

the

STEM

SCHOOLS PROJECT

Science • Technology • Engineering • Math

CASE STUDY:

THOMAS WORTHINGTON HIGH SCHOOL

ABOUT THE CASE STUDY

This case study is one of a series of case studies produced for The STEM Schools Project. The purpose of the STEM Schools Project is to document promising practices in high schools and middle schools that are providing students a STEM-rich experience, drawing upon a high quality implementation of Project Lead The Way's Pathway To Engineering and/or Biomedical Sciences programs.

The Meeder Consulting Group conducted the site visits, wrote the case studies and final report, and is managing all aspects of The STEM Schools Project. The project is funded through generous support from the Kern Family Foundation based in Waukesha, Wisconsin (www.kffdn.org).

From information collected during each of the nine site visits, the authors prepared detailed, reader-friendly reports describing the schools' accomplishments, approach to STEM learning, and school improvement strategies. The case studies organize material into three overarching themes related to how schools use PLTW to spur STEM-related learning emerged:

- **CREATE AN EXCEPTIONAL PLTW IMPLEMENTATION,**
- **DEVELOP A SCHOOL-WIDE STEM CULTURE, AND**
- **IMPLEMENT RELATED SCHOOL IMPROVEMENT STRATEGIES.**

In addition to the case studies, a Final Report will be released that synthesizes key findings from all the case studies and places them in the larger context of STEM education reform. For more information about the STEM Schools Project, visit www.meederconsulting.com.

PART I. INTRODUCTION AND OVERVIEW

SUMMARY

At Thomas Worthington High School in Worthington, Ohio, teachers from the disciplines of math, science, engineering, and technology education are actively collaborating to create an integrated STEM (Science, Technology, Engineering, and Mathematics) learning experience for their students. With the encouragement of school administrators, teachers create cross-walks of their respective curricula, visit and observe other classes regularly, and offer students lessons and activities that explicitly link subject matters across multiple classes and previously discrete disciplines. Students experience science, technology, engineering, and mathematics as integrated and connected aspects of an overarching STEM education rather than as purely distinct subjects. Connecting across the STEM silos is not yet the norm for all teachers, but for a growing number of math, science, engineering, and other teachers, it is becoming a more pervasive approach to delivering their curriculum each progressive year. As one administrator stated, "For us, STEM is a verb, not a noun."

PROFILE OF THOMAS WORTHINGTON HIGH SCHOOL¹

Located in the northwest Columbus, Ohio, suburb of Worthington, Thomas Worthington High School (TWHS) is one of three high schools that serve the Worthington School District. TWHS, which is the oldest secondary school in Ohio and was the original high school in Worthington, enrolls approximately 1,485 students in grades nine through 12.

The Worthington School District serves a total of approximately 9,300 students and includes three high schools (TWHS, Worthington Kilbourne High School [WKHS], and Linworth Alternative Program), four middle schools, 11 elementary schools, and one Pre-K school. A five-member, elected school board and an appointed superintendent govern the district. The district is approximately 20 square miles and includes the City of Worthington, the Village of Riverlea, and parts of the City of Columbus and Sharon and Perry townships. The district's population increased dramatically from approximately 27,000 in 1980 to approximately 58,000 in 2000. Growth is now leveling off.

Of the 1,486 students enrolled at TWHS, 74 percent are white, 11 percent are black, 7 percent are Asian, 4 percent are Hispanic, and the remaining 5 percent are American Indian/Alaskan or of "other" (multiracial) origin. Approximately 33 percent of the students receive Free and Reduced Lunch, and 11 percent of the students receive special education services. The administrative team at TWHS

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includes one principal and three assistant principals. The school employs 85 teachers, five counselors, and two deans.

SYNOPSIS OF PROJECT LEAD THE WAY IMPLEMENTATION

In the fall of 2005, teachers from the Worthington Technology Education Department sought to develop a blueprint for refining the entire Technology Education program. They began a “Graded Course of Study Review,” a district process for reviewing curriculum and content. During this process, school personnel involved in curriculum review the current course of study and make formal recommendations on updating and/or modifying the content.

The Technology Education teachers from TWHS and WKHS formed an initial ad hoc advisory group that included members of the community, engineering professors from The Ohio State University, and representatives from local engineering companies/businesses. The input of the advisory committee, along with their own investigations, led the Technology Education teachers to determine that Project Lead the Way’s (PLTW) Pathway To Engineering (PTE) program was a good “fit” for their student population, and they decided to recommend its implementation.

The Graded Course of Study Review process requires a justification of the need for change, along with information on the sustainability of the change. The Technology Education teachers developed recommendations regarding the sequence and extent of PLTW courses to be offered and facility changes to be made to accommodate the program.

In Worthington, changes to the graded course of study go through an approval process including department chairs, school leaders at all impacted buildings, and all high school principals. Once those approvals are attained, the changes are voted on by the Board of Education.

The Worthington Board of Education approved the PLTW program during the 2006–2007 school year. Once the district approved the PLTW curriculum, the implementation of PTLW at TWHS took place over several years. In 2007, the first group of students at TWHS enrolled in the Introduction to Engineering Design (IED) course. In 2008–2009, a second class, Principles of Engineering (POE), was added. Two additional classes, Civil Engineering & Architecture (CEA) and Digital Electronics (DE), were added in 2009–2010. In 2010–2011, Engineering Design & Development (EDD) was added.

Most of the start-up costs for the initial PTLW implementation were paid for with a combination of Perkins funds and district and building funds. Additional funds are

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provided annually through the allocation of building funds. In 2012, TWHS administrators were informed that district and Perkins funds will probably not be available for the future. There is no current solution to this funding issue.

In the early phases of PLTW implementation, the Worthington Education Foundation, whose mission is to identify, fund, and support projects that enrich learning experiences for the students of Worthington Schools, facilitated the award and receipt of a \$20,000 grant from the Grainger Company for PLTW programs. The grant money, which was awarded on the basis of successful proposals from the PLTW teachers, was used to fund a 3-D solid modeling printer that is shared between the two high schools as well as robot supplies for the middle schools.

The table below provides a quick glance at the timing of, and historic and current enrollment in, PLTW at TWHS.

Project Lead the Way Enrollment					
PLTW Courses	Number of Students Enrolled				
	2007–2008	2008–2009	2009–2010	2010–2011	2011–2012
Introduction to Engineering Design *	80	69	60	63	38
Principles of Engineering	N/A	48	47	40	47
Digital Electronics	N/A	N/A	28	29	20
Civil Engineering & Architecture*	N/A	N/A	12	7	29
Engineering Design & Development	N/A	N/A	N/A	14	25
NOTES: *Students in IED must be enrolled in Algebra I or higher. CEA is also open to non-PLTW students who are juniors or seniors and are concurrently enrolled in Functions Statistics Trigonometry (FST). Source: Thomas Worthington High School, October 2011.					

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During the Graded Course of Study Review process (2005–2006), the Technology Education teachers reached out to their colleagues in the math and science departments to explore opportunities to link their curricula. This outreach began as informal conversations among the teachers and evolved into formal, coordinated meetings and planning during the second year of the PLTW implementation (2008–2009). This effort was based, in part, on feedback from their students, who were talking about their math and science lessons in their PLTW classes and beginning to make connections between their PLTW and academic courses. According to one teacher, the students were realizing that “the real world doesn’t work in silos” and that there are connections between content areas.

This collaboration among PLTW, math, and science teachers ultimately led to the development of a STEM School, a small learning community (SLC) focused on STEM education, in 2008 at TWHS. One PLTW teacher explained, “By year two of Project Lead the Way, we realized that the program could help connect core knowledge to the real world. We thought, ‘What if we worked as a team with core content teachers?’ “

THE STEM CONTINUUM MODEL

The working theory of the STEM Schools Project is that there is a natural continuum of integration and connection of STEM education occurring in schools that use Project Lead the Way’s Gateway to Technology (middle schools) or PTE and/or Biomedical Sciences (BMS) programs (high schools). In some schools, PTE and BMS are offered as sequences of courses that offer an excellent learning experience to students, but the courses stand alone and do not connect to other courses that fall under the STEM umbrella. In some schools, teachers—on a case-by-case basis and through individual initiative—inculcate some of the project-based and inquiry-based approaches of PLTW courses into the math and science courses that they teach. Alternatively, they may informally collaborate with colleagues in other content areas to create a smattering of integrated or linked curriculum units. Further along the continuum are schools that are actively and intentionally creating integrated and connected learning between STEM courses, and in some cases with other courses such as English Language Arts and the Social Sciences. In these schools, teachers are actively and consistently collaborating with the support of administrative team members.

The STEM continuum includes the following groupings of strategies:

- **CREATE AN EXCEPTIONAL PLTW IMPLEMENTATION,**
- **DEVELOP A SCHOOL-WIDE STEM CULTURE, AND**
- **IMPLEMENT RELATED SCHOOL IMPROVEMENT STRATEGIES.**

The remainder of this case study is organized around these groupings, although not every strategy in the continuum will be observed in every case study. If the strategy was not observed during the site visit or subsequent interviews, this fact is noted but should not be construed to reflect negatively on the school that is profiled.

PART II. STRATEGIES

1. CREATE AN EXCEPTIONAL PLTW IMPLEMENTATION

1.1 BUILDING READINESS AND SUPPORT FOR PLTW IMPLEMENTATION

Although the Graded Course of Study Review process provided the impetus and framework for change, James Gaskill, principal at TWHS, noted that the initiation and rollout of the PLTW program was largely teacher driven. He stated, “The administrators put the necessary structure in place to support the program, but this evolved from grassroots efforts. The teachers are the driving force behind it.”

Preliminary Analysis and Determination of Need

As part of their Graded Course of Study Review, the Worthington Technology Education teachers conducted an extensive review of state standards and textbooks and considered many options that could be used as a model for their program.

The input of an ad hoc advisory committee, which included members of the community, engineering professors from The Ohio State University, and representatives from local engineering firms, along with their own investigations, led the Technology Education teachers to determine that the PLTW PTE program was a good fit for their student population given the number of students who go on to study engineering in college. In addition, they saw the program as a solid framework from which career pathways could be built. (At that time, state and local education leaders emphasized the importance of developing better-defined “pathways” to help students make decisions about their postsecondary plans.)

The PTE curriculum seemed to meet the interests of local business, industry, and university partners who stressed the importance of applying core knowledge in relevant ways. It also supported the development of a scalable, STEM-based curriculum in the traditional high school setting. (In Ohio, there are many small

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magnet schools promoting STEM programs but few such programs in traditional high schools.)

The Technology Education teachers identified the following components of PLTW as opportunities to meet the needs of Worthington students and teachers²:

- Ongoing professional development and continuing education;
- Pre-engineering curriculum grounded in problem-based learning;
- End-of-course, nationally validated college proficiency exams;
- Statewide articulation to two- and four-year colleges and universities; and
- Opportunity for students to receive college credit (once PLTW program was nationally certified).

To build support for PLTW and to convince school and district leaders to adopt the PTE program, they developed a set of materials and presentations, which they shared widely at meetings with administrators, school board members, and community partners. They identified nine critical components that they wanted to see for their pathways³:

- Developing articulation agreements with postsecondary options;
- Alignment with the Ohio Department of Education Technology Standards;
- Sustainable programs that meet students' needs;
- Developing closer ties with business and industry;
- Establishing an Advisory Council;
- Ongoing professional development;
- A national network of similar programs;
- Evolving the current program; and
- Developing a blueprint for creating career pathway models.

The teachers also identified the following "Anticipated Student Outcomes" as a result of implementing PLTW⁴:

- Students learn to connect information they learn to the real world and to use the information in ill-defined and/or dynamic situations.
- Students learn to synthesize information and make informed decisions and predictions as they apply core knowledge to complex design problems. Knowledge is utilized from all disciplines.
- Classwork becomes more relevant to students because they know they will be using knowledge in problem-based learning.
- Students begin to make informed choices regarding career and postsecondary decisions.

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They set goals related to these outcomes, including:

- Increase interest, and ultimately, increase the numbers of students pursuing STEM-related professions in college.
- Increase standardized scoring in math and science.
- Increase student ability to apply math and science concepts in ill-defined and/or dynamic situations, utilizing an organized problem-solving model that guides students to successful solutions.

Worthington administrators are currently using Measures of Academic Progress (MAP) data to measure the growth of math and science content knowledge and are developing a matrix to measure their growth in the “problem solving” aspects of applying core knowledge.

Initial Implementation Recommendations

The Technology Education teachers recommended that both high schools develop an elective four-year sequence of PLTW PTE courses that would be phased in over a multiyear period. They set a goal to be as inclusive as possible, with all levels of students following multiple “tracks.” All students enrolled in PLTW would be required to take two foundational courses (POE and IED). They would have a choice of additional elective courses, to be followed by a required capstone course (EDD).

They also recommended that the district adopt PLTW’s Gateway to Technology (GTT) middle school curriculum. They determined that this program closely aligned with Ohio’s Technology Academic Content Standards in the middle grades. According to the Technology Education teachers, GTT would provide new and different ways of addressing Ohio content standards and the No Child Left Behind mandate for eighth grade technological literacy. The Board simultaneously approved GTT and the high school PLTW program; however, administrators note that the program has yet to be fully implemented in all Worthington middle schools.

To accommodate the classrooms and labs needed for PLTW, the Technology Education team recommended several facility changes, including the conversion of the existing Computer-aided design (CAD) lab at TWHS into a dedicated PLTW computer lab.

The recommendations of the Technology Education teachers received strong community support, notably from Dr. David Dickenson and Dr. Robert Gustafson (both engineering professors from The Ohio State University), who wrote letters of support, spoke at Board of Education meetings, and met with administrators to endorse the program.

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During the 2006–2007 school year, the Board of Education approved the implementation of PLTW. Worthington administrators noted that their actual expenditure for the first three years was very close to the budget estimates.

Program Launch

In 2007, the first group of students at TWHS enrolled in the IED course. Administrators and PLTW teachers anticipated running one section of IED in the first year of the program. Instead, they held three sections because of a high level of student interest, with approximately 70 total students enrolled.

In 2008–2009, a second course, POE, was added. Two additional courses, CEA and DE, were added in 2009–2010. In 2010–2011, EDD was added.

In 2009, the Ohio Department of Education, the Ohio Board of Regents, and the national PLTW organization awarded TWHS “National Accreditation” for excellence in program delivery in the PLTW program. Although the comments in the accreditation report were mostly complimentary, the accreditation team noted that Worthington needed to improve the program’s outreach and recruitment, particularly in targeting female students. On the basis of the comments, the Worthington PLTW teachers have made specific efforts to increase the visibility of the program. For example, they requested and were granted a time slot in the freshman orientation program. During this session, a PLTW teacher addresses the families of incoming high school students and presents an overview of PLTW and STEM.

1.2 SELECT AND SUPPORT A STRONG PLTW INSTRUCTIONAL TEAM

When developing their district’s PLTW program, Worthington administrators made the decision to keep it as a stand-alone curriculum taught by the school’s Technology Education teachers, rather than asking math and science teachers to be trained to teach the courses. Administrators determined that the Technology Education teachers’ backgrounds and training in hands-on projects and real-world problem-solving situations provided the best fit with the PLTW curriculum. As a result, the district’s 13 existing Industrial Education certified/Technology Education teachers from the high schools and middle schools were selected by administrators to be trained as PLTW instructors. As new Technology Education-certified teachers are hired to fill open PLTW teaching positions, they also receive training to become PLTW certified.

The high school PLTW teachers are located at two separate comprehensive schools in Worthington (TWHS and WKHS). This can be challenging because they operate as a single, unified department. However, they meet together regularly and are in almost daily contact to share information, training, certain equipment, and responsibilities such as recruitment and decision making.

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There are no current plans for core academic teachers to become PLTW-trained teachers. However, math and science teachers work in synergy with the PLTW teachers through the STEM Collaborative Team. There are currently approximately 12 teachers on this team. These teachers were selected by building administrators on the basis of their ability to be forward thinking, flexible, and invested in the STEM concept. With the support of building administrators, the team meets weekly.

1.3 SET GOALS FOR PROGRAM ENROLLMENT

Worthington administrators hold the philosophy that PLTW is a program that should be made available to all students. They believe that students can benefit from the knowledge and hands-on problem-solving processes that result from taking some or all of the PLTW courses, even if the students do not intend on continuing their engineering studies.

At TWHS, administrators initially planned for a cohort of 40–60 incoming students to enroll in IED classes (the PLTW introductory class offered at TWHS) each year. Their long-term goal, at full implementation, is to have at least 300 students (approximately 20 percent of the student body) enrolling in PLTW and/or STEM-related classes. For the 2012–2013 school year, TWHS has 61 students signed up for STEM, plus an additional 20 enrolled in the stand-alone PTLW IED class.

1.4 REACH OUT TO PROSPECTIVE PLTW STUDENTS

In Worthington, PLTW is an elective program at the middle and high school levels. Enrollment in the PLTW program is largely driven by student interest and the positive reputation of the program.

Although three middle schools offer GTT, the enrollment and degree of implementation varies by school. The two middle schools that feed into TWHS both offer GTT; however, only approximately 12 students from those middle schools who took GTT courses enrolled in PLTW at TWHS in 2010–2011. TWHS administrators stated that they are working to strengthen ties with the feeder middle school GTT programs to develop a formal bridge between the middle and high school programs. For example, in 2011, the PLTW teachers invited all middle and high school counselors for a 15-minute debriefing session where they explained the program and answered questions. Starting in 2012, middle school and high school counselors will work together to help incoming students set up their freshman year schedule.

In addition, PLTW teachers indicated that they are developing outreach and awareness programs for prospective middle school and incoming high school students and their families. For example, they hold an incoming freshman visit day, where current students give tours of the building and show the various labs in

action. Teachers talk with each group and answer questions about the program. They host a curriculum night where PLTW teachers talk to parents and students about the PLTW and STEM programs and meeting requirements for graduation. They also host a follow-up session for parents to learn more about the small learning communities. Their goal is to eventually work with science, math, and technology teachers and students at the middle school throughout the year so they can see what goes on at the high school.

The PLTW team at TWHS is also working to extend its outreach to female and minority students. One possibility they are discussing with Shawna Fletcher, a member of the STEM advisory committee and the associate director for outreach for The Ohio State University's Women in Engineering group, is the feasibility of introducing an all-female cohort at the IED level.

1.5 REACH OUT TO LOCAL BUSINESSES TO GAIN AND SUSTAIN SUPPORT

During their initial research stage, the Technology Education teachers formed an ad hoc advisory group that included members of the community, engineering professors from The Ohio State University, and local engineers from Ventura Engineering and Danis Construction.

Teacher Bryan Brown explained why they felt it was so important to get broad support: "We were taking a considerable risk by eliminating traditional Technology Education programming that had some of the strongest enrollment in the overall elective department to make room for something unknown at the time (PLTW). Also, in the last decade, the actual and perceived (core academic course-taking) requirements for students has significantly increased, making it more difficult, and in some cases almost impossible, for students to take electives. Finally, as an elective department trying to survive in a district that has a tradition of highly competitive elective course offerings—along with diminishing financial abilities to fund elective programming—we hung our hat on trying to align ourselves with what the experts said they needed most from our graduates in the 21st century."

The role of the current advisory committee remains somewhat informal, with a small core group of volunteers who provide as-needed support and guidance to the PLTW teachers. For example, Lauren Drinkwine, a project engineer from Danis Construction, helps mentor female PLTW students and hosts them at off-campus Women in Engineering events. Jay Fuller, an engineer from Ventura Engineering, helps with FIRST Robotics and is also an evaluator for the EDD capstone presentations. Matt Justus, an engineer with S&ME Engineering, serves as a guest teacher and evaluator of student work. Dr. Gustafson, an engineering professor with The Ohio State University, supports PLTW outreach efforts and works with students to answer questions about college. Many of these individuals also provide field trip and networking opportunities as well as connections with

professionals who can provide technical assistance.

2. DEVELOP A SCHOOL-WIDE STEM CULTURE

District and school administrators in Worthington recognize the value of STEM as a tool for integrating course content with an emphasis on inquiry-based applied problem solving through real-world-relevant, project-based lessons.

2.1 ESTABLISH SHARED GUIDING PRINCIPLES FOR STEM LEARNING

Under this strategy of establishing shared guiding principles for STEM Learning are three related, but distinct sub-strategies: Define STEM Education, Define STEM Literacy, and Develop District-Wide Vision for STEM Learning.

2.1.1 DEFINE STEM EDUCATION

At TWHS, the creation of a “STEM School” is helping to move the conversation about STEM education forward. Students who wish to pursue a STEM-based curriculum can choose to enroll in the PLTW engineering academy, the “STEM School,” or both. The STEM School, introduced in 2009, is a Small Learning Community (SLC) organized around science, technology, engineering, and math courses and links to the PLTW engineering academy.

The concept of STEM School emerged from informal discussions among teachers and administrators during the initial years of PLTW. They saw the positive impact PLTW courses were making on student learning and wanted to pursue a more holistic student experience by integrating PLTW with academic math and science classes.

Formal discussions about creating a STEM school began in 2008–2009 and resulted in the development of an official plan, called the Cardinal Communities Plan, for a STEM SLC. Per the terms of teacher contracts at TWHS, any significant programmatic change requires approval of at least two-thirds of the staff. According to Mr. Gaskill, whether or not the creation of a STEM School required staff approval was a bit unclear. However, administrators decided to take the vote because they saw the STEM School as a shift in the school culture and they wanted to generate teacher buy-in.

Upon first consideration by school staff, the Cardinal Communities Plan for SLCs in 2011 did not receive the necessary favorable votes. Teachers voiced concerns over the impact of the SLCs, so administrators revised the plan, and in May 2011, it won approval of 88 percent of TWHS staff members.

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The STEM School was officially launched in the 2011–2012 school year, and TWHS has 64 students enrolled in the STEM pathway (27 in STEM POE, 18 in STEM IED, and 19 in STEM DE).

The charts below show the typical course schedule for students in the STEM School. There are two “tracks” to accommodate students with varying levels of math preparation. The first chart represents the courses for students who enter the STEM program at the Geometry level. The second chart represents the path for students who enter at the Enriched Algebra II level. (Algebra I [commonly taken in a student’s eighth grade year] is a prerequisite for the STEM School.)

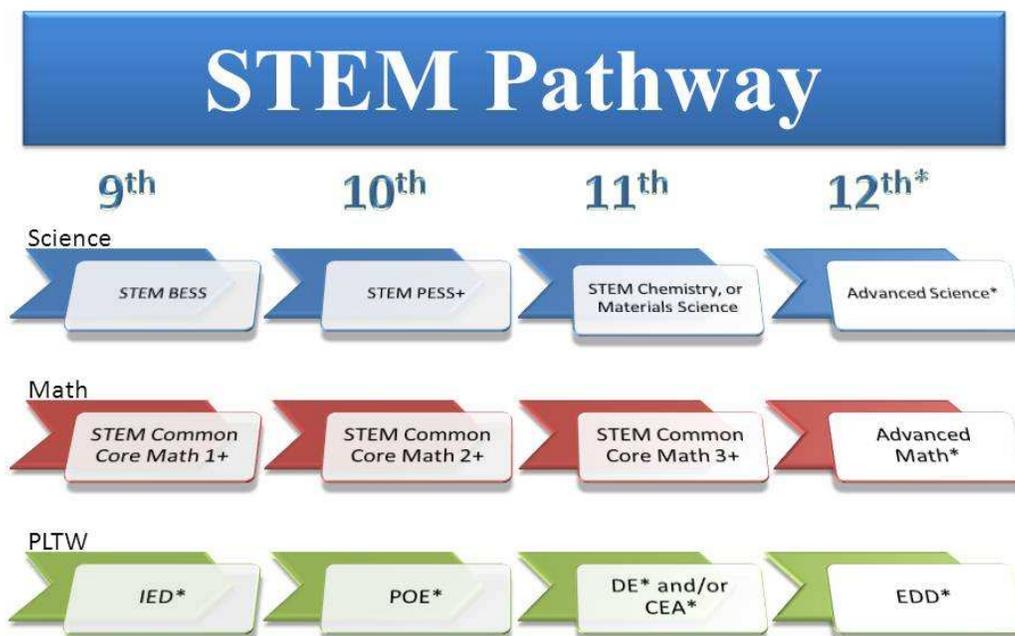
Students who choose to participate in PLTW but not the STEM SLC sign up for their traditional math and science courses and then supplement these courses with PLTW courses. However, many students choose to enroll in both PLTW and the STEM School, which allows them to enroll in STEM science, STEM math, and STEM PTLW courses.

<i>2011–2012 STEM Pathway – Students Entering at Geometry Level</i>				
	Grade 9	Grade 10	Grade 11	Grade 12
Math	STEM Geometry	STEM Honors Algebra II	STEM FST (Functions Statistics Trigonometry)	STEM PDM (Pre-Calculus Discrete Math)
Science	STEM PESS (Physical Earth Science Systems)	BESS (Biological and Earth Systems Science) & STEM Physics	STEM Chemistry with optional AP Courses	AP Courses or Postsecondary
PLTW	STEM IED	STEM POE	STEM DE (Possible Future CEA)	STEM EDD

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<i>2011–2012 STEM Pathway – Students Entering at Honors Algebra II Level</i>				
	Grade 9	Grade 10	Grade 11	Grade 12
Math	STEM Honors Algebra II	STEM Honors FST (pending dept. approval)	STEM Honors PDM	STEM Calculus or Postsecondary
Science	STEM PESS	BESS & STEM Physics	STEM Chemistry with optional AP Courses	AP Courses or Postsecondary
PLTW	STEM IED	STEM POE	STEM DE (Possible Future CEA)	STEM EDD

The chart below shows the updated STEM pathway for the 2012–2013 school year. This new pathway includes CEA and reflects changes to the way that science classes align. The administration’s goal is for the STEM Pathway to be in place over the next two to three school years, starting with the STEM science courses.



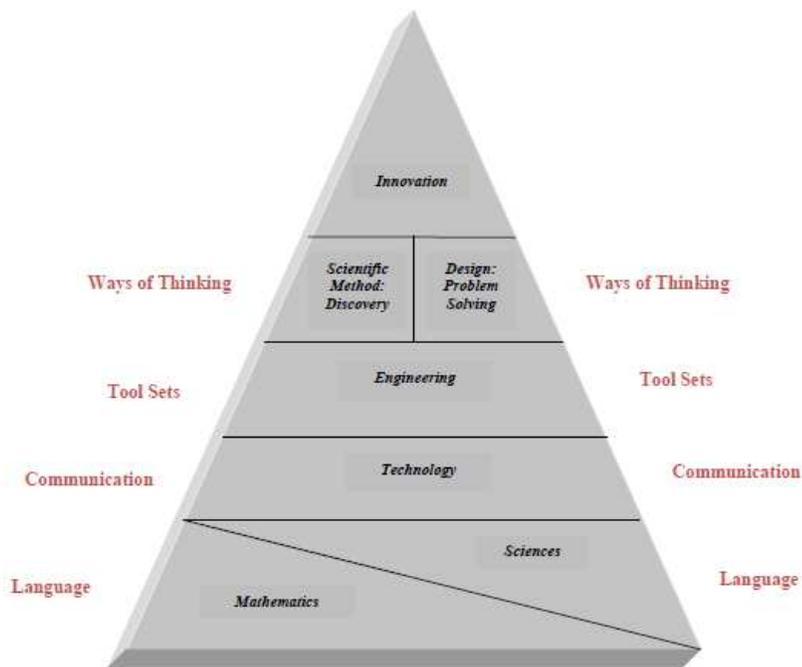
* Opportunities for dual enrollment to earn college credit while in high school.

With the STEM School up and running, Worthington teachers and administrators are now working together to develop an official, integrated STEM curriculum for the district. They are developing STEM standards and plan to seek Board of Education approval for new graded courses of study for three STEM science classes.

2.1.2 DEFINE STEM LITERACY

As part of their early planning stages for PLTW, Worthington teachers developed the following STEM definition⁵: “A metadiscipline created through the collaboration of a science teacher, technology/engineering teacher and math teacher. These teachers contribute to the creation of a ‘new’ discipline based on the successful bridging among these discrete disciplines.”

Instructors created a STEM Literacy Pyramid,⁶ adapted from a report out of the University of Maryland, to help define what skill sets and tools are key to STEM literacy.



They also mapped out the commonalities among problem-solving processes, or the STEM process, across math, science, and engineering. The list below illustrates those commonalities.

<i>STEM PROCESSES</i>		
Engineering Design Process	Scientific Method Process	Mathematical Problem-Solving Process
<ul style="list-style-type: none"> • Identify the problem • Plan project • Problem specifications • Conceptual design • Final design 	<ul style="list-style-type: none"> • Ask and define the question • Gather information and resources through observation • Form a hypothesis • Perform one or more experiments and collect and sort data • Analyze the data • Interpret the data and make conclusions that point to a hypothesis • Formulate a “final” or “finished” hypothesis 	<ul style="list-style-type: none"> • Read the problem • Identify and organize important information • Choose an appropriate strategy and/or formula • Solve the problem • Check your work

2.1.3 DEVELOP DISTRICT-WIDE VISION FOR STEM LEARNING

As of 2011, Worthington schools are developing a district-wide vision for STEM education. According to Bryan Brown, the need for a vision statement emerged as the PLTW and STEM programs grew. He explained, “In the first few years of Project Lead the Way and STEM, there were only a couple people involved, and we were all focused on the same targets. As the program grew, we wanted to make sure that the original vision was clearly stated and that the growing number of people involved in the program were on the same page.”

Under the leadership of Director of Academic Achievement and Leadership Jennifer Wene, a group of PLTW and STEM teachers, along with district curriculum leaders, are working collaboratively to define the STEM vision. The current working version of the STEM vision statement reads: “The vision for STEM education for Worthington City Schools is to engage students in a rigorous integrated PK-16 inquiry-based education that substantially increases the number of youth who possess not only the valuable skills of problem solving, logical thinking, and innovating, but who graduate from high school both college and career ready.”

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Although this vision statement has not yet been officially adopted by the Board of Education, it is expected to become part of the STEM graded course of study once that curriculum is approved in the next year or two.

2.2 IMPLEMENT INNOVATIVE STEM CURRICULUM AND INSTRUCTION

Under this strategy of implementing innovative STEM curriculum and instruction, there are two related, but distinct sub-strategies: Integrate STEM-Rich Instruction, and Implement Inquiry-based and Project-based Learning Strategies.

2.2.1 INTEGRATE STEM-RICH INSTRUCTION ACROSS MATH, SCIENCE, AND OTHER APPLIED STEM PROGRAMS

TWHS has a history of interdisciplinary planning, including participation in a district-wide Integrated Math initiative in the 1990s, which established an early math–technology connection. The integration of the PLTW program and the STEM School at TWHS provides a strong foundation to support the continued development of holistic STEM-based education.

The PLTW and academic teachers at TWHS work continuously to build connections between their classes and to develop collaborative lesson plans. They are working on curriculum design to identify synergies and to discover ways to link the classes together.

Through a curriculum mapping process, teachers identified topics that they taught in common with other disciplines but realized that they often teach these concepts at different points in the year. For example, the physics instructor teaches kinematics/motion in the beginning of the curriculum, but the Principles of Engineering instructor teaches this concept at the end of the course.

To help students make connections across classes even when the sequence of topics does not align perfectly, instructors are developing methods to store and record information. For example, the engineering classes may videotape their projects and record the associated data on a spreadsheet for later use in a math or science class. Using “real” data provides an additional benefit; as explained by a math teacher, “PLTW provides students with access to real science data that they often generated themselves. We can use this data for modeling. Since the data isn’t perfect, like textbook data, the students have to use higher-level thinking and analysis.”

In another example of collaboration, the geometry teacher introduces students to the use of Inventor (software used in PLTW) at the beginning of the year as a tool to review geometry concepts. In his words, “I found that I was teaching concepts built into the Inventor program. By using Inventor for STEM geometry, students begin to make connections faster than I can in the classroom.” This also benefits

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the Introduction to Engineering Design teacher because students come to his class ready to use the software.

Instructors at TWHS continually find new ways to demonstrate the links between math, science, and engineering. For example, they created a STEM Literacy Pyramid, which is adapted from a University of Maryland report. They are also creating posters that illustrate the commonalities among problem-solving processes across the three disciplines (engineering, math, and science). Both the STEM Literacy Pyramid and the problem-solving process are described in more detail later in this section.

Examples of classes they have connected include:

- Introduction to Engineering Design with Geometry, Algebra II, and Physical Earth Science Systems (PESS),
- Principles of Engineering with Physics, Algebra II/Functions Statistics Trigonometry (FST), and Pre-Calculus Discrete Math (PDM), and
- Digital Electronics with Functions Statistics Trigonometry (FST).

It should be noted that the PESS course is currently connected to STEM IED; however, in 2012–2013, it will replace Physics as the POE connection and the Biological and Earth Systems Science (BESS) course will be connected to STEM IED.

The following example illustrates how a PLTW activity is supported and integrated in math and science courses.

STEM Integration Project for STEM Algebra II, Principles of Engineering, and STEM Physics

This project involves the sharing of data and activities between science, technology, and math in the second year of the STEM sequence. This project also integrates with the first-year STEM sequence by gathering data on the CO₂ powered cars that students build their freshman year.

This project starts in Algebra II, where the students are assigned to make a calculator program to solve for any variable in a kinematic equation. In Physics, the students are learning how to use kinematics and work on a project to develop a measurement system for the acceleration of a CO₂ car and also the force on the car from a pierced CO₂ canister. The students are given a list of data-collection equipment, and they must design the system to obtain the appropriate data. The winning design is saved by the instructor for future use, and a Google spreadsheet is created to collect the necessary data.

The freshman STEM students then design and build their cars in the IED class.

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Once the cars are built, the science class then builds their testing system to measure the acceleration of the cars. This information is then collected and put into the Google spreadsheet for the POE class. The POE class uses the data to create spreadsheets that calculate accelerations of the cars based on different sets of available data. This teaches the students when to use certain kinematic equations versus other equations. The students are to use their calculator programs made in Algebra II to check the first line of their spreadsheets for correctness. The STEM Physics class also used the data to calculate forces and momentum of the CO₂ and the cars.

2.2.2 IMPLEMENT INQUIRY-BASED AND PROJECT-BASED LEARNING STRATEGIES

While there is currently not a formal school-wide emphasis on project- and inquiry-based teaching, the Technology Education and science teachers at TWHS incorporate many of the inquiry-based and project-based learning strategies that are modeled in PTLW curriculum into their academic classes that are not specifically connected to PLTW courses. Bryan Brown explained that these strategies are a natural fit for the PLTW teachers: “Because PLTW teachers are Tech Ed certified, most of their post-graduate training has been in these areas. They have been using these strategies their entire career.”

One science teacher noted, “My regular [non-PLTW] science classes have morphed significantly in last few years. We now work on more open-ended problems. The non-PLTW students might not make all the connections but they still benefit.”

Another teacher explained the incorporation of more open-ended problems into other classes, “When I find methods that work, I use them in my regular classes too. All students benefit, but the students in STEM and PLTW understand at a higher level and ‘get’ the real-world connection.”

2.3 ENGAGE MATH, SCIENCE, AND PLTW TEACHERS IN COLLABORATIVE PLANNING AND INSTRUCTION

At TWHS, establishing a strong STEM focus for the school met with some initial challenges. Whereas many individual teachers embraced the possibility of collaboration, departmental administrators had some concerns about the impact that cross-curricular collaboration and integration might have on scheduling and other responsibilities. In 2008–2009, PTLW teachers met extensively with departmental administrators and ultimately gained their acceptance for the formation of a STEM Collaborative Team. According to one PLTW teacher, “We always had a good relationship with the science staff, but once we showed them how the PLTW curriculum related, the collaboration really took off.” (This may have been aided, in part, by the fact that one of the physics teachers is a former

engineer.)

Teachers at TWHS seem to appreciate the ability to build connections between PLTW and STEM. The geometry teacher explained, “For us, STEM means problem-based learning. I was a hands-on learner, so I connect with students like that. Any way we can get students to have that ‘aha’ moment is important.” Another math teacher added, “Teaching STEM math has taken lots of extra work to develop the lessons. But the payoff is great. For me, collaboration has been the best. Working with other teachers makes me a better teacher.”

Vertical Integration

Teachers at TWHS also focus on vertical integration. By “vertical integration” they mean that they want to make sure that concepts taught at the freshman level are then brought up to the next-level PLTW and academic courses. To accomplish this, they are experimenting with the use of electronic student portfolios to store student work and online tools to allow students to use data and results from previous-year projects in their current courses.

Although some teachers were concerned about taking focus off their content early on, now teachers want to be part of the STEM team and the STEM School. One teacher commented, “Comparing STEM geometry kids to the typical geometry students, we’ve never seen anything so exciting.”

3. IMPLEMENT RELATED SCHOOL IMPROVEMENT STRATEGIES

3.1 PROVIDE ACADEMIC SUPPORT AND INTERVENTION TO ENHANCE STUDENT LEARNING

Administrators and guidance counselors at TWHS use MAP testing and benchmarks to identify students who may need additional academic support. Students may seek out academic assistants during open periods for help with math and science. In addition, guidance counselors can also help identify resources and needs.

According to TWHS administrators, if PLTW students struggle academically, it is most likely to happen during the freshman or sophomore year. To support these students, all freshmen at TWHS are scheduled with an enrichment period, when they may seek out additional assistance from any of their core subject teachers plus one PLTW teacher. In addition, STEM/PLTW teachers are scheduled with open periods during student lunch periods or study halls so they can be available to assist students.

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Administrators note that sophomore year presents a big challenge for many PLTW students, since they often are taking a heavy academic load that includes two science classes plus PLTW. Teachers support students by encouraging them to persevere and to see the benefits of completing the required courses. They find that the Small Learning Community (*see below for more details*) provides an additional sense of support and positive peer pressure.

Small Learning Communities

The mission statement at TWHS is “to provide a comprehensive program in a learning environment that ensures each individual has the opportunity to discover and develop talents and capabilities to assume a responsible role in our global society.”⁷ In 2006, the administrators established several “academies” or “teams” that operate as small learning communities (SLCs) to achieve these goals. An SLC, also referred to as a School-within-a-School, is designed to create a more personalized learning environment for smaller groups of students within a school.

As of the 2011–2012 school year, TWHS offers the following SLCs:

- Project Lead the Way (implemented in 2006),
- Freshman Academy (implemented in 2007),
- STEM School (implemented in 2008), and
- Entrepreneurship Business Academy (implemented in 2008).

It should be noted that although PLTW is not a pure SLC at TWHS (students do not move as a cohort from one PLTW teacher to another), the students are often grouped together in their classes.

Expansion of SLCs

Through the district-supported “Renewal Process,” which was launched in the 2006–2007 school year, all individual Worthington schools were challenged to examine their current programs and to begin shifting their practices and structures to reflect 21st-century thinking. Each building in the district was required to develop a renewal process that would reflect improvement, achievement, and growth. For each school, this plan was voted on by staff and ultimately approved by the Board of Education.

To meet the requirements of the Renewal Process, during the 2009–2010 school year, the TWHS leadership team conducted several forums called “World Cafes” to gather input from staff, students, and families on a variety of topics. On the basis of the feedback about the SLCs received during these sessions, the administrators at TWHS decided to expand the number of SLCs over a period of several years, with an ultimate goal of offering a total of five or six SLCs. Before the SLCs are officially expanded, the administrators plan to solidify the current instructional teams and to conduct a staff vote to determine readiness for

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expansion. The following graphic⁸ illustrates how additional SLCs would align with the existing structure of TWHS.



Administrators noted that it has taken approximately three to four years to embed SLCs in the culture of TWHS but that the payoff has been worth the effort, particularly for students. They find SLCs empower students to take control of their learning while providing a sense of community, ownership, and “positive peer pressure.”

One student characterized the difference between his classmates in the STEM School and non-STEM School students in this way: “When we have a tough problem in science, students not in STEM School stop working; they wait for the teacher’s help. STEM School students experiment and try to work through the problem.”

3.2 PREPARE STUDENTS FOR POSTSECONDARY AND CAREER SUCCESS

Under this strategy of preparing students for postsecondary and career success, there are two related, but distinct sub-strategies: Offer Career Development and College Planning, and Offer Opportunity to Earn College Credit.

3.2.1 OFFER CAREER DEVELOPMENT AND COLLEGE PLANNING

Students gain exposure to postsecondary and career options through career exploration lessons, which are incorporated into many of the PLTW classes. These

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lessons typically require students to research, interview, and explore information related to careers, professionals in those careers, and college requirements.

PLTW teachers also take students on field trips and invite admissions/recruitment personnel from colleges and universities visit students in class. On occasion, local industry professionals may serve as guest teachers, and the PLTW teachers are working with Dr. Robert Gustafson, director of the OSU Engineering Education Innovation Center and a member of the PLTW Advisory Committee, to explore opportunities to include OSU personnel in the delivery of some PLTW lessons. This would give students a greater exposure to the type of teaching styles they can expect in their college courses.

TWHS provides support for all students going through the college application process. Guidance counselors meet individually and in groups with students and parents to review processes for college applications.

3.2.2 OFFER OPPORTUNITY TO EARN COLLEGE CREDIT

Because Worthington's PLTW program is nationally certified by PLTW, students are eligible for transcribed and/or elective college credit from all colleges and universities that articulate with PLTW. TWHS currently has a direct articulation agreement with Sinclair Community College and The Ohio State University for students completing PLTW. Through these agreements, all students can potentially earn college-level credits for their PLTW coursework during high school. For example, all courses in PLTW articulate directly to an existing course at Sinclair.

TWHS does not formally track how students apply the credits earned during high school to their college plan. However, administrators note that through conversations with graduates they know that some students receive transcribed credit to entry-level engineering courses, some are given elective credits, and others are given preferential admissions consideration but are recommended to take the full program of engineering courses in college.

TWHS benefits from its proximity to The Ohio State University (OSU) in Columbus, which offers one of the country's top engineering programs. PLTW students from TWHS are typically eligible to receive credit for two out of three introductory college-level engineering courses. However, according to Dr. Gustafson, he usually encourages students to forgo the credits and to take the classes because they will be an opportunity for students to acclimate to the college environment. He noted that in many cases, former high school PTLW students take on a leadership role within their introductory classes because they are so well prepared through their high school experience with PLTW.

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Assistant Principal Julie King noted that the possibility to earn college credits is one of the aspects that attracts students to PLTW. She added that the administration is looking into collaborative relationships with other universities, including the possibility of developing dual-enrollment opportunities with Columbus State Community College.

3.3 FOCUS ON PROFESSIONAL DEVELOPMENT, GROWTH, AND COLLABORATION

In Worthington, the district's teacher evaluation system requires all teachers to address professional growth annually by pursuing continuing education and professional development opportunities. At TWHS, all teachers are expected to be trained in Assessment for Learning, which centers on teachers using learning targets, providing effective feedback, building background knowledge and vocabulary, and formative assessment. To gauge implementation of the strategies, a team of peers visits selected classrooms for five minutes each and evaluates the teacher based on the components of Assessment for Learning. An observation report is emailed to the classroom teacher the same day, and the results are reviewed by administrators.

District-wide, staff members are provided the opportunity to assemble in small groups, or Professional Learning Communities (PLCs), to work on an aspect of their professional practice in which they would like to grow. These groups are given 90 minutes per month to meet and work on their goals.

In addition to standard professional development, all PLTW teachers attend the required PLTW Summer Training Institute (STI) sessions and yearly PLTW conference updates. PLTW and STEM teachers in Worthington actively engage in ongoing peer support and development. They meet regularly as a group and frequently visit each others' classrooms. They also pursue online coursework, review tutorials related to subject matter, and collaborate with industry professionals. Several teachers are involved STEM-related organizations such as the Central Ohio Technology & Engineering Educators Association, the Ohio STEM Learning Network, and FIRST Robotics.

The Worthington PLTW and STEM teachers have begun an informal STEM network with another local school, Hilliard. Through site visits and meetings, the teachers from Worthington and Hilliard are able to share knowledge, ideas, and best practices.

3.4 USE DATA TO MAKE INSTRUCTIONAL DECISIONS

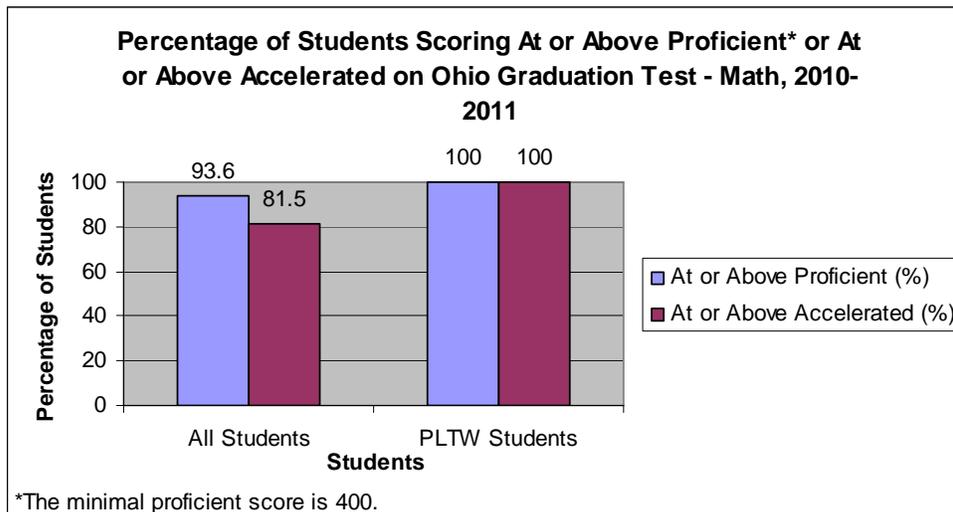
TWHS administrators use a variety of metrics to measure student performance. In addition to statewide assessments, PLTW teachers collect data from several inventories that are commonly used both nationally and internationally, including the Force Concept Inventory and the Lawson Test of Scientific Reasoning. They

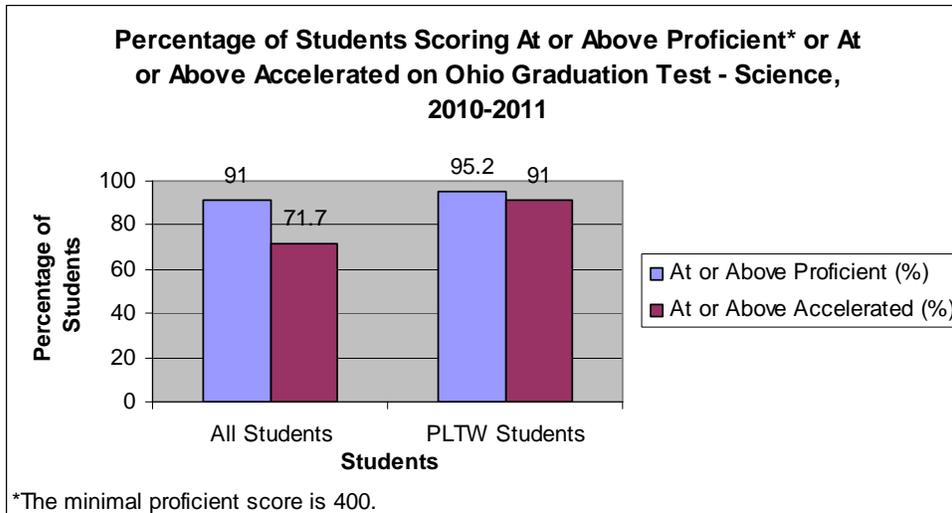
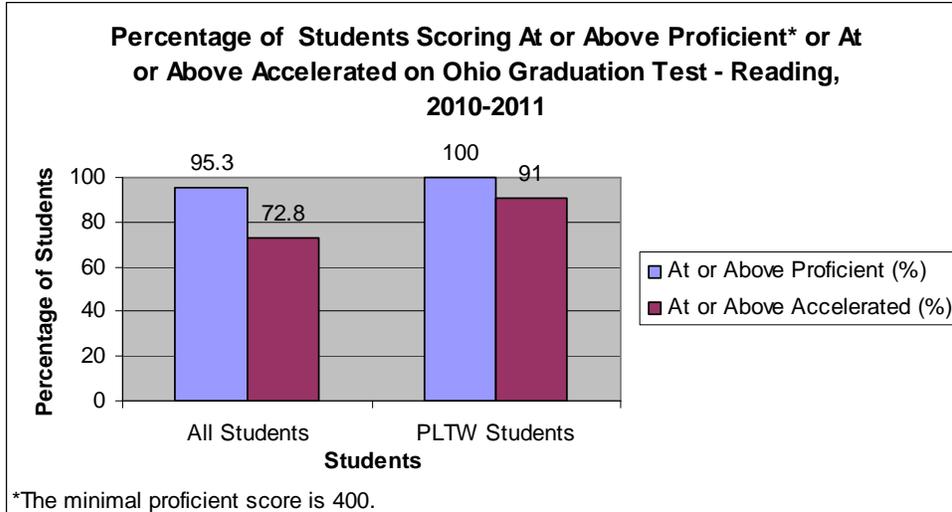
also collect information about student and parent attitudes toward the PTLW program and science and technology in general. Analytical support is provided by Dr. Lei Bao, a physics professor at The Ohio State University.

PART III. DATA AND NEXT STEPS

PERFORMANCE DATA

In Ohio, students take the Ohio Graduation Test (OGT) at the end of their sophomore year. The chart below shows the results for the 2010–2011 school year. *(All data was provided by TWHS. Charts showing assessment performance for all students and PLTW students are not intended to indicate a correlation between enrollment in PLTW and student achievement.)* The graduation rate in 2010 was 94.5%.





THOMAS WORTHINGTON'S NEXT STEPS

In addition to meeting students' needs through the expansion of SLCs, administrators at TWHS have identified flexible scheduling options as a school-wide goal. They are investigating ways to provide students the opportunity to take classes outside of the regular school day. This could alleviate class scheduling conflicts and enable more students to participate in the PLTW program.

APPENDIX

PLTW AT WORTHINGTON KILBOURNE HIGH SCHOOL

Worthington Kilbourne High School (WKHS), the district’s second high school, opened in 1991 and enrolls 1,215 students in grades nine through 12. Of the students enrolled at WKHS, 80 percent are white, 6 percent are black, 6 percent are Asian, 3 percent are Hispanic, and the remaining 5 percent are of “other” (multiracial) origin. Approximately 14 percent of the students receive Free and Reduced Lunch, and 14 percent of the students receive special education services. The administrative team at WKHS includes one principal and two assistant principals. WKHS employs 82 teachers.

WKHS launched PLTW at the same time as TWHS. Although WKHS does not have the same Small Learning Community (SLC) structure as TWHS (described earlier), WKHS students who take PLTW courses are grouped together in cohorts whenever possible. There are currently three PLTW teachers at WKHS.

The table below provides enrollment information for PLTW at WKHS.

Project Lead the Way Enrollment	
PLTW Courses Offered	Number of Students
2010-2011	
Introduction to Engineering Design	61
Principles of Engineering	41
Digital Electronics	35
Civil Engineering & Architecture	8
Engineering Design & Development	14
Source: Worthington Kilbourne High School, October 2011.	

The WKHS school leadership team also plans to implement an International Baccalaureate (IB) Diploma program for students in grades 11 and 12. Administrators view the IB program as a complementary program to PLTW

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because it also encourages the development of students' problem-solving and critical-thinking skills. They are developing a course of study, referred to as the "WolfP.A.A.C.C.-IB," which stands for "Principled, Analytical, Adaptable, Creative, Community-Minded." This course of study is intended to intertwine STEM, and possibly PLTW coursework, with the IB program.

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The site visit was conducted on September 26–28, 2011. This case study was written by Hans Meeder and Jennifer Grams of the Meeder Consulting Group. Site visit coordination and follow up was provided by James Gaskill, principal of Thomas Worthington High School and Bryan Brown, Department Chair, PLTW Coordinator and Instructor, and Technological Studies Instructor at Thomas Worthington High School.

ENDNOTES

¹ Note: The Project Lead the Way (PLTW) Pathway to Engineering Program is currently offered at both TWHS and Worthington Kilbourne High School (WKHS). Information on WKHS is provided in the Appendix.

² Worthington internal document, "Project Lead the Way Proposal Accepted by BOE, 2007." Copy available upon request to TWHS.

³ Worthington internal document, "Project Lead the Way Proposal Accepted by BOE, 2007." Copy available upon request to TWHS.

⁴ Worthington internal presentation, "Reality Check STEM Next Steps" 2008.

⁵ Worthington internal presentation, "Reality Check STEM Next Steps," 2008.

⁶ Worthington STEM Literacy Pyramid, adapted from "STEM Literacy: Pathways to Education, Workforce, and Innovation," Leigh R. Abts, PhD, University of Maryland.

⁷ Cardinal Communities, "Thomas Worthington High School: Renewal Plan," May 27, 2011. http://www.worthington.k12.oh.us/uploads/2/File/documents/twhs_renewal.pdf

⁸ Cardinal Communities, 2011.