforce in strategic areas.
- In Wisconsin, science and engineering occupations represent 3.22% of the workforce, compared to 3.61% nationally and 4.20% of total employment in Minnesota.
- If some of the predicted declines in annual earnings and limited economic growth are accurate, by 2024 the typical Wisconsin citizen will be earning only 83 percent (\$40,598) of the national average annual income.
- Low income growth rates lead to lower incomes, decreased tax bases and budget deficits, fewer public services, and lower quality of life.

The competencies and skills of the workforce are extremely important assets in the knowledge-based global economy. Recent studies of regional economic growth patterns reveal that a *skilled*

workforce is a significant factor in predicting business performance, as well as growth in productivity and per capita income. In an Ohio study, the Upjohn Institute for Employment Research (2006) found that several indicators for a skilled workforce were particularly important: percent of the population with undergraduate and graduate degrees, the number of occupations with high education content (e.g., professional occupations, patents per employee), and the productivity of the information sector.

It is unequivocally clear that Wisconsin's educational priorities and investments must focus on key workforce preparation and development needs. Based on the state's substantial scientific research and discovery capacity, expansion of the science and engineering sector shows great promise for creating and sustaining high wage jobs and sustained economic growth. However, fulfillment of this promise rests heavily on the willingness of educators, communities, and parents to make exposure to and engagement in STEM education a reality for all students.

Emerging High School Redesign Initiatives

These economic and social challenges bring an urgency to the continuing dialogue on re-designing or reforming comprehensive high schools in Wisconsin as well as nationally. Both the 2005 report of the National High School Alliance (NHSA) and the 2006 Wisconsin State Superintendent's High School Task Force Report echo themes that emphasize the importance of quality pre-engineering and technology education instruction, which prepares youth for success in college, career pursuits, and lifelong learning, not one or the other. The national debates on high school reform and the growing crisis in STEM education have caused a growing number of Wisconsin districts to implement innovations in science, pre-engineering and technology education curricula.

In 2006-07, 92 schools were implementing Gateway to Technology (GTT) modules in middle schools or the Project Lead the Way (PLTW) curriculum in high schools. *Project Lead the Way* is a technology education and pre-engineering program offered in more than 1,300 middle and high schools in 45 states. Taken in conjunction with college preparation courses, the PLTW program of study (foundation, specialization, and capstone courses) uses project- and problem-based learning experiences that allow students to gain and apply knowledge to real-world problems and situations. More specifically, the standards-aligned courses provide opportunities for students to:

- 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 PLTW curriculum and its middle school companion—five 9-week technology education modules (Gateway to Technology)—were designed to address several of the issues surrounding student engagement and academic achievement.

The NHSA report—*A Call to Action: Transforming High Schools for All Youth*—contends that schools must develop or adopt academically rigorous curricula that meet or exceed standards, link learning to real-world contexts, and build on student community assets. The State Superintendent’s High School Task Force Report challenges Wisconsin high schools to identify best practices in student learning that are both authentic and relevant, and fully assess the rigor and viability of multiple pathways to academic achievement. The alignment of any new instructional interventions or assessments with established content or graduation standards is an important consideration in any educational setting. The pre-engineering and technology

education courses in the PLTW initiative are aligned with both national and Wisconsin standards for mathematics, science, and technology education (Worldwide Instructional Design System, 2006). Moreover, these courses involve students in working alongside engineers and community leaders to study and solve real-world engineering problems. For example, in the Principles of Engineering course (unit 7), students must analyze an engineering failure (e.g., the failure of an airbag to deploy) or problem (e.g., a safety analysis of playground structures) and prepare and present a report that identifies causes, damage created, design failures, and the impact on the environment or society.

The NHSA report notes that the next generation of high schools must “use multiple measures to assess student outcomes, including performance-based assessments.” Correspondingly, the State Superintendent’s report recommends “...providing professional development for educators in the use of multiple assessments, including assessment tools that incorporate hands-on demonstration of knowledge and skills.” Students completing PLTW courses receive college credit if they pass both parts of a nationally developed end-of-course exam, which is prepared by engineering and technology professionals and professors. One portion of the three-part exam requires students prepare essays on course content *applications* of engineering principles, digital electronics, and the like.

In the NHSA Report, high schools are strongly encouraged to “...provide individualized guidance, information, and resources on career pathways and opportunities for participating in work-based learning.” The State Superintendent’s report stresses the need for schools and communities to “...provide an adult advocate for each student to establish a meaningful and on-going relationship.” In the capstone PLTW course and in many technology education program sequences, students spend a semester or a full school year working directly with engineering mentors who advise them an in-depth study of real world engineering problems.

Insights from Early Implementers

During 2005-06, researchers from the Center on Education and Work conducted an early-stage evaluation of the PLTW and GTT implementation efforts in four Wisconsin high schools and two middle schools. The findings from student surveys and focus groups and staff interviews revealed some promising initial results and identified emerging priorities for science and engineering-focused curriculum innovations across the state.

- Student focus groups in the middle schools and high schools revealed that the curriculum provided for highly engaged learning, illustrated the value of using real-world projects to acquire academic content, and helped students clarify their goals.
- A survey of student engagement revealed high school PLTW students were 10-20% more likely than non-PLTW students in the same schools to say that in the past school year they:
 - Were encouraged to continue schooling beyond high school
 - Had developed clear career goals
 - Had solved real-world problems
 - Were connecting ideas or concepts from one class or subject area to another
 - Had worked on a project or paper that required research outside of assigned texts.
 - Were reading and understanding challenging learning materials.

Participating in focus groups, educators from these schools noted that the recent curriculum innovations had provided students with challenging, rich, and community connected learning experiences. The structure of the curriculum and the growing network of Wisconsin schools and teachers implementing PLTW programs made implementation relatively easy. However, the educators raised questions about the alignment of the curriculum with admission standards for the UW System institutions and the Wisconsin Technical Colleges.

Emerging Priorities to Address Key Challenges

As noted earlier, it is imperative that leaders from education, business and government must focus on systematically improving the STEM education pipeline. Four critical challenges confront all states, communities, and schools seeking to implement innovations in science, math, technology and pre-engineering education aimed at building the capacity of the workforce. Addressing these challenges successfully will require expanded or new, strategic collaborations among leaders from the schools, business and industry, higher education, and government. Each of the following challenges must be addressed by setting and addressing a set of key priorities at the state and local level.

Challenge #1: *State and local leaders must ensure a common vision and agenda for all STEM education programs and workforce development initiatives in Wisconsin.*

- Adopt academic, college admission, and career development standards that are well integrated to ensure that all students graduating from high school are prepared for three simultaneous life roles—further education and lifelong learning, finding and entering rewarding careers, and civic engagement.
- Align standards and assessments for curriculum, instruction, high school graduation, as well as admission and placement in 2 and 4 year collegiate settings.
- Establish or expand education, industry, higher education and community partnerships to set and monitor education priorities aligned with regional STEM economic growth and workforce development targets.
- Continuously promote public awareness of regional and statewide workforce needs, promising career development opportunities, and the benefits of academic achievement and attainment.

Challenge #2: *Schools and postsecondary education institutions must offer expanded, standards-based courses and programs of study, which ensure that all students acquire the readiness levels of competency needed to pursue STEM careers and majors in postsecondary education.*

- Require three years of college-level science and mathematics for high school graduation, including career-relevant science (e.g., environmental science, anatomy, physiology) and mathematics (e.g., data analysis and probability, reasoning, and the use of mathematics in communication, making connections, and developing representations).
- Recruit, support, and retain well-qualified educators, mentors, and other professionals with expertise in science, engineering, technology and mathematics for middle school, high school, and postsecondary settings.
- Provide all students with project-based and community-based learning experiences that reinforce the application and relevance of core academic knowledge in STEM careers.
- Provide all high school students with access to dual credit college-level learning opportunities, including but not limited to Advanced Placement, International Baccalaureate, and transcribed credit programs in the Wisconsin Technical College System, including Youth Apprenticeships (e.g., Biotechnology, Plastics Manufacturing, and Computer Science) and STEM-focused Youth Options courses in local technical colleges and universities.

Challenge #3: *Regional STEM-focused partnerships must develop more effective student guidance and mentoring initiatives to create high expectations and to support the learning and career development of all students, including young women and students from low income families.*

- Make information about emerging trends in STEM fields, such as recent advances and new career options in bio-medical, bio-technology, advanced manufacturing, and aerospace engineering, widely accessible in science and technology curricula in middle schools and high schools.
- Provide career interest assessments for all middle and high school students, along with the academic assessments, to inform parental input and students' decisions on appropriate educational pathways and careers.
- Provide existing high school-level assessments to all students (such as the ACT and WorkKeys) and use the results for college admission and advanced placement.
- Create incentives and supports so students will enroll in and complete the end-of-course assessments for AP and PLTW courses, which provide access to advanced standing in colleges and universities.
- Provide appropriate assessment accommodations, and alternate assessments when needed, that enable students with disabilities and limited English proficiency, as well as at-risk students, to participate fully in STEM programs.
- Provide all students with individualized career development plans and electronic portfolios permitting them to: (a) integrate and reflect on their academic, work- and community-based, and co-curricular learning experiences, (b) compile evidence of their competence and proficiency for high school graduation exhibitions, college admission processes, and employment, and (c) plan and manage upcoming transitions to further education and career opportunities.

Challenge 4: *Schools, colleges, and regional STEM partnerships must commit to measuring progress.*

- Set school and community-wide performance benchmarks for achieving the regional or state-level STEM vision and agenda.
- Use longitudinal and multi-sector data systems (schools and higher education) to measure, document, and improve the progress of every student at multiple points in the STEM education pipeline.
- Use data systems to assess the progress of schools and state agencies in raising the post-high school readiness of STEM students.
- Create and support data-based decision making teams in all schools and communities.
- Assist educators and community leaders in being accountable for graduating students who are college and work ready by creating appropriate incentives for students.

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The PLTW leadership teams in the four high schools and two middle schools agreed to serve as our field sites for collecting, reporting, and critiquing evaluative information on PLTW students, the program, and its interface with other secondary school curriculum improvement initiatives. In exchange for access to their schools, classrooms, and local data sources, we agreed to keep their identity confidential. Throughout the 2005-06 school year each of these teams (instructors, guidance counselors, building administrators, and data analysts) met with the researchers on multiple occasions to discuss the critical evaluation and assessment questions, and to identify the data needed to address an array of program improvement and accountability

challenges. Their candid reactions and comments were most helpful in designing and producing both this report and the Guidebook for Local Teams, a companion document.

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INTRODUCTION

The times are a changing—an over-used but increasingly accurate axiom. As global economic competition intensifies, ensuring that all students leave high school prepared to succeed in both college and high-wage careers is a critical public policy issue. Aligning education reform efforts with economic development initiatives is a recurring theme for local and state governments, as well as national leaders. Many states, including Wisconsin, are in the early stages of re-examining the role of secondary and postsecondary in preparing future citizens for the 21st century global economy.

Over the past decade several leading policy groups, including the National Governors Association, have urged states to increase the percentage of graduates who are prepared for college and the workplace, as well as to increase the rate of postsecondary education enrollment and completion. Regrettably, ACHIEVE, Inc. – a non-profit organization formed in 1996 by the nation’s governors and business leaders – finds that *...far too many young people leave our schools without the skills they need to compete in college or the workplace (ACHIEVE, 2006).*

Through 2014, science, technology, and engineering job openings will increase by 18.3% compared to 11.5% for all other occupations in Wisconsin (Camfield & Barroilhet, 2006). Of these 13,800 annual openings, more than 70 percent (71.2) will require a 2-year or 4-year college degree or certificate, according to the Department of Workforce Development. However, only 21% of the degrees awarded by the UW System, the technical colleges, and private institutions (approximately 7,500 in 2004-05) provided credentials for graduates to immediately enter the rapidly growing science, technology, engineering, and mathematics (STEM) fields.

Thus, while Wisconsin’s science and engineering workplaces are currently creating 9,800 openings each year requiring an associate or bachelors degree less than 7,500 degrees or certificates are awarded each year in these fields by Wisconsin’s higher education

institutions. Thus, Wisconsin’s present STEM workforce preparation GAP is at least 2,500 college graduates each year, and likely to rise substantially as the 14-17 age youth population declines by 11% over the next decade.

In Wisconsin, the most recent educational pipeline data indicate that *for every 100 students who enter the 9th grade in Wisconsin high schools:*

- 79 graduated from high school on time
- 47 entered college immediately
- 34 returned for their sophomore year, and
- 25 graduated with an associate degree within 3 years or a bachelor’s degree in 6 years (*The educational pipeline: Big investment, big returns, 2004*).

With 25% of 9th graders graduating from college on time, Wisconsin ranks 9th among all states on this key indicator. However, it is equally important to consider the majors and careers that students choose to enter when they enroll in higher and postsecondary education. States such as Colorado, Maryland, and California, where 38-37% of college graduates complete degrees in the rapidly expanding STEM fields, rank well ahead of Wisconsin. While more young adults and adults are attending college than ever before, their choice of majors and career fields has important consequences for the state’s economy, as well as for their futures.

Although Wisconsin schools and colleges have been highly successful over the past several decades, the Wisconsin Technology Council’s Vision 2020 report outlines the challenges that lie ahead:

- With a culture and business climate much like our own, Minnesota’s 2005 per capita income (\$37,373) is well above the U.S. average (\$34,586); the income gap between Minnesota and Wisconsin (\$33,315) is nearly \$4,000 per person and widening.
- Wisconsin needs 150,000 more college graduates to meet the U.S. per capita income average... and another 150,000 workers with

post-graduate degrees to exceed the U.S. per capita income average (*Vision 2020: A model Wisconsin economy, 2002*).

When considering other education and economic indicators, Wisconsin currently ranks substantially below the performance level of the top 5 states and several countries. To sustain the state's economic productivity and tax base, the Governor, along with the Wisconsin Technology Council and several other organizations, have called for new initiatives to strengthen science, technology, engineering, and mathematics education and workforce development.

Project Lead the Way is a technology education and pre-engineering program offered in more than 1,300 middle and high schools in 45 states, including 92 Wisconsin schools. Taken in conjunction with a college preparation course of studies, PLTW courses use project- and problem-based learning experiences that allow students to apply knowledge to real-world problems and situations. More specifically, the standards-aligned courses provide opportunities for students to:

- 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.

A recently published, rigorous analysis of student achievement in high school PLTW courses, conducted by the Southern Regional Education Board (Bottoms & Anthony, 2005), revealed some promising results. When compared to similar students enrolling in other career and technical education courses, 275 PLTW students who completed two or more PLTW courses scored *significantly higher* in reading, mathematics, and science on an assessment similar to the National Assessment

of Education Progress (NAEP). Moreover, these students had completed higher level mathematics and science courses, and enrolled in classes in which real world problems and group work was used to learn mathematics and science content. These results suggest clearly that PLTW and similar technology education courses offer the opportunity to raise the academic learning outcomes for a wide range of diverse students, who, in many cases, might not consider pursuing higher or postsecondary education.

This report summarizes recent trends and promising developments in Wisconsin's pre-engineering and technology education landscape. Initially, the changing landscape is examined by asking why engineering and technology education matters? Attention is given to recent trends in data that inform policymakers, educators, and other stakeholders about important performance benchmarks in developing the science, technology, engineering, and mathematics (STEM) education pipeline. Next, the report considers the extent to which recently published recommendations for redesigning high schools are consistent with the essential components of the PLTW and GTT curriculum. Additionally, findings from student surveys and focus groups in four Wisconsin high schools and two middle schools that have implemented PLTW courses over the past two years are summarized. Data from school-level focus groups, student engagement surveys, and existing data systems illustrate both the benefits and challenges associated with implementing this problem and project-based curriculum. Finally, a set of observations and recommendations for advancing pre-engineering and technology education initiatives and improving the STEM pipeline in Wisconsin are offered.

Why Learning for and about Engineering Matters

For Wisconsin schools and communities, *Project Lead the Way* (PLTW) programs represent a strategically critical response for strengthening the state's economic future. As the Governor and the Wisconsin Technology Council have noted in **Vision 2020: A Wisconsin Model Economy...** *Wisconsin must make the most of its people, resources and opportunities, and meet the challenges posed by the rise of the Knowledge Economy* (2002, p. 2). Several aspects of the global economy call for major changes in the ways in which secondary schools and colleges function and interact with employers to prepare future citizens for the expanding sector of science and technology careers. In Wisconsin, PLTW can be an essential component of both educational expansion and renewal efforts, as well as the economic and workforce development priorities.

The Governor's Grow Wisconsin initiative (Doyle, 2005) includes two strategic goals that form a centerpiece of a productive economy: (a) preparing worker's for tomorrow's economy, and (b) retaining and creating high-wage jobs. To understand the role of engineering and technology education in achieving these goals, we will examine more closely the current status of the K-16 educational systems, and examine the role of education in creating a high wage economy.

Troubling Trends

Rigorous, college-level science and mathematics instruction, along with effective pre-engineering and technical education, has been identified by distinguished commissions and panels, researchers and policy makers as a cornerstone of educational preparation for today and tomorrow's workplace (ACT, 2006; NSF, 2006; and National Commission on the High School Senior Year, 2001). However, a number of worrisome indicators and trends in science, technology, engineering and mathematics (STEM) education have emerged. The troubling trends for the U.S. and Wisconsin economies are documented in Figure 1.

Wisconsin's impending STEM workforce preparation crisis is evident at several points in the educational preparation pipeline: (a) the widening gaps in math and science achievement and school engagement by students from diverse backgrounds, (b) the limited career planning and development experiences provided in college and university settings, and (c) the continued emergence of significant scientific and engineering workforce needs.

1. Compared to other states, Wisconsin's secondary schools are graduating a substantially larger share of 9th graders on time. However, recent math and science scores for high school seniors suggest that both U.S. and Wisconsin high schools are less challenging than secondary schools in other countries.
 - According to the National Science Foundation (*Science and engineering indicators 2006, 2006*), U.S. 12th graders recently performed below the international average for 21 countries on a test of general knowledge in mathematics and science.
 - In the most recent National Assessment of Educational Progress (NAEP) 12th grade science assessment, the average science score for Wisconsin students was lower than in 1996, and showed no significant change from 2000. (Grigg, Lauko, & Brockway, 2006)
 - In the 2005 NAEP assessment for mathematics (Perie, Grigg, & Dion, 2005), 36% of WI 8th graders scored at the proficient or advanced level compared to 29% of 8th graders nationally.
2. An up-close analysis of the achievement data indicates that while the overall math and science performance of Wisconsin 8th graders is comparable to other states, the achievement gap for diverse students is growing at an alarming pace. The achievement gap was not statistically significant for males and females in the 2005 NAEP mathematics assessment, but the

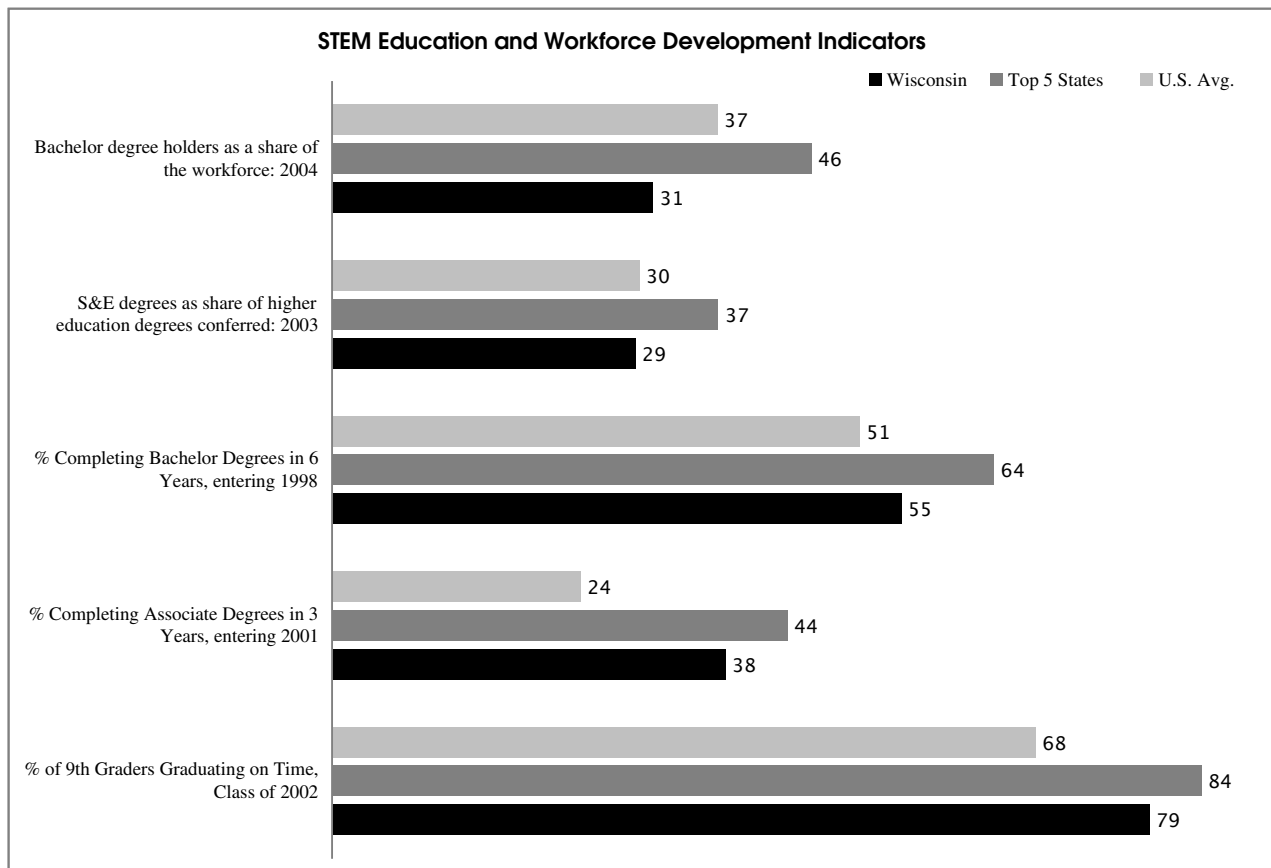


Figure 1: STEM Education and Workforce Development Indicators

scores for Black, Hispanic, and poor students was substantially lower than for their White counterparts.

For the 2005 NAEP Science assessment, 39% percent of Wisconsin 8th graders scored proficient or advanced on the science exam compared to 27% nationally. The science scores for males and females were comparable, but Black, Hispanic, and poor students all performed at levels substantially below Wisconsin’s White students. The gap between students performing at the 75th and 25th percentiles grew from 39 points in 1996 to 44 points in 2005, indicating a growing inequity in science learning.

3. Of the 79 Wisconsin 9th graders who graduate on time from high school, 47 will enter a 2- or 4-year college the following fall semester. With 16 technical colleges and a

comprehensive UW System, young adults can take advantage of opportunities to begin college without many of the added costs found in more urban or rural states (e.g., higher living costs, residence halls). However, several states with long-standing dual credit arrangements and financial aid incentives, which make college more affordable, are enrolling, on average, 55 high school graduates immediately following high school.

4. Wisconsin colleges and universities are particularly strong in retaining and graduating students. As noted in Figure 1, more than one third (38%) of Wisconsin students who enter college complete an associate degree within 3 years, which is well above the U.S. average for states (24%) but below the level achieved by the top 5 states (44%).

Similar results are achieved by Wisconsin students who pursue bachelor's degrees, although the gap between Wisconsin 4-year institutions and universities in the top 5 states is somewhat higher (9% compared to 6%).

5. What students select to study after enrolling in college is influenced by a number of factors. As Figure 1 reveals, of all undergraduate, graduate, and professional fall degrees granted by Wisconsin colleges and universities in 2003, only 29% of the degrees were in science and engineering. At this point in the STEM education and workforce pipeline, Wisconsin falls below the estimated average (30%) and well below the productivity of the top 5 states (37%).
6. A well educated workforce is vital to Wisconsin's future economy, as documented throughout this report. However, in 2004 less than one third (31%) of the state's workforce held a bachelor's degree, compared to 46% in the top 5 most educated states, according to the National Science Foundation (2006).
7. In Wisconsin's economy over the next ten years, growth in all occupations is expected to be 11.5%, while job growth in science and engineering fields will be 18.3%. Job growth in the science and technology sector will be nearly 60% larger than for Wisconsin's workforce overall. For every 5 new job openings, 8 new positions will be created in the STEM fields during the next ten years. These projections include both replacements for retiring and departing workers, and new openings created by industry and labor market growth.
8. As Figure 2 confirms, more than two-thirds (67.4%) of the new STEM jobs will require either an associate's or bachelor's degree for entry, compared with just 17.3% of all new positions in the Wisconsin economy requiring educational credentials beyond a high school diploma, according to the Department of Workforce Development
9. During 2000-05 only 18.6% of undergraduate degrees awarded by the UW System 4-year campuses were in engineering and science related fields, as shown in Figure 3 (*Bachelor's degrees conferred by UW system institutions, 2000-2005, 2006*). Of the 20,000-25,000 degrees and certificates issued by the Wisconsin Technical Colleges annually, approximately 15% of the credentials prepare graduates for technical and industrial occupations (Wisconsin Technical College System 2004-05 graduate follow-up report, 2005). On a global scale, 32% of U.S. undergraduates received their degrees in science and engineering. In Germany, China, and Japan, the corresponding figures were 36%, 59%, and 66%, according to the National Academy of Science (2005).

With the widespread use of media technology and games by children, one might expect that college majors in science, engineering, and computing would be on the rise. However, over the past ten years, according to American College Testing (ACT), the organization responsible for one of the two nationally-recognized college admission assessments, the percentage of ACT-tested students planning to major in engineering has declined from 7.6 percent to 4.9 percent. Over the past five years, the percentage of students interested in computer and information science has dropped from 4.5 percent to 2.9 percent (ACT, 2006).

2004–2014		
STEM Occupational Sector	Average Annual Openings	Percent of Change
Science Occupations	7,234	25.3%
Technology Occupations	3,402	12.3%
Engineering Occupations	1,610	9.9%
Mathematics Occupations	1,659	15.6%
Total STEM Occupations	13,813	18.3%
All Occupations in Wisconsin	106,609	11.5%

Figure 2: Wisconsin Occupational Growth Projections: 2004-2014

STEM Fields of Study	Number of Graduates	Percent of all BS Degrees Awarded
Agricultural Science	1,219	1.1%
Natural Resources	1,596	1.5%
Computer Science	2,668	2.4%
Engineering	5,130	4.7%
Engineering Technology	886	.8%
Life/Biological Science	7,225	6.6%
Mathematics	1,318	1.2%
Physical Science	1,515	1.4%
TOTAL	21,557	19.6%

Figure 3: UW System Bachelor Degrees: 2000-2005

Skilled Workforce: An Essential, Core Ingredient for the New Economy

The critical role of secondary and postsecondary education in creating high-wage jobs is receiving considerable attention in policy discussions at the state and national level.

Recent econometric studies of labor markets and workforce trends have identified several factors associated with high rates of economic and productivity growth. Researchers at the Upjohn Institute for Employment Research (Eberts, Erickcek, & Kleinhenz, 2006) identified four common measures of regional growth in studies conducted between 1994 and 2004: growth in gross regional output (business performance), growth in employment, growth in productivity, and growth in per capita income. Eight hypothesized growth factors were established using factor analysis. The subsequent regression models indicated that a *skilled workforce* was highly predictive of *gross regional output, productivity, and per capita income*. Included in the skilled workforce factor were the following indicators: percent of the population with bachelor and graduate degrees; the number of occupations with high education content, such as professional occupations and patents per employee; productivity of the information sector; and skills of the workforce. *Overall, the skilled workforce factor ranked as the most influential factor in predicting growth in: gross regional output, productivity, and per capita income. Clearly, the knowledge and skills of the workforce are essential ingredients for developing and maintaining robust regional economies.*

In their analysis of Wisconsin's readiness to engage the New Economy, David Ward and Dennis Winters (2005) cite trends that argue for a major priority on STEM-focused economic and workforce development.

- From 1973 to 1998, the annual average growth in personal income was 2.8% for the U.S, but only 2.3% in Wisconsin. The 1999-2024 forecasted annual growth rates will be 2.3% nationally, but limited to 1.8% in Wisconsin.

- By 2024, the typical Wisconsin citizen will be earning only 83% (\$40,598) of the national average annual income.
- Low income growth rates lead to: lower incomes, decreased tax bases and budget deficits, fewer public services, and lower quality of life.

Without question, Wisconsin's educational investments must focus on a set of strategically selected workforce preparation and development priorities. Based on the state's substantial scientific research and discovery capacity, expansion of the science and engineering sector shows great promise for creating and sustaining high wage jobs and sustained economic growth. However, fulfillment of this promise rests heavily on the willingness of educators, communities, and parents to make exposure to and engagement in STEM education a reality for all students.

STEM EDUCATION IN WISCONSIN'S 21ST CENTURY SECONDARY SCHOOLS

In many areas, Wisconsin has a distinguished history of offering students challenging high school learning experiences. Each year between 65-70% of Wisconsin's students complete the ACT college admissions test and perform at a high level. With an average composite score of 22.2 for the past three years, Wisconsin ranks 1st or 2nd among the 25 states in which more than 50% of high school students complete the exam (*ACT national and state scores*).

Despite an exemplary record of excellence, the 21st century has created new demands on high schools and significantly greater expectations for high school graduates entering a rapidly changing economy and society. In 2004 State Superintendent of School Elizabeth Burmaster commissioned a High School Task Force (*State Superintendent's High School Task Force Report, 2006*) to examine ways to "...ensure our high school graduates leave school with a strong

foundation for success” in the 21st century’s knowledge-based economy. The Task Force provided four recommendations:

- Encourage educators and policymakers to move outside of existing structures and pursue innovation.
- Give students the opportunity to engage in rigorous, authentic learning experiences that are relevant to their learning needs and future ambitions.
- Create small, personalized learning environments and require learning and lifelong education plans for individual students.
- Promote and enhance partnerships among schools, parents, businesses, and communities, linking community resources with school programs and curriculum.

Over the past five years, reforming and redesigning America’s high schools has been a major point of debate on the national scene as well. State education agencies, national organizations (including the National Governor’s Association and Education Commission of the States), and several major foundations, including the Bill and Melinda Gates Foundation, have argued that the comprehensive high school must be transformed into smaller learning communities, which engage students and teachers deeply in acquiring knowledge and skills for the 21st century.

The National High School Alliance—a partnership of nearly 50 organizations and associations has served as a catalyst for advancing the excellence, equity and development of the nation’s high school youth. In April 2005, the NHSA issued a widely-cited and acclaimed publication entitled: *Call to Action: Transforming High School for All Youth*. A diverse collection of organizations, including the College Board, the National League of Cities, the National Education Association, and the Chicago Community Trust, have embraced NHSA’s six core principles *for ensuring that all*

students are ready for college, careers, and active civic participation:

- Academic engagement for all students
- Personalized learning environments
- Empowered educators
- Accountable leaders
- Engaged community and youth
- Integrated system of high standards, curriculum, instruction, assessments, and supports

Several of NHSA’s high school redesign recommendations are closely aligned with the strategic objectives and design elements of high quality STEM curricula for secondary schools. The Project Lead the Way (PLTW) pre-engineering program, described earlier in this report, has been cited by the National Academies Press (2005) as a model curriculum for “...vastly improving K-12 science and mathematics education.” With support from the Wisconsin Department of Public Instruction, the Kern Family Foundation, and the Greater Milwaukee Foundation, the PLTW curriculum, which includes a set of 9-week instructional modules for middle schools (Gateway to Technology-GTT), had been adopted by 92 middle and high schools across Wisconsin.

For high school educators and school boards, an important question emerges. To what extent are the PLTW and GTT curriculum components aligned with current “best practice” recommendations from national and Wisconsin-focused high school reform reports? Figure 4 illustrates the 3-way alignment of the NHSA and State Superintendent’s High School Task Force recommendations and the essential components of the PLTW and GTT curriculum (center column). The letters and numbers in parentheses denote the specific recommendations from each report.

(A): Personalized Learning Environments	National High School Alliance <i>Recommended High School Redesign Strategies</i>	Essential Features: PLTW and GTT Curriculum	Wisconsin High School Task Force <i>Recommendations</i>
	<p>(A2): <i>Develop academically rigorous curricula that meet or exceed standards, are relevant to real-world contexts, and build on student and community assets.</i></p> <p>(A6): <i>Work across the school system to address student needs at critical transitions, in particular the transition from the middle grades to high school and from high school to post-secondary education.</i></p>	<p>PLTW curriculum is aligned with the national and State of Wisconsin (DPI) model academic standards for mathematics, science, and technology education.</p> <p>The GTT middle school curriculum consists of five independent units to be taught in conjunction with a rigorous academic curriculum. The units are designed to challenge and engage the exploratory minds of middle school students, and provide a foundation for choosing academic and elective high school courses. Performance objectives and student assessments are included with each unit.</p> <p>Selected colleges and universities are accepting PLTW courses for university credit. For example, at the Milwaukee School of Engineering students from a PLTW certified school may apply for three college credits for any of the PLTW courses, except the capstone course. In addition to graduating from a PLTW certified school, the student must have an average of 85% or better for the course, have a completed course portfolio, and have a grade of 70% or better on the PLTW college exam and pay the required tuition.</p>	<p><i>Ensure that all students have access to a variety of options for learning, including the arts, co-curricular activities, work-based learning, service learning, and accelerated offerings, to fully engage all types of learners (B1)</i></p>

Figure 4: Alignment of High School Reform Recommendations with the Essential Features of the PLTW and GTT Curricula

(B): Academic Engagement for All Students	National High School Alliance <i>Recommended High School Redesign Strategies</i>	Essential Features: PLTW and GTT Curriculum	Wisconsin High School Task Force <i>Recommendations</i>
	<p>(B1): Engage all students in a rigorous, standards-based core academic curriculum</p> <p>(B2): Emphasize project-based learning and other engaging, inquiry based teaching methods that provide opportunities for students to master academic content, learn workforce skills, and develop personal strengths</p> <p>(B5): Connect curriculum to real-world contexts that build upon student and community resources</p> <p>(B6): Provide individualized guidance, information, and resources on career pathways and opportunities for participating in workplace-based learning</p> <p>(B8): Use multiple measures to assess student outcomes, including performance-based assessments</p>	<p>PLTW curriculum is aligned with the national and State of Wisconsin (DPI) model academic standards for mathematics, science, and technology education.</p> <p>Tesla Engineering Charter School, a 4-year charter school in Appleton, which uses the PLTW curriculum with a CIM specialization, has been in operation since 2002. For the past 4 years, the school has experienced increasing enrollments. Of its 39 graduates, 95% are enrolled in engineering and technology programs in 4-year colleges.</p> <p>Instruction is heavily focused on problem based and workplace-connected learning. The capstone course, Engineering Design and Development, is 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 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.</p> <p>Mandatory professional development for guidance counselors focusing on workforce needs in engineering and technology careers (counselors from certified schools must participate every three years).</p> <p>Nationally standardized, end-of-course assessments featuring both traditional and constructed student response formats.</p> <p>Some universities and colleges are reviewing students' PLTW course portfolios for admission and placement.</p>	<p><i>Fund innovative strategies to increase academic rigor and integration of curriculum at the local level, including creation of new schools, including charter schools. (A2)</i></p> <p><i>Examine new models and identify best practices in student learning that are both authentic and relevant, and fully assess the rigor and viability of multiple pathways to academic achievement. (B2)</i></p> <p><i>Promote instructional practice that includes problem-solving and creativity and prepares students to solve real-world problems and participate as citizens in a diverse and multi-cultural world.(B3)</i></p> <p><i>Provide an adult advocate for each student to establish a meaningful and on-going relationship. (C2)</i></p>

	<p>National High School Alliance Recommended High School Redesign Strategies</p>	<p>Essential Features: PLTW and GTT Curriculum</p>	<p>Wisconsin High School Task Force Recommendations</p>
<p>(C): Empowered Educators</p>	<p>(C2): Build educators' capacity to use data and research to inform instructional practice and to guide professional learning priorities and needs</p> <p>(C5): Utilize communities of practice as a mechanism for transforming the way educators are prepared, inducted, and retained</p>	<p>Wisconsin Guidebook provides tools and resources for analyzing data to strengthen professional development, generate curriculum change and improve student recruitment and learning.</p> <p>Intensive 2-week summer institutes held at national affiliated universities with strong engineering programs</p> <p>Virtual academy for professional development is available nationally and several state PLTW projects have teacher websites.</p>	<p>Provide professional development for educators in the use of multiple assessments, including assessment tools that incorporate hands-on demonstration of knowledge and skills. (B4)</p>
<p>(D): Accountable Leaders Environments</p>	<p>(D1): Engage state, district, school, community, youth, and municipal leaders in articulating a shared vision for all high-school-age youth and in defining accountability at each level.</p> <p>(D3): Use data to monitor and communicate progress to all stakeholders</p> <p>(D4): Assess the impact of any reform or policy practice on all populations of students, particularly those traditionally marginalized such as English-language learners and students with disabilities</p>	<p>Each high school maintains a local Partnership Team, which links the school technology program with the community and creates a multidisciplinary support network for teachers and students</p> <p>The PLTW Guidebook provides annual data profiles for each high school documenting changes in: school and community context, course enrollments and program implementation, school and student outcomes, and post-school outcomes for graduates.</p> <p>Guidebook data profiles provide a tool for examining the status and progress of special student populations.</p>	<p>Use collaborative partnerships among schools, businesses, and community-based organizations to ease the strain of funding limitations. Involve business members in classroom activities and students in workplace sites. (D1)</p>
<p>(E): Engage Community and Youth</p>	<p>(E2): Commit community resources and establish partnerships with the school and district to support this vision</p> <p>(E4): Hold education leaders accountable for communicating data on youth outcomes</p>	<p>PLTW certified high schools maintain a Local Partnership team. This team creates community support for the technology program, links the school and community, provides additional resources to students and teachers, and opens pathways for students to career opportunities and further education, and provides professional development resources for educators.</p> <p>PLTW data profiles include annual reports on school and post-school outcomes for all students and recent graduates.</p>	<p>Encourage collaboration within the entire education community, including schools, colleges, universities, and technical colleges, to design and deliver programs to meet individual student learning needs and expand course offerings. (A1)</p> <p>Promote credit-based work experiences, school-business partnerships, and school-to-work opportunities to link 9-12 with post-high school education and employer workforce needs. (D2)</p>

(F): Integrated System of High Standards, Curriculum, Instruction, Assessments, and Supports	National High School Alliance <i>Recommended High School Redesign Strategies</i>	Essential Features: PLTW and GTT Curriculum	Wisconsin High School Task Force <i>Recommendations</i>
	<p>(F1): Establish clear and rigorous standards aligned with curricula and entrance requirements for post-secondary education and careers</p> <p>(F2): Develop and utilize multiple assessments, including performance-based measures (e.g., portfolios, public exhibitions, capstone projects), that align with standards</p> <p>(F3): Plan intended outcomes and assessment strategies before initiating a learning activity or project</p>	<p>PLTW curriculum is aligned with the national and State of Wisconsin (DPI) standards in mathematics, science, and technology education.</p> <p>The Wisconsin Technical Colleges provide advanced standing and college credit for selected PLTW courses completed in high school.</p> <p>The end-of-course assessments include traditional and constructed response items. For some universities and colleges, the assessments indicate</p> <p>Each of the units in PLTW courses include performance objectives and learner outcomes. Many of the instructional units utilize problem based or project based teaching strategies.</p>	<p><i>Enhance PK-16 partnerships that foster seamless education to prepare students for success after high school, life-long learning expectations and citizenship engagement. (B5)</i></p>

This analysis suggests clearly that the adoption of a rigorous and engaging STEM curriculum is supportive of the recommended action plans for improving high schools nationally and in Wisconsin. Curricula such as PLTW and GTT can directly address many of the challenges that communities and high school confront in preparing students for 21st century careers.

PRE-ENGINEERING EDUCATION IN WISCONSIN SCHOOLS: PROMISING DEVELOPMENTS

During the 2005-06 school year, the GTT and PLTW implementation efforts in six schools—two middle schools and four comprehensive high schools—were examined and studied by a team of researchers from the Center on Education and Work. Each of the schools was in the first or second year of implementing PLTW or GTT courses. Two of the schools had diverse student populations.

In addition to compiling some early evidence on the implementation of PLTW programs, the project focused on designing and field-testing assessment tools and processes that would assist local school teams in examining student outcomes and using data to improve instructional practices in technology and pre-engineering programs. In consultation with the school teams, data were compiled from multiple sources. A Program Progress and Performance Profile was developed, which serves as a tool for educators and community partnership teams to continuously monitor the implementation and effects of PLTW instruction at the school and district level.

During the year we collected and compiled data from several sources to gather a snapshot of the successes and challenges that educators, students, and schools are encountering as GTT and PLTW courses are being implemented. In the following sections, we summarize the data collected from three sources: (a) students'

perceptions on the engaging features of the PLTW curriculum, (b) the perspectives of local PLTW teams, and (c) the school-level and postsecondary education databases describing student's academic success and the progress graduates are making in higher education institutions.

Engagement: Student Perceptions and Voices

The nature and extent of student engagement in high schools offering the PLTW curriculum was examined using a survey and by posing engagement questions in the student focus groups. In total, 26 students who had completed one or more PLTW courses participated in one-hour focus groups held at each of the high schools. Focus group participants were selected by the PLTW staff at each school as representative of the students enrolled in PLTW courses during the 2005-06 school year.

In May, 150 students from the four high schools completed a nationally-marketed student engagement survey to compile their assessment of the current year high school learning experiences. Our January meetings with teacher and counselor teams at each school led to the selection of the High School Survey of Student Engagement (HSSSE) instrument. Developed by the Center for Evaluation and Educational Policy at Indiana University, HSSSE is a survey that offers teachers and administrators summary information on the school's characteristics that shape students' experience. In 2004 and 2005, the survey was completed by 200,000 students from high schools across 29 states. The HSSSE instrument is a short, reliable paper-based survey that students complete in approximately 20 minutes. All students completing the survey had returned an informed consent statement signed by a parent or guardian. Of the students surveyed in the four schools, approximately 100 had completed one or two PLTW courses, while 50 students who had not completed a PLTW course were selected to serve as a comparison group. Students were chosen to complete the survey by teachers or counselors.

These initial survey findings should be interpreted with caution. Due to local circumstances, it was not possible to randomly select students for participation in the focus groups. In this analysis of the survey data, the samples of PLTW and non-PLTW students were not large enough to be matched by gender, income level, grade level, academic ability, or other factors, which may contribute to their assessment of school engagement factors.

Several findings from the HSSSE survey reveal the following emerging engagement effects, which may be associated with implementing the PLTW curriculum. In parentheses, the results for PLTW and non-PLTW students are presented along with the comparable data from the 2006 national sample, which included 81,499 high school students.

1. In rating their feelings about the high school they attend, PLTW students are 9-13% more likely than non-PLTW students attending the same high schools to say:
 - They have opportunities to be creative in classroom assignments and projects (91% vs. 81%; national benchmark (nb) 71%)
 - (That they) are an important part of the high school community (63% vs. 54%, nb 55%)
 - The school makes them feel confident in who they are (76% vs. 63%, nb 58%)
 - They are engaged in school. (82% vs. 72%, nb 72%)

In focus group settings, student comments included:

- *(PLTW) is a better learning experience because you are self-motivated.*
- *I had some interest in engineering, but wanted to get some background.*
- *Some students are scared off because it is 'engineering'.*
- *After PLTW, you can see 'why' the ideas from Physics are important.*

In these schools, students say that PLTW programs do not detract from their participation in the high school community. These findings suggest that the PLTW project-based learning experiences are potentially associated with promoting: students' self-confidence and creativity, their career exploration goals, and their overall engagement with or connection to the school.

2. In describing how often during this school year (2005-06) they *spent time engaged in various learning experiences*, PLTW students are 8-18% more likely to say that "sometimes or often" they were:
- Working on a paper or project that required research outside of assigned texts (90% vs. 72%; national benchmark (nb) 77%)
 - Working with other students on projects/ assignments during or outside of class (73% vs. 65%; nb 70%)
 - Connecting ideas or concepts from one class (or subject area) to another in doing assignments or participating in class discussions (75% vs. 63%; nb 68%)

Student comments and insights expressed in the focus groups included:

- *I used math and some physics in the IED class.*
- *This is the only elective where you apply core subjects.*
- *The Digital Electronics course encouraged me to take senior level math.*
- *I took a lot of math and science, and I was looking for a class in which I could apply that.*
- *This is as challenging as an AP math or science course.*

PLTW's emphasis on project-based or problem-focused teaching methods is reflected by students indicating they often go beyond the assigned text material and spend time with other students studying outside of class. With 75% of PLTW students saying they sometimes or often connect ideas across the curriculum, it appears that the PLTW alignment with math, science, and English standards is seen by students as reinforcing learning. Students also note that math

and science concepts were applied in PLTW courses, and conversely PLTW applications were found in math and science courses. Moreover, the comments from juniors and seniors affirm the rigor and relevance of PLTW courses in relation to academic and AP courses.

3. When asked to what extent their high school encourages students to *engage in active learning and futuristic thinking*, PLTW students were 10-20% more likely than non-PLTW student to say the school encourages them to:
- Use computers (72% vs. 52%; national benchmark (nb) 50%)
 - Explore new ideas (63% vs. 51%; nb 49%)
 - Continue schooling beyond high school (college, career training, etc.) (88% vs. 78%; nb 78%)

In discussing PLTW courses, students offered some key observations about the applied and futuristic learning experiences they encountered:

- *PLTW gives us a taste of what we are getting into.*
- *This is practical for any profession.*
- *You think so differently because you cannot just look up the answers. You have to come up with the solution. It is more critical thinking.*
- *The learning that comes when it doesn't work is just as valuable as the learning when it does work.*

For some students, the availability of college credits for the PLTW courses encouraged them to enroll. Further, students exposed to this pre-engineering and technology education curriculum say they develop a better understanding of available career options and talents and interests required. The technology tools used in PLTW classes, such as the Inventor software, appears to give students more time with computers and more opportunities to develop new understandings about various concepts and phenomena. Finally, the problem-focused learning experiences have general intrinsic value for many students.

4. The differences in how PLTW and non-PLTW students see their recent school *experience as contributing to their growth* are profound. As noted in Figure 5, when compared to non-PLTW students, those completing PLTW courses are 12-20% more likely to say they had grown quite a bit or very much in seven interpersonal, developmental, and technical areas:

Comments from the student focus groups illustrate how PLTW learning promotes growth in particular areas:

- *Even though I'm not pursuing an engineering profession, the problem-solving skills learned are important no matter your field.*
- *PLTW has helped me choose a career and college major.*
- *PLTW teaches you how to work with people.*

Exposure to courses in engineering principles and digital electronics appears to help students clarify their goals and gain skills for pursuing careers and to solve workplace problems. Involvement with the curriculum gives students skills in working with others, treating others with respect, and developing personal values. Equally important, PLTW students are 20% more likely to indicate they had experienced substantial growth in reading and comprehending challenging material.

Use of the HSSSE 2006 survey provided the opportunity to compare the responses of Wisconsin's PLTW and non-PLTW students from four high schools to a large national sample of high school students (n=81,499). Compared to the 2006 national benchmarks, both PLTW and non-PLTW students were 5-10% more likely to indicate: (a) they had opportunities to be creative in classroom assignments and projects, (b) the school helped them feel confident in who they are, and (c) they had grown substantially in using computers and the internet. For Wisconsin's PLTW students, they were 5-10% more likely than their national peers to say they:

- Worked on a paper or project that required research outside of assigned texts (90% vs. 77%)

- Were encouraged to continue schooling beyond high school (88% vs. 78%)
- Were engaged in school (82% vs. 71%)
- Connecting ideas or concepts from one class (or subject area) to another in doing assignments or participating in class discussions (75% vs. 67%)
- Were using computers (72% vs. 50%)
- Were exploring new ideas (63% vs. 49%)
- Were developing clear career goals (57% vs. 51%)
- Were solving real world problems (56% vs. 47%)

Compared to a national sample of high school students, the four Wisconsin high schools in this study had teaching and learning practices in place that enabled students to feel creative in their classroom learning, build their self-confidence, and expand their knowledge of computers and the internet. However, the value-added factors for PLTW students placed them well above the school engagement ratings of their peers from other states in several areas crucial to improving the STEM education pipeline. Notably, Wisconsin's PLTW students were: 22% more likely to be using computers, 10% more likely to indicate they were working on projects requiring research beyond assigned text material, 9% more likely to indicate they were solving real world problems, and 6% more likely to have clear career goals.

Twenty middle school students from two schools also participated in end-of-the-year focus groups and provided their perspectives on the Gateway to Technology modules. Two major themes emerged. First, these 6th, 7th, and 8th grade students found that *using computers and building machines and vehicles created highly engaged learning experiences*. Some of the illustrative comments included:

- *Building the contraption was fun because you could see how it works.*
- *The best part of the whole project is that at the end you can see all of your hard work paid off when the project works.*
- *I'm interested in being on the high school robotics team.*

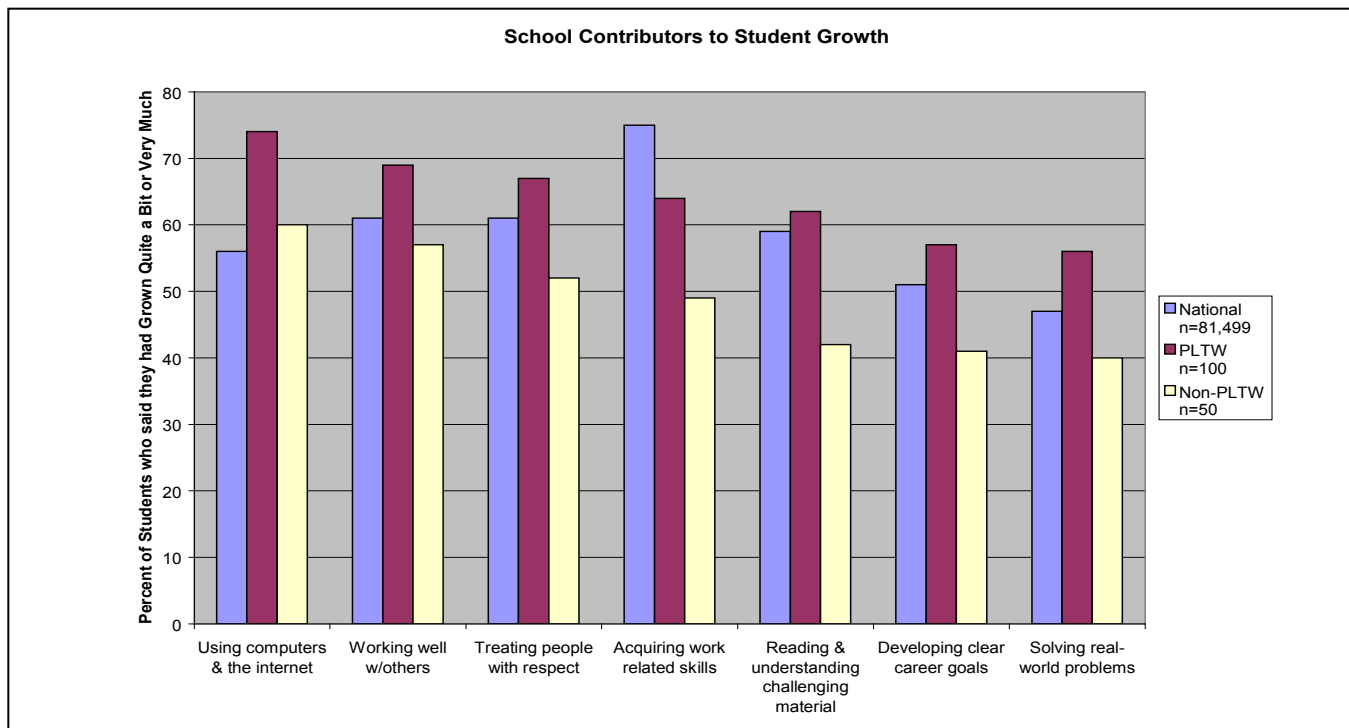


Figure 5: Recent School Learning Experiences and Student Growth

Second, the GTT modules and learning experiences demonstrated the value of academic content learning and showed students the mutual benefit of applied and academic learning. Student insights included:

- *We used math and motion principles in the engineering projects.*
- *In GTT activities, we got to use what we learned in science.*
- *We learned how to use it, not just read about it.*
- *Geometry was easier to understand after the GTT project.*
- *We used the same project for our science and GTT class.*

Generally speaking, the middle school students were enthusiastic about the GTT learning experiences, particularly the design-focused and project-based instructional units. Several students felt the units would be more difficult and expressed having doubts at the beginning of the year on whether they would be successful. For those students with some initial reservations, it turned out to be exciting, challenging, and rewarding.

Educator Perspectives and Reflections

In May, hour-long focus groups were conducted with the PLTW implementation teams at each of the six schools. In most schools, the focus groups included 2-4 technology education teachers, a guidance counselor, school principal, and at three schools, a math or science teacher. Across the six schools, 27 educators participated in the focus groups.

Five major themes emerged from these interviews:

1. Several aspects of the PLTW curriculum provide engaging, rich, and connected learning experiences for students:
 - Support from local industry partners enables students to see and participate in real world projects and assignments.
 - Real world assignments lead to important outcomes, like summer engineering jobs.
 - In some courses the physical properties of materials and products are tested, which gives students the opportunity see the relevance of chemistry and physics. It allows them to test out their solutions

- to important, real world problems.
 - The curriculum attracts more college bound students, which makes the learning environment more challenging for all students. More of our students are “driven”, rather than “exploring”.
 - Students can see the life and real-world applications of what they are learning.
 - Teachers and counselors report that interest in PLTW is high among a broad range of students, including students who are not traditionally technology education students.
2. The structure of the curriculum and the emerging network among teachers makes the process of teaching new material easier.
- The real world learning experiences included in the curriculum validate and extend the PLTW teachers’ knowledge.
 - By being a PLTW school, teachers are able to participate in a larger support network of teachers. The online tutorials and state conferences provide excellent opportunities for communicating with colleagues, and the common curriculum focuses teachers across the state on the same student learning goals.
 - With the prescribed PLTW curriculum, required teacher training, and end-of-course assessments, schools and teachers avoid using outdated content and software.
3. In some districts, the PLTW curriculum is contributing to school-wide improvements in student learning.
- PLTW students in one high school are doing better on the state mathematics assessment, partly because the state exam now uses more items that require problem solving.
 - In an urban high school, a cohort approach was being used so that freshman and sophomores are with the same team of PLTW, math, and science teachers. This academy approach is designed to promote curriculum integration and team teaching. Some educators report that this approach does not foster independence and individual growth.
- When district-mandated reading and writing tasks and assessment rubrics were implemented in one high school, the PLTW teachers were able to include them in the courses without difficulty.
 - In one school, teachers noted that the problem-solving items on the end-of-course assessments enabled some at-risk students to achieve scores that were close to giving them college credit. This suggests the curriculum and assessments provide significant authentic learning opportunities.
4. The program cost issues are not trivial and may affect the future implementation of the program.
- Funds from Kern and Greater Milwaukee Foundations have seeded the teacher training and other essential program start up costs. With the precarious federal funding for career and technical education programs, some educators envision challenges in keeping the programs in place.
 - As courses are updated, the rising cost of software licenses and new equipment may be difficult to support as local school funding continues to shrink. Educators encourage national and state PLTW leaders to support and broker large group purchase arrangements.
5. The curriculum alignment with and endorsement of higher and postsecondary education institutions in Wisconsin is critical to long term success of the PLTW program.
- Expansion of the transcribed credit arrangements with WTCS System or local campuses is needed.
 - All public 4-year engineering colleges need to make public affirmations about their support for the PLTW curriculum and their interest in attracting these students. Schools are unlikely to adopt new arrangement for granting high school math and science credits unless the college admission offices are ready to accept them.

Enhancing School Improvement and Accountability Capacity

Like schools and districts across the U.S., Wisconsin educators are intensely focused on improving student learning and reducing the achievement gaps between student sub-groups. Under the No Child Left Behind (NCLB) Act, states must implement grade-level assessments, set benchmarks for ensuring that all students will become proficient by 2014, and monitor the annual progress of schools and districts in meeting this goal for all students. A number of other concerns (many of which were cited earlier) have led the National Governor Association, the Bill and Melinda Gates Foundation, and other groups to call for major changes in the American high school. In the preface to *High Schools for the New Millennium: Imagine the Possibilities*, *The Bill & Melinda Gates Foundation* (n.d.) captured the essence of the call for increased improvement and accountability:

Every year our country loses thousands of young people—students who leave school without graduating or without the skills and knowledge to succeed in life. This failure to prepare the next generation for tomorrow’s challenges threatens our nation’s economic and civic health. Our schools, particularly our high schools, must prepare all students for the demands of college, work, and citizenship.

Today’s large, impersonal high schools were designed for a different era and a different economy, and they are leaving far too many young people behind. We are asking teachers to succeed in a system that is broken. Millions of young people are drifting through high school without adult attention or the relevant, rigorous coursework necessary to keep them engaged. Consequently, students—particularly African Americans and Hispanics—are dropping out at alarming rates. Indeed, three out of every 10 students do not even graduate.

The national agenda for the Project Lead the Way initiative seeks to address several of the problematic outcomes cited by the Gates Foundation. Some striking parallels can be found in the national goals for PLTW, which include: (see: www.pltw.org)

1. Increase the number of young people who pursue engineering and engineering technology programs requiring a four or two-year college degree.
2. Provide equitable and inclusive opportunities for all academically qualified students without regard to gender or ethnic origin.
3. Provide clear standards and expectations for student success in the program.
4. Reduce the future college attrition rate with four and two-year engineering and engineering technology programs.
5. Provide leadership and support that will produce continuous improvement and innovation in the program.
6. Contribute to the continuance of America’s national prosperity.

LOCAL PROGRESS AND PERFORMANCE PROFILE: A RESOURCE

To assist Wisconsin school leaders and educators in using PLTW as a resource for high school improvement and accountability, a Progress and Performance Profile was developed and field tested. By constructing and testing the Profile jointly with local teams, we sought to align the data and information collected to improve PLTW programs with the accountability and performance standards called for by state and national policy makers. In two design team workshops and a series of school visits, our local teams and advisors outlined the program improvement and accountability data needed to address 11 core questions in four primary focus areas:

School and Community Context Questions

- 1.1 Who attends this school?
- 1.2 What are the regional STEM career opportunities?
- 1.3 What are the credentials of educators at this school?

Implementation Questions

- 2.1 Who enrolls in Technology Education and PLTW classes?
- 2.2 What are the career interests of students at this school?
- 2.3 What community resources and postsecondary connections support the program?

Student and School Outcome Questions

- 3.1 To what extent are student motivated and engaged by PLTW instruction?
- 3.2 To what extent are PLTW students learning important engineering knowledge, as represented by the end of course assessments?
- 3.3 To what extent are PLTW enrollment increases associated with increased academic learning and achievement?

Post-School Outcome Questions

- 1.1 Are graduates entering and succeeding in 4-year colleges?
- 1.2 Are graduates entering and succeeding in 2-year colleges?

A Guidebook for Local Teams was produced to describe the procedures that local educators and community partnership members can use to compile the data annually for each inquiry question. When compiled over several years, the Profile data document the extent of program development, as well as the performance and accomplishments of students and graduates in pursuing college and career outcomes related to science and engineering. The Profile incorporates data from multiple sources, including state education websites and annual reports, the school district's instructional management database, standardized school climate instruments such as the High School Survey of Student Engagement, and focus groups of students, staff, and other key stakeholders.

In each of the six participating schools, the principals and PLTW team used the Profile in different ways to guide instructional improvements and to document changes and improvements in the technology education programs for both internal and external stakeholders. When asked to report on the school-specific uses and impact of the Local Progress and Performance Profile, the following examples were provided in interviews and summary memos.

Using the Profile: Instructional Improvement

A middle school principal offered the following reflections on using the profile data to strengthen the career exploration and math outcomes, as well as the transition to high school for 8th grade students:

- The study of physical science in our grade 7 science classes is aligned with the design and building of the CO₂ car in the technology education class. There is a need to include math teachers in this integrated unit to strengthen the rigor of our math program. Also, as we re-align the science curriculum this year, we will look for additional connections between science and technology education content and teachers.

- Each year our 8th grade students complete the Wisconsin Career Assessment (WCA) and undertake a research project on a career of interest. Our PLTW Profile indicates that girls show less interest in Realistic and Investigative careers than boys on the WCA. By inviting community members to speak to 7th and 8th graders about careers in science, engineering, and technology this coming year, we hope to spark interest among our students in these career fields, and eventually to see increases in the WCA responses. This will also strengthen our relationship with the local industry partnership team and provide students with more resources for their research papers.
- One of our middle school improvement goals is to provide specific counseling to students showing an interest in Realistic and Investigative careers before they schedule high school classes. One of the high school PLTW teachers is providing us with information to share with students and parents about high school PLTW courses and the college credit opportunities. Also, we plan to move the 8th grade PLTW electives to the fall semester, so that students have more exposure to technology education opportunities before they register for high school.

Feedback from high school principals and PLTW teams offered different but somewhat similar uses for the data and information contained in the Profile. Several high school principals and PLTW teams described specific uses that have been made of the Profile data:

- The information on STEM career opportunities is an important part of the Local PLTW Profile at XXX High School. Over the past several years, we worked with the local 2-year college deans to align our career and technical education offerings with associate degree programs using the Wisconsin and county-wide job growth trends. We discontinued 13 courses and added 11 new courses that were aligned with the data. Working in collaboration with local businesses and the local technical colleges, we have

started new programs in Printing Technology and Certified Nursing Assistants. As a result of these efforts, the number of students receiving college credit at the local technical college doubled (from 317 to 771) in the past year. XXX High School has increased from six to 15 the number of high school courses awarding transcribed credit at the local technical college.

- At XXX High School, community based learning experiences are integrated into several courses. For example, last year several technology education teachers established a partnership with the city utility commission to design an alternative lighting plan for the new high school tennis courts. A team of students won the design competition and was awarded grant funds to complete the project. The industry and community partnerships data table in the PLTW Profile was used to document: (a) the number of meetings and consultations held with staff and engineers from the utility commission, (b) the number of students and teachers participating in design presentations, and (c) the number of utility commission engineers involved in reviewing the student design proposals.

Using the Profile: Internal and External Accountability

The Local Progress and Performance Profile has been used in several schools to provide information to internal audiences, such as teachers and students, as well as external audiences including parents, school board members, and local business leaders. Generally, accountability data is used to address summative questions about matters such as the status of enrollments in technology education and pre-engineering courses, levels of student learning or achievement attained in the program, or information describing how graduates are performing in college and university settings. Some of the recent accountability applications of the Local Profile are described below:

- Working with the Local guidance counselor, a high school principal generated a spreadsheet

summarizing student achievement outcomes for PLTW students for the recently completed school year. Using data extracted from the school's data management system, the report included data elements for the student outcome data tables in the Local Profile. Student scores on the PLTW end-of-course assessments were compared with student scores on the 10th grade state assessments in reading, mathematics, and science. With the student names removed, this report was shared with the State education agency officials interested in determining whether or not patterns of high, moderate, or low student achievement, as measured by state assessments, are associated with the completion of PLTW courses and students' success on the end of course assessments.

- In a recent summary of STEM-focused high school accomplishments, a principal referred to several data trends found in the Local Profile. His report noted that over the past four years, the high school had met the following benchmarks for improving STEM learning:
 - Implemented five PLTW courses in a three year period.
 - Increased the math and science scores in the past two years.
 - Improved the composite ACT math and science scores in the past year.
 - Increased the science graduation requirement from two credits to three credits.
 - Provided professional development opportunities for 25 teachers to attain certification in teaching Advanced Placement, International Baccalaureate, and PLTW courses in STEM fields.
 - Recognized by the Milwaukee School of Engineering as the Wisconsin high school with the largest number of entering PLTW freshmen students.

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