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> *America's drop-out crisis erodes our country's capacity to be competitive in the 21st century.*
> — *National Association of Secondary School Principals (NASSP)*[1]

Value Added Engineering Education

The challenge of productively engaging middle school and high school youth, particularly youth from diverse backgrounds is well documented over the past decade. According to national Child Trends Data Bank:

- In 2005, nearly one in ten (9%) of American young adults ages 16-24 had not completed a high school diploma.
- Hispanic youth represented 41% of high school dropouts but only 17% of the U.S. population. [2]

Failing to finish high school has wide ranging consequences for both youth and their communities. Dropouts lack the essential skills for succeeding in technology intensive workplaces, entering community colleges and technical schools, and productively participating in society. Follow-up studies continue to reveal that students without high school diplomas experience higher rates of unemployment, lower earnings, higher rates of criminal behavior, and receive public assistance more frequently and for longer periods of time.[4]

The National Center for Education Statistics notes that, for every 100 students who entered the 9th grade only 81 graduated from a Wisconsin high school on-time in 2006.[3]

Trends in Middle School Reform

Recently, reports from national organizations have documented the key contributions that middle and high schools are making to engage all youth in grades 6-10. The NASSP report entitled *Breaking Ranks in the Middle: Strategies for Leading Middle Level Reform*[5] offers 30 recommendations for building collaborative learning teams, personalizing the school environment, and aligning curriculum, instruction, and assessment. Middle schools with the capacity to break ranks are: (a) implementing academically rigorous essential learning that enables each student to successfully make the transition to high school, (b) aligning programs so that all economic and racial/ethnic groups have open and equal access to challenging activities and learning, (c) connecting the content of the curriculum to real-life applications of knowledge and skills, and (d) making technology integral to curriculum, instruction, and assessment.

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Technology Learning in Middle Schools: Value Added Engagement

Middle schools need the capacity to "break ranks"

Middle school technology programs have long been considered an important strategy for making connections between math, science, and other subjects students will study in high school. Recently, longitudinal research examining course-taking patterns in middle and high school has discovered a significantly lower dropout for students who enter high school at less than 15 years old (on grade) having completed one career and technology education (CTE) course for every two academic courses.[6] While not generated from an experimental study, the 1:2 course-taking ratio in the middle school and early high school years appears to suggest that some CTE courses provide the contextual and authentic exposure needed for students to find relevance in and engagement for high school.

To upgrade student learning and instructional engagement, a significant number of middle schools in the Midwest have adopted the Gateway to Technology (GTT) modules. The GTT series includes five, activity-oriented units that expose students to math, science, and technology concepts. The five nine-week units include: Design and Modeling, The Magic of Electrons, The Science of Technology, Automation and Robotics, and Flight and Space. Marketed as part of the widely adopted high school Project Lead the Way Engineering curriculum, nearly 100 middle schools across Iowa, Illinois, Minnesota, and Wisconsin implemented the modules with approximately 35,000 sixth, seventh, and eighth graders in 2008-09.[7]

A ratio of 1:2 academic-to-career and technical education courses

In each middle school, the GTT modules are integrated differently depending how the selected modules are aligned with the science, technology education and math curriculum, and whether the content is deemed part of the core curriculum or an elective. Depending upon the state standards, some schools integrate the modules as units within science or technology courses that all 6th, 7th or 8th graders complete, while other schools have incorporated the modules in a practical arts rotation. Other implementation strategies include using the modules in a technology education elective course(s) or an honors course.

Within the GTT modules students are involved in multiple project- and problem-based learning activities, which illustrate how science principles and math content, such as computation and measurement, are used to solve challenging questions or to create new devices that could benefit people or businesses. For instance, in the Science of Technology module student teams design, build, and test a Rube Goldberg machine to illustrate their knowledge of simple machines such as levers and pulley, student demonstrate how the machines transfer energy from one location to another they evaluate their machines against criteria, such as design complexity, imagination, and repeatability of performance by the machine.

Building a Rube Goldberg machine is a useful illustration of the integration of science and technical learning included in the GTT modules.

To measure the influence of GTT modules on middle school students' engagement, Center researchers recruited three middle schools in the 2008-09 year and surveyed of 6th, 7th, and 8th graders in two groups: (a) students who had completed two or more GTT modules, and (b) students who had not completed any GTT modules. To assess student's academic, social and personal engagement with middle school learning, classes were asked to complete a popular student engagement survey[8] during spring 2009. This comprehensive instrument includes 70 items that document how students experience and engage in learning in middle school.

This descriptive analysis suggests that when middle school students experience the GTT modules, some important "student engagement value" is associated with the learning activities. While the limited scope of the study did not permit the identification of the engagement outcomes for specific modules or selected groups of students (e.g., girls, English language learners), the overall implementation of GTT modules in these schools was linked to students who reported higher levels of: science, technology and academic engagement indicators.

Figure 1. Promising Value-Added Middle School Engagement Indicators

Across three Wisconsin middle schools, students completing the GTT modules (n=165) were more likely than students ($p < .10$) who had not completed the modules (n=103) to:

Science and Technology Engagement Indicators

- Participate in school sponsored activities (clubs, student government, etc.)
- Use computers for class work

Academic Engagement Indicators

- Be challenged academically by class work
- Write a paper of fewer than five pages
- Take a test with show-your-work problems or essays
- Work on a project with at least one student who differs from you in terms of religious beliefs, income background or personal values

The engagement benefits for middle school students are closely aligned with the national middle school reform priorities arguing for greater academic challenge and reducing social inequity in the middle grades.

Engineering Learning in High Schools: Motivational Value-Added Outcomes

To address the dropout retention and middle-to-high school transition issues, many schools have adopted small learning communities to personalize the learning environment and raise academic learning outcomes. Career academies — engineering and health science — are common templates for small learning communities in which three levels of integration often occur: academic-career curriculum alignment, school-work based learning, and secondary-postsecondary career pathways.[9] In Wisconsin and across the Midwest, several high schools are designing and implementing engineering or engineering and technology academies using the Project Lead the Way (PLTW) Engineering courses.

Using surveys, focus groups, and student record data from eight high schools over the past three years, Center researchers have examined the extent to which these courses promote: (a) academic, social and personal engagement, as well as (b) better academic learning outcomes.

Value-Added Motivational Indicators: Key Findings

- At two urban high schools, the seniors who had completed PLTW courses were significantly more likely to have higher attendance rates during the senior year than non-PLTW seniors. This difference translates into an additional 7-8 days of instruction during a year (or a 5% increase), during a year in which many seniors find high school less challenging. In many schools, the advanced PLTW courses involve seniors working on a team with local engineers and firms to design solutions to engaging problems. Through these projects seniors begin to develop networks of engineers and technicians who help them develop insights about STEM careers.
- At one of the urban high schools, the PLTW seniors were significantly more likely to complete mathematics courses during the senior year. On average, the PLTW seniors were completing one semester of math coursework during the senior year, while the non-PLTW seniors were registered for only about 1/3rd of a semester of math. While the overall math course completion rate was about the same for PLTW and non-PLTW seniors, the opportunity "to see how math is used in solving engineering and technical problems" may have motivated the PLTW seniors to enroll in more math courses.

During 2008-09 more than 100 Wisconsin high schools were implementing PLTW courses in engineering academies and other, more traditional configurations.

In the U.S. high schools offering PLTW courses, the vast majority of certified teachers (~75%) are career and technical education (CTE) teachers. This trend suggests that in many communities, PLTW courses and programs are seen as a "new or modernized" version of CTE. In these schools, it is important to

consider value-added differences between PLTW courses and CTE courses in business, marketing, agriculture/natural resources, information technology, or family and consumer sciences. When comparing the academic returns for CTE concentrators (seniors who had taken five or more semester-long CTE classes) who had also taken at least one PLTW course with CTE concentrators who haven't taken any PLTW courses, some important value-added benefits were seen for the PLTW seniors:

Engineering courses are associated with higher attendance rates and more math course taking.

In an urban career academy focused on engineering, the PLTW seniors were significantly more likely than CTE seniors to:

- Complete math courses in the 12th grade
- Come from a low income family

In a large suburban high school with an extensive CTE program, the PLTW seniors were significantly more likely to:

- Score higher on the 10th grade state assessment in math and reading
- Complete math courses in the 12th grade.

Here again, it is important to note that these findings cannot and should not be interpreted as being caused by PLTW courses. However, they suggest clearly that PLTW courses offered in high school academies or as part of new CTE programs, are associated with attracting more academically able students, providing higher rates of attendance, and increasing math course taking decisions.

In this study of multiple high schools, it was also clear that PLTW course and program implementation over time matters. To illustrate, in a well-established Engineering Academy located in a comprehensive high school, the 2008 ACT and ACT-Math scores for seniors completing a PLTW course were significantly higher after controlling for gender, family income, and prior academic test scores. This academy enjoys strong support from local industry and higher education partners. (Details regarding the academic outcomes for the TESLA Engineering Academy Class of 2008 can be found on the CEW website in a companion research brief entitled: Engineering the Math Achievement Gap.)

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Endnotes

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