Delivering STEM Education through Career and Technical Education Schools and Programs

James R. Stone III
University of Louisville

Career and technical education (CTE) is an important component of the U.S. high school enterprise. More than 90% of students in high school take at least 1 CTE credit according to the National Center on Educational Statistics (Levesque, et al 2008). Analyses conducted by the National Research Center for Career and Technical Education (NRCCTE) of transcript data collected as part of the ELS2002 study by the National Center for Education Statistics (NCES) show that 56% of all students take less than 3 credits of CTE with no particular focus or concentration. For such students, CTE is likely an elective in their programs. We find another 27% take 3 or more CTE credits—however, these credits are taken with no focus. Such students are possibly exploring career fields. Finally, about 17% take three more credits with a focus or concentration. These students are taking enough CTE to constitute a serious focus or major.

Measuring CTE participation is relatively straightforward: Select a definition and query the data. This is less true for measuring STEM-CTE participation. For many, STEM (Science, Technology, Math, and Engineering) is primarily, if not exclusively, about science and mathematics education, not CTE.[1] Others think of STEM as a set of skills nested in specific occupations such as accountants, software engineers, electrical and mechanical engineers, scientists of all varieties, operations research analysts, database administrators, among many others. STEM programs for such occupations generally lead to careers in these areas. Most, if not all, narrowly defined STEM occupations require a baccalaureate or more for entry. Such occupations account for only 5% to 7% of current or expected employment in the United States. That said, such is the importance of STEM that STEM-related occupations have disproportionately contributed to job creation and wealth creation in the past century and no doubt will do the same in years to come.

Other perspectives argue for a three-fold focus for STEM education such as that advanced by the STEMEd Caucus in the U.S. Congress.[2] This group has articulated a need for three kinds of STEM intellectual capital: scientists and engineers, technologically proficient workers, and scientifically literate voters.

CTE and STEM

Although all CTE programs address some aspects of science, mathematics, and most certainly technology, not all are focused on engineering or engineering-related jobs. Many CTE programs do, however, address STEM-related careers, the second focus of the STEMEd caucus. These include careers in auto-technology, medical technicians, registered nurses, process control processors, machinists, financial managers, and many other kinds of technicians. In a very real sense, all occupationally oriented CTE is STEM-related. Some of these occupations require a

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[1] See, for example, the STEM Education Coalition at http://www.stemedcoalition.org.
[2] See http://www.stemedcaucus.org.

bachelor's degree or more, but many can be found in the sub-baccalaureate labor market and vary in the amount and kinds of mathematics and science they require.[3]

This paper seeks to identify which CTE delivery systems (e.g., schools), programs, and curricular and pedagogic strategies promote and enhance the learning of STEM subjects. It also examines the extant research on STEM-focused CTE with special attention given to the needs of diverse learners.

The paper begins with a survey of the ways in which CTE is delivered and how STEM is addressed by CTE. This is followed by a discussion of CTE programmatic approaches that address STEM. Finally, the paper explores how pedagogic approaches are used to enhance STEM learning in CTE programs. The paper concludes with a brief discussion of the limited data available to address the questions raised by this paper.

CTE Delivery Systems

Students who participate in STEM-related CTE programs do so through a number of delivery systems. These include regional shared-time centers, CTE high schools, and CTE offered within traditional comprehensive high schools. Within these structures, STEM-related CTE may also be delivered through programmatic structures such as career academies, programs of study (POS), linked learning (only in California), or other variations on a similar theme. Within programs, STEM-related content is delivered through a variety of pedagogies (e.g., project-based learning, problem-based learning).

In this paper, I discuss five types of school structures through which CTE is provided. These structures are not necessarily mutually exclusive (e.g. the Career Academy structure may be in any of the other school structures). In this section, school types and purposes are briefly discussed and examples of STEM-oriented foci are highlighted.

Because there are no national or state databases that isolate STEM-focused CTE schools or programs, brief case descriptions of exemplars of each of these five delivery systems will be provided. However, I do so with this caveat: A challenge in linking student outcomes broadly (e.g., achievement in math or science) or outcomes associated with targeted populations (e.g., minorities or females) is the problem of self-selection bias. That is, the schools of interest described in this paper are universally schools students choose to attend, which introduces a potential source of selection bias into the data.

There are an estimated 16,000 school districts across the United States. Within those districts, there are an estimated 27,000 high schools enrolling more than 16 million students. In addition to the estimated population of these high schools, there are also nearly 1,200 area or regional shared-time career and technical centers; students attend part of their day in a home school and part of their day at these centers. Finally, there are an estimated 900 full-day CTE high schools. I first describe these regional centers.

Regional Career Tech Centers

[3] See http://www.iseek.org/careers/stemcareers.html.

Regional Career Technical Centers are defined by NCES as CTE schools that provide part-time instruction to high school students who receive all or most of their education from their home school (NCES, 2002). Most students who participate in a regional center program do so for a half-day beginning in junior year.

These centers were originally structured as a cost-effective way to provide CTE to a variety of students, including adult and GED students. Their structure was intended to be flexible enough to provide for the changing needs of the local economy (Russo,1966). Because of an historic focus on skilled occupations, there are a disproportionate percentage of teachers in regional centers who do not hold traditional teaching credentials—many do not hold a baccalaureate degree (Silverberg, Warner, Fong, & Goodwin, 2004). Further, only some of these centers employ academic faculty (e.g., math and science teachers), limiting their capacity to provide academically enriching resident programs (Bottoms, 2002). This makes it difficult for regional centers to build STEM program capacity.

Lenawee Vocational-Technical High School in Michigan[4] is typical of regional centers across the United States. Students come from more than 20 sending schools districts for one-half day of instruction selected from 22 occupational programs including such STEM-focused programs as advanced manufacturing, agri-technology, biochemical technician, electrical engineering, information technology, and engineering design/computer-aided design (CAD).

Because students' data are linked to their home or sending schools, it is not possible to parse out the performance of regional centers to assess their independent influence on student outcomes, STEM-related or otherwise.

CTE High Schools

The distinction between a regional shared-time center and a CTE high school is that the latter delivers all coursework required for graduation (e.g., core academics) in addition to requirements for a substantial amount of CTE courses. Unlike a traditional comprehensive high school, all students in a CTE high school are required to "major" in an occupational or career area. A second difference is that students typically enroll in a program beginning in the ninth grade rather than their junior year as is typical in a shared-time center.

Schools organized in this way can provide very effective general education and prepare students for both postsecondary education and careers. One exemplar of this college- and career-ready approach is Blackstone Valley Regional Vocational-Technical High School in Massachusetts.[5] Students begin their technical programs in the ninth grade, choosing from traditional areas like carpentry, auto technology, and culinary arts to more technologically advanced STEM-related programs in electronics, manufacturing technology, and information technology. Students may choose to include the Project Lead the Way (PLTW) sequence of courses in pre-engineering. Students also have access to Advanced Placement (AP) courses and honors courses as well as advanced technical courses.

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[4] See https://webapps.lisd.us/sites/TECHCEnter/Pages/Home.aspx.
[5] See http://www.valleytech.k12.ma.us/.

Blackstone Valley has one of the highest first-time pass rates on the Massachusetts Comprehensive Assessment System (MCAS) tests in the state: 97% in Basic English Language and 95% in Basic Math. On all academic measures, students at Blackstone exceed state averages. In addition, the school reports that virtually all (97%) of their students graduate and progress into postsecondary education (69%), the military (4%), or apprenticeship programs or jobs (27%). Blackstone Valley's graduation rate is 15 points higher than the state average. Most students also complete high school with one or more industry certifications.[6]

The student population at Blackstone, however, does not mirror the state averages. There are fewer minorities enrolled, and the percentage of students from low-income families is half the state average. Blackstone has admissions requirements, making it a selective school. Criteria include middle school scholastic record (40%), attendance (5%), behavior (15%), interview performance (25%), and teacher/guidance counselor recommendations (15%). Students also answer four written questions. Such admissions criteria are common to all of Massachusetts' CTE high schools.

STEM-Related CTE Offered Within Traditional Comprehensive High Schools

CTE in high school encompasses non-occupational CTE, which includes family and consumer sciences education and general labor market preparation, and occupational education, which teaches skills required in specific occupations or occupational clusters (NCES, 2004).

Specific to this paper are several data points derived from an MPR Associates (Laird, Fowler, & Daniel, 2009) report. Defining STEM as including only academic courses in math, science, engineering, and computers, Laird et al. found that:

- High school students who graduated in 2005 earned more STEM-related credits than students who graduated in 1990.
- In 2005, White graduates earned more credits than Black and Latino graduates in two STEM course categories (advanced mathematics and advanced science and engineering). There were no statistically significant changes in these gaps from 1990 to 2005.
- In 2005, a larger percentage of females than males earned credits in four specific STEM courses: Algebra II, advanced biology, chemistry, and health science/technology. A larger percentage of males earned credits in physics, engineering, engineering/science technologies, and computer/information science.
- Suburban 2005 graduates earned more credits in advanced mathematics and advanced science and engineering than did their rural counterparts.
- White, Black, and Asian high school graduates earned more credits in all three STEM course categories in 2005 than in 1990. Over this period, Latino graduates earned more credits in one category (advanced mathematics).

Comprehensive high schools have developed many approaches to incorporating STEM-focused CTE. Los Altos High School in California, building on its partnership with a neighboring

[6] These data are derived from public No Child Left Behind records.

regional occupational center, created an Academy of Engineering. Students in this program design green automobiles: In 2007, they constructed a fuel cell car that averaged the equivalent of 1,038 miles per gallon. This program has engaged business partnerships with Edison, Toyota, and the Air Quality Management District (AQMD), and has relationships with higher education through Cal Poly Pomona and Cal State Los Angeles. Beyond the school's high-profile STEM projects, students participate in a rigorous academic and technical program that includes advanced mathematics and science, computer science, and manufacturing and engineering technology. Students may also elect to complete an electrical apprenticeship. The student population reflects the demographics of the area: 44% of the students are White, 26% are Latino, and 18% are Asian. The high school ranks amongst the highest performing in California on academic measures.[7]

Many comprehensive high schools have adopted the career clusters approach to organizing curriculum offerings, which I also discuss in the section that follows.[8] The career clusters include a specific STEM cluster that focuses on occupations in engineering and mathematics and other STEM-related clusters like health science, information technology, manufacturing, transportation and logistics, and agriculture.

Verona High School in Wisconsin typifies this career clusters-oriented approach. All 16 career clusters are accessible to students through academic coursework, but the school offers a more focused Engineering and Technology Pathway that includes coursework in advanced power mechanics, electronics, and applied electricity. Students may also take more advanced courses in local colleges as well as gain valuable experience through Wisconsin's Youth Apprenticeship program.

CTE Programmatic Models

Within and across the different CTE delivery systems, various programmatic approaches are used to enhance CTE. These include career academies and Tech Prep and programs of study (POS).

Career Academies

A Career Academy is defined as a multi-year program in which the curriculum integrates academic and CTE content organized around one or more broad career themes (NCES, 2002). Career academies exist in at least 2,500 high schools and have become a popular high school reform framework. Academy students take classes together, remain with the same group of teachers over time, follow an integrated curriculum that includes both academic and career-oriented courses, and participate in internships and other career-related experiences outside the classroom. Improving the rigor of academic and career-related curricula has become an increasingly prominent part of the Career academies agenda (Kemple & Willner, 2008).

The typical academy operates as a school within a school and typically enrolls some 30 to 60 students per grade. Career academies are usually organized around such themes as health,

[7] Data derived from the California School Ratings website http://www.school-ratings.com/.
[8] See www.careerclusters.org.

business and finance, engineering, computer technology, and the like. In addition to being structured as small and supportive learning communities, they maintain relationships with local business and industry in order to create contextual learning opportunities (Kemple, 2001).

Career academies are not a school type per se, although some high schools choose to organize their curriculum within “wall-to-wall” academies. In these models, all curricula are delivered through an academy framework. Many school districts include one or more Career academies in each of their high schools—these become programs of choice and attract students from across the district.

Career academies have particular characteristics for which a growing body of evidence suggests academic and economic benefits:

- Students are clustered in career-themed courses and may share many of the same classes each day and have some of the same teachers from year to year.
- There is sufficient depth and breadth of academic courses that meet high school graduation and college entrance requirements and sufficient career and technical courses sufficient to comprise a career major.
- Many build work-based learning experiences into the curriculum
- Groups of business persons advise the school district on important components of the program such as curriculum, work-based learning, financial aspects, specific courses to offer, and equipment needs. (Lynch, 2000)

A large body of research exists regarding the impact of career academies, but the most rigorous was conducted by MDRC (Kemple & Willner, 2008). Using a random assignment research design that included nine high schools in low-income, urban settings, this research found strong economic gains for young men (largely Latino and Black) and strong gains in stable, independent living eight years following high school graduation, but no difference in academic performance, high school completion, or postsecondary enrollment and completion. The lack of academic differences in this carefully controlled experiment is at least in part explained by the self-selection bias inherent in schools of choice. Students who have the motivation to apply to such schools have characteristics that serve them well whether they are selected to attend the schools or not. The same result may also be construed as positive, as the MDRC study demonstrates that it is possible to infuse work-related education with academic learning without negatively affecting academic development.

Other researchers have noted academic effects of career academies specifically related to STEM. Maxwell and Rubin (2000) found that students receive more exposure to STEM-related courses in career academies that focus on career development for which science and math courses are important such as engineering, IT and health.

The National Academy Foundation (NAF), a non-profit support organization, provides the following summary statistics on academies that are part of its network, including STEM-focused academies (e.g., engineering, health), on its website:

- More than 90% of NAF students graduate from high school—compared to 50% in the urban areas where most NAF Academies are located.
- Four out of 5 NAF students go on to college or other post-secondary education.
- 52% of NAF graduates earn bachelor's degrees in four years—compared with 32% nationally.
- Of those who go on to postsecondary education, more than 50% are the first in their families to go to college.
- 90% of students report that the Academies helped them to develop career plans.[9]

Tech Prep and Programs of Study

Tech Prep. Dale Parnell (1985) advanced the idea that the middle of the high school academic ability curve was neglected and would benefit from a more technically focused program that would begin in high school and conclude with a community college degree. Tech Prep became the shorthand label for this effort, which eventually generated federal legislation that (a) defined "a 2 + 2 design" for Tech Prep, meaning that coursework for two years in high school should be aligned to two years of coursework in postsecondary education; (b) sought to establish articulation agreements between secondary and postsecondary programs to create a "seamless" transition between the two; (c) emphasized a preparatory process to inform students of options; and (d) called for curriculum development, teacher training, and guidance training (Hershey, Silverberg, Owens, & Hulsey, 1998). Promoted by federal legislation, more than 1,000 Tech Prep programs arose across 70% of school districts serving 90% of all secondary students in the United States (Hershey et al., 1998).

National research on Tech Prep has been largely inconclusive, however. A Congressionally mandated study undertaken by Hershey et al. (1998) found that few programs had all the components specified in the legislation. Bragg and her associates (2002) studied eight programs selected by a national panel because of the fidelity of their implementation of Tech Prep. Their follow-up with approximately 4,200 Tech Prep participants and a matched comparison group yielded few significant differences in the number of math and science credits earned, high school completion, or postsecondary enrollment and completion.

Some states and districts have data that run counter to national trends for Tech Prep. In Texas, for example, Texas Education Agency data show that students of Rio Grande Valley Tech Prep are doing well despite demographic challenges. For 2009-2010 mathematics testing, 93% of Tech Prep students met the standard, compared with 77% for non-Tech Prep students. Data for 2007-2008 reflect a 94% graduation rate for Tech Prep students, compared with 76% for non-Tech Prep students. Seventy percent of those Tech Prep graduates entered college the fall after high school graduation, compared with 50.8% of non-Tech Prep graduates. These results are from a low-income, largely Latino school district.

Programs of Study. In the recent Perkins IV legislation, Tech Prep, which was voluntary, was largely replaced by Programs of Study (POS). Each school district is required to have at least one POS in order to qualify for federal funds. POS are similar to Tech Prep but place a greater focus

[9] See http://naf.org/statistics-and-research.

on the rigor of the academic and technical content and on workforce outcomes. POS are built on the career clusters framework—as noted earlier, a number are STEM-focused.

Curricular and Pedagogic Approaches to Infusing STEM in CTE

Curricular Approaches

As noted, all occupational CTE addresses aspects of mathematics, science, and technology; engineering is addressed in a more limited number of CTE programs. Overall, however, applications of STEM are broad and varied in CTE.

Project Lead the Way. Perhaps the best know STEM curriculum is Project Lead the Way (PLTW), which began as a "pre-engineering" curriculum that is now used in several thousand schools across the nation. Recently it has added a biomedical focus. PLTW combines a number of pedagogies that are designed to engage learners in a hands-on, applied approach. Although a number of PLTW-sponsored evaluations report on student demographics and surveys of intentions, only one longitudinal study has been conducted independent of the PLTW organization.

Schenk, Rethwisch, and Laanan's (2009) study of PLTW in Iowa found that:

- PLTW participants were more likely to be enrolled in gifted and talented programs. 30% of participants met the requirements in 2008, compared to 12.6% of nonparticipants.
- PTLW participants performed better in math and science before high school and in their junior year.
- PLTW participants performed comparatively better on the junior year ITEDs [Iowa Tests of Educational Development].
- PLTW participants were more likely to enroll in math, life and physical sciences, industrial and technology, foreign language, and drafting courses than nonparticipants. Nonparticipants disproportionally enrolled in business, consumer and homemaking education, English language and literature, military science, social sciences, and history course at a higher rate.
- PLTW participants were less likely to be eligible for free or reduced lunch than their peers.
- PLTW participants were more likely to jointly enroll at a community college.
- PLTW participants were disproportionally white compared to nonparticipants
- PLTW participants were predominantly male. (Shenk et al., 2009)

We find similar patterns of gender bias in STEM-focused CTE programs. Mason and her colleagues (2009) summarized studies that showed five of six students were female in traditional female CTE courses (e.g. child care, health care) while five of 6 are male in male traditional courses (e.g. construction, IT).

In an unpublished document obtained from PLTW (Author, nd), several studies described as rigorous impact studies were cited that provide contrary evidence to the two PLTW studies cited above. Evaluation studies are cited where researchers created comparison groups, matching participating and non-participating students based on potentially relevant characteristics. Each of the quasi-experimental studies matched participants with nonparticipants on key characteristics (i.e. test scores, demographic characteristics, year of enrollment, etc.). In these independent quasi-experimental studies using carefully matched comparison groups, researchers reported providing strong evidence for PLTW's effectiveness in reducing achievement gaps, improving standardized test scores, and college readiness.

Contextualizing math and science in CTE. All curriculum integration approaches attempt to move away from the traditional model of instruction, in which subjects are taught by themselves, completely isolated from any context. Traditional mathematics, for instance, is seen as abstract, disconnected from any real application (Brown, Collins, & Duguid, 1989). In the case of algebra, equations are presented as things to be solved, symbols to be moved around, or graphs to be drawn without any discussion of the real-life applications of the math (Kieran, 1990). Some math educators believe that students have a lot of trouble learning algebra in a decontextualized way (Boaler, 1998; Kieran, 1992). For many students, the subject matter becomes too abstract too quickly and does not make any sense. This issue is particularly acute with low achievers (Woodward & Montague, 2002). Perhaps more than other students, low achievers need lessons designed to link to a context of interest as a way to make sense out of abstract mathematics.

The goal of curriculum integration is to demonstrate to students the connection between academic subjects. However, not all curriculum integration models are the same. Some use a *coordinated* approach, such as in specialized career academies in which all teachers coordinate their subjects around specific themes. This method corresponds to the definition offered by the Association for Supervision and Curriculum Development (Association for Supervision and Curriculum Development [ASCD], 2003): Integration is a philosophy of teaching in which content is drawn from several subject areas to focus on a particular topic or theme. Rather than studying math or social studies in isolation, for example, a class might study a unit called The Sea, using math to calculate pressure at certain depths and social studies to understand why coastal and inland populations have different livelihoods (ASCD, 2003). Still other integrated learning models are *context-based* and try to fit mathematics into CTE by changing the content of word problems, for example. In these models, CTE is the context for delivery of traditional academics. Such approaches are also called *related math* or *applied math.* Attempts to contextualize the symbols in word problems may not be an adequate or effective fix for all learners, however, especially for "students with mild disabilities and at-risk students, who have few resources to guide their problem-solving performance" (Montague, 1992, as cited in Jitendra & Xin, 1997, p. 435). Two prominent examples of this approach are PLTW and the Center for Occupational Research and Development (CORD). As noted, PLTW provides a pre-engineering and biomedical curriculum whereas CORD provides what it describes as contextual teaching materials in mathematics and science. Both of these programs are well represented in CTE schools.

A curriculum integration model created and experimentally tested by the NRCCTE employs a contextual approach (as opposed to a context-based approach) in which math learning occurs within a real-world CTE context (e.g., manufacturing, engineering, auto technology). In this way, learning involves students connecting the content with the context in which that content could be used. This brings meaning to learning. The use of authentic situations serves to "anchor" the symbolic and abstract math in situations that are familiar and real to students, which serves to help them make sense of the content (Brown et al., 1989; Cognition and Technology Group at Vanderbilt, 1990). The National Science Foundation (NSF) has funded several contextual mathematics projects at the high school level, one of which is Core-Plus. Core-Plus has been found to increase students' conceptual understanding and problem solving in applied contexts; however, students in Core-Plus do not score any higher than students in the traditional math (Stone, Alfeld, Pearson, Lewis, & Jensen, 2006).

The genesis and focus of a contextualized approach to integration is the CTE content. In other words, the process of integration begins with the CTE curriculum and the identification and enhancement of the academic content naturally occurring within it. Contextualized teaching and learning does not require the sacrifice of CTE content or the addition of artificially imposed academic content. Rather, the academic concepts resident in authentic applications of CTE support the understanding of both; rigor resides in combining CTE and academic skills as applied to real-world problems.

The NRCCTE completed one study of contextualizing math in CTE and is currently engaged in a test of science integration. Math-in-CTE is an experimentally tested model of teaching embedded mathematics through high school occupational education (e.g., auto technology, health, business and marketing, agriculture and IT; see Stone, Alfeld, & Pearson, 2008). After one year of math-enhanced CTE lessons averaging 11% of total class time, students in experimental classrooms performed significantly better than control students on two tests of math ability—the TerraNova and ACCUPLACER—without any negative impact on measures of occupational or technical knowledge. On the TerraNova, the average experimental class scored at the 71st percentile of the control classes. The effect measure for the ACCUPLACER showed the average experimental class scored at the 67th percentile of the control classes (Stone et al., 2008). The study showed that the "M" in STEM education can be successfully integrated with the "T" and improve students' math skills. The NRCCTE's related Science-in-CTE study is experimentally testing a model of teaching embedded science through high school occupational education (NRCCTE Curriculum Integration Workgroup, 2010). Results are expected in the summer of 2011.

Pedagogic Approaches

Project-based learning. Project-based learning is defined as students going through an extended process of inquiry in response to a complex question, problem, or challenge.[10] The entry event for a project can take many forms, but it generally reflects the learning standards that the project will address and engages students so they want to learn more about the topic. Teachers anticipate the types of information students will need to know to carry out the project and plan (scaffold) activities that will provide this information. These activities may take the form of short lectures or workshops, resources students can be referred to, writing prompts for journal entries, data collection, and guest speakers. Teachers develop rubrics indicating what they expect students to learn and the criteria that will be used to assess learning. Teachers guide the process, but students must make key decisions about how the project will be conducted. This is usually accomplished in teams, which require communication, problem solving, and cooperation—all skills frequently cited by employers as essential in the modern workplace. A project typically ends with a

[10] See http://www.bie.org/.

presentation of its process and results. Such presentations may involve inviting interested community representatives to provide critiques.

Evidence suggests that project-based learning improves the student's process for self-learning, and increases problem-solving skills, but there is little evidence that it improves motivation or communication skills (Hmelo-Silver, 2004).

One of the most visible examples of STEM-related project-based learning is the FIRST Robotics competition.[11] Teams are challenged to build robots that can compete in games that differ each year. Teams design, build, and program their own robots in a short time period from the time the game is announced until the first round of competition. Successful teams can progress to the national level. A study at Brandeis University compared high school students who participated in FIRST Robotics to non-FIRST Robotics participants who entered college at the same time and found that participants were:

- More than three times as likely to major specifically in engineering.
- Roughly 10 times as likely to have had an apprenticeship, internship, or co-op job in their freshman year.
- Significantly more likely to expect to achieve a post-graduate degree.
- More than twice as likely to expect to pursue a career in science and technology.
- Nearly four times as likely to expect to pursue a career specifically in engineering.
- More than twice as likely to volunteer in their communities. (Melchoir, Cohen, Cutter, & Leavitt, 2005)

Work-based learning. Work-based learning (WBL) provides supervised learning activities for students that occur in paid or unpaid workplace assignments and for which course credit is awarded (NCES, 2002). When WBL is done well, students are able to compare and utilize the knowledge they learn in both the classroom and the worksite to create a learning process that appears like a cycle. Abstract concepts learned in the classroom can be applied in practice at the worksite, and industry standards and needs learned at the site are considered as students process lessons in the classroom (Raelin, 1997). Studies show that organized WBL programs that have strong links to schools result in better outcomes for students compared to informal WBL programs (Bennett, 2007; Stasz & Brewer, 1998). Students who graduate from a WBL program form realistic plans following high school that help them to meet their goals and are more likely to be employed (Orr, 1996).

Ryken's (2006) study analyzed the progress of 256 students in a WBL program linking high school and community college that was geared towards creating opportunities for minorities in biotechnology laboratories. There were three typical outcomes: (a) students were interested in the program and were employed later in the program, (b) students found they had interests in higher education and dropped out of the program to pursue a 4-year degree, or (c) students found an interest in a related field and dropped out of the program to follow a career path that the program did not offer.

[11] See www.usfirst.org/Default.aspx.

Apprenticeships are the original WBL, but they are rarely used at the high school level. Delta High School[12], a full-time high school in Washington State, is a notable exception. Delta has a STEM educator in residence from the Pacific Northwest National Laboratory (PNNL). Students can apply for internships as early as their junior year of high school with PNNL; apprenticeships and job shadowing are also available.

Kuna high school in Idaho[13] offers a STEM academy that incorporates WBL. Here, students take four of their eight classes together to facilitate project based learning that incorporates an integrated approach to teaching math, science, research, and language arts. Students in this program are eligible to participate in WBL, including job shadowing and internships with local STEM-related businesses and enterprises.

A well-integrated WBL program in STEM-focused CTE was described by Hoachlander and Yanofsky (2011). Linked Learning, or ConnectEd as it was originally titled, is a whole school reform strategy designed to prepare all students to meet the California A-G requirements for college entry and also address career preparation. The WBL they describe involves students engaged in real work under the guidance of industry professionals. Internships, paid and unpaid, are the best-known examples of this kind of opportunity. WBL also takes other forms. Mentoring and job shadowing introduce students to offices, laboratories, manufacturing facilities, and a wide range of working professionals. Even more advantaged students have little or no contact with working adults or much awareness of the range of career opportunities in STEM fields. Such experiences can be especially powerful for disadvantaged students who have rarely ventured out of their immediate communities. Hoachlander and Yanofsky (2011) note that internships or other placed-based opportunities are difficult to provide for large numbers of students. The age of students, nature of the enterprises, geography, and other barriers often limit traditional sorts of WBL.

Linked Learning has begun to create new forms of virtual WBL. As described by Hoachlander and Yanofsky, "ConnectEd is collaborating with Chevron to develop a series of engineering- and energy-related design challenges for students in academies of engineering and for the growing number of green technology partnership academies in California. These design challenges may involve different kinds of pipeline valves, for example, or LED displays monitoring fuel flow through landbased pipeline systems." Students may post their work in online portfolios which are reviewed by their teachers and industry professionals at Chevron.

Another promising WBL strategy is school-based enterprise—student-led business or community service initiatives in which students design, produce, and deliver real products and services (Stern, Stone, Hopkins, McMillion, & Crain, 1994). For example, in collaboration with a local utility, students engage in energy audits for local homeowners and small businesses. Alternatively, schools may team with a local economic development agency to undertake environmental impact analyses. School-based enterprise can be especially useful in schools with limited access to industry partners and other WBL opportunities.

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[12] See www.thedeltahighschool.com.
[13] See http://www.kunaschools.org/schools/khs/departments/stem/index.php.

Although promising, virtual WBL and school-based enterprise as well as more traditional internships hold promise for meeting the STEM goals of many advocates, they remain largely untested in relation to their academic as well as more narrowly defined STEM-related educational outcomes.

Problem-based learning. Problem-based learning has many parallels with project-based learning, but it places a greater emphasis on guiding inquiry and less of an emphasis on structuring learning experiences (Pierce & Jones, 1998). Problem-based learning grew out of medical education and developed for medical students as a strategy to engage them in investigations that require the use of skills and knowledge from various content areas. The approach requires students to, synthesize information, and determine if their solution is viable. A popular model used at both the elementary and secondary level is Computer Supported Intentional Learning Environments, which guides students through the scientific method and takes place in learning communities (Scardamali & Bereiter, 1994). This method is most likely to combine the aspects of other contextualized learning approaches, but the most effective are opportunities that allow the students to go through the scientific method to answer the question or problem themselves.

Does CTE Promote or Enhance STEM Learning?

STEM-focused education can be incorporated into any CTE delivery system, program, or curricular or pedagogic approach within CTE. As described earlier, specific pedagogic interventions developed over the past several decades have sought to infuse more math and science in CTE through various forms of curriculum integration. Although the literature is replete with descriptions of what appear to be innovative approaches to addressing STEM and CTE, little rigorous research exists to inform policy about what might actually improve education in STEM disciplines. At this time, only one approach (Math-in-CTE; Stone et al., 2008) has been rigorously tested. Further, there is no evidence that any one delivery system (e.g., school) or another is particularly efficacious in delivering STEM education or education in related STEM disciplines.

MDRC’s study (Kemple & Willner, 2008) showed that career academies provided documented economic benefit to participants, but only for males. The lack of academic benefit was likely due to the inherent challenge of potential selection bias for such programs. It is still too soon to determine the impact of programs of study (POS), although the NRCCTE currently has three longitudinal, field-based studies in process in seven states that will help generate scientific evidence of their impact and effectiveness.

There is limited evidence regarding specific STEM-related curricula in CTE programs. The most recognized of these, PLTW, is beginning to develop a literature base and not surprisingly, the findings are mixed. A limited number of longitudinal evaluations suggest that the program attracts students who are already proficient in mathematics and science. Despite efforts to reach underserved populations (e.g., minorities and females), these efforts have not borne fruit with PLTW. Other, quasi-experimental studies suggest the program is having an achievement effect amongst minority populations as well as majority populations.

Abundant research remains to be done. There are testable questions regarding whether, for example, teaching chemistry or algebra II through a CTE program affects students' acquisition of science or mathematics knowledge beyond that naturally embedded in the curriculum. Another testable question is the extent to which teaching STEM subject matter through a STEM career-focused school or program like affects students' acquisition of learning in related chemistry or mathematics.

Descriptive case studies could target model STEM-focused CTE schools and school-level strategies for enhancing CTE-based STEM education; such case studies could focus on schools that have overcome gender bias and attracted students from underserved populations.

State and local databases could be accessed to examine programs like POS, extract data from STEM-focused CTE programs, and develop cross-sectional or longitudinal studies that could identify programs in which STEM-focused CTE is meeting or exceeding ambitious STEM-related goals. Although the NRCCTE's field-based POS studies were not designed to specifically address STEM-focused CTE, our experience in the conduct of these studies suggests the potential for additional research in these areas.

Testing curricula like PLTW may also be possible. The challenge in such a study is separating the curriculum from the pedagogy. The problems, projects, and manipulatives that are central to PLTW are pedagogies that are also used outside the PLTW curriculum framework.

There is evidence that integrating math in CTE courses can increase the STEM knowledge of CTE participants. Using a contextual approach, students who learn to use math to solve authentic work-based problems improve their understanding of mathematics (Stone et al., 2008). What is yet to be rigorously tested are context-based strategies that use a work-based context to deliver a traditional math (or science) curriculum. A rigorous test of existing context-based curricula would be relatively easy to construct. Such studies are, however, expensive to implement.

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