Association for Career and Technical Education
ACTE

ISSUE BRIEF

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CTE's Role in Science, Technology, Engineering & Math

IN THIS BRIEF:

This Issue Brief will explore the integral role CTE programs and initiatives play in addressing the STEM challenge and securing America's leadership in innovation. CTE programs offer students a deeper understanding of STEM career pathways, build interest in STEM-related careers by making math and science content more relevant and tangible to students, and help grow the STEM workforce pipeline by encouraging more students from underrepresented populations to enter these career fields.

For the last several years, concern has been growing about America's underinvestment and underperformance in the fields collectively known as STEM (science, technology, engineering and mathematics). These concerns have been heralded in several high-profile books, reports and policy proposals from groups ranging from U.S. business leaders to the National Governors Association.[1]

What is STEM, and why is it drawing so much high-profile attention? STEM can be described as an "initiative for securing America's leadership in science, technology, engineering and mathematics fields and identifying promising strategies for strengthening the educational pipeline that leads to STEM careers."[2] The elements of science, technology, engineering and math are integral parts of our nation's critical economic sectors, from health care to energy, and infrastructure to national security. STEM careers include not only those requiring a research-based advanced math or science degree, but a broad range of related occupations in areas as diverse as aquaculture, automotive technology, accounting and architecture. More careers than ever before require a deep understanding of science, technology, engineering or math principles.

Despite the increased importance and focus placed on preparing students for STEM fields, more must be done to ensure a fully developed, skilled STEM workforce that will help secure America's economic future. Career and technical education (CTE) programs offer an important instructional approach that strengthens students' understanding of STEM content and helps attract more individuals into STEM career pathways. Expanding and strengthening CTE programs are critical parts of the solution to the STEM challenge.

The Concerns

TOO FEW STEM PROFESSIONALS

To regain a high level of American economic competitiveness and well-being, American-based industries need to perpetuate a steady stream of innovative

STEM-intensive Career Clusters and Sample Careers

Agriculture, Food and Natural Resources	Health Science	Information Technology	Manufacturing	Science, Technology, Engineering and Mathematics	Transportation, Distribution and Logistics
• Veterinarian • GPS Technician • Food and Drug Inspector	• Dietician • Pharmacy Technician • Microbiologist	• 3-D Animator • Network Administrator • Computer Programmer	• Electrical Engineer • Safety Technician • Wind Turbine Machinist	• Statistician • Lab Technician • Drafter	• Aerospace Engineer • Logistics Analyst • Diesel Engine Specialist

technologies and processes. Policymakers and business leaders have emphasized that this ability to innovate is predicated on the readiness of a large pool of talented individuals with expertise in the principles of science, technology, engineering and advanced mathematics. The demand for U.S. STEM professionals is expanding rapidly, but the supply of STEM talent is not increasing to meet the growing need.

Two main factors are affecting the supply side of the STEM equation. First, the looming retirement of the baby boom generation will significantly affect the STEM labor force. The number of current scientists and engineers retiring will increase rapidly over the next decade. Twenty-six percent of people with science and engineering degrees currently working are 50 years or older. Second, too few students are currently choosing to prepare for STEM careers. From 1985 to 2005, the number of bachelor's degrees earned in engineering fell from to 77,572 to 66,133, and the number of associate degrees in engineering technology fell from 53,700 to 28,800.[3]

The United States is standing still or falling behind in terms of producing home-grown STEM talent. At the same time, other nations, particularly population-rich ones like India and China, are rapidly increasing the number of STEM professionals that their secondary and postsecondary education systems produce.[4]

These sobering facts indicate that the United States is struggling to keep up with increasing global competition for talent, which depends in large measure on STEM education. The U.S. business community has set a goal of doubling the annual number of U.S. science, technology, engineering and mathematics bachelor's-level graduates to 400,000 by 2015.[5]

An exponentially higher level of STEM technicians with associate degrees or certificates will also be needed across a broad spectrum of industries in the future. Demand for STEM professionals with education and training above a high school diploma but below a bachelor's degree is expected to grow significantly in the coming years.[6] For example, veterinary technicians, nursing assistants, pharmacy technicians, forensic-science technicians and dental hygienists are all among the fastest-growing occupations projected by the Bureau of Labor Statistics.[7]

LACK OF BASIC SCIENCE AND MATH SKILLS

While some of the deficit in STEM professionals can be attributed to lack of interest, there is growing concern that students are not gaining the foundational skills necessary to be successful in STEM career areas even if they choose that path.

Low student performance is evidenced on the U.S. National Assessment of Educational Progress (NAEP). Math scores for 17-year-olds were essentially unchanged from 2004 to 2008, despite the fact that students are taking more and higher-level math courses in high school.[8] In fact, test results showed that 41 percent of those students did not even have an understanding of moderately complex math procedures and reasoning, such as finding averages and making decisions based on graphs.[9]

According to the 2006 Programme for International Student Assessment (PISA), U.S. students performed much worse in science and math than students from other industrialized countries.[10] Of the 30 countries tested, students from 16 countries performed higher than U.S. students in science, and students from 23 countries performed higher than the United States in math.

In addition, scores in the United States were much more closely correlated to socioeconomic status than in other countries. For the U.S. students who took the PISA, 18 percent of the variance was related to socioeconomic status, while only 14 percent of the variance was related to socioeconomic status in other countries.[11] This U.S. income-based achievement gap is further evidenced by the fact that lower-income U.S. students scored an average of 23 points below higher-income students on the math portion of the 2005 12th-grade NAEP.[12]

Achievement gaps also exist among U.S. students based on race and ethnicity, and the gaps are even more dramatic when gender is added. Hispanic and black students lag behind white students on practically every measure of science and math proficiency.[13] On the mathematics portion of the SAT college entrance exam, Asian-American and white students' scores are much higher and are increasing more rapidly than those of black and Hispanic students. Boys significantly outperform girls across all four race/ethnicity categories.[14]

Given the demographic trends of rapidly increasing non-white and less-advantaged populations in the United States, this pattern of low performance among disadvantaged students is a serious concern for the potential future of the STEM workforce.

CTE Provides a Solution

In facing these serious challenges, there is also reason for optimism in America's ability to ignite interest in STEM-related careers and strengthen the STEM literacy of the entire student population. The reason for that optimism stems from a growing level of STEM innovation that has evolved from CTE.

CTE has long been a leader in the integration of high-level academics and technology. For example, CTE courses in agriculture, nutrition and health care have always contained strong science components, in many places earning students core academic credits. During the last decade, however, literally thousands of new cutting-edge, STEM-intensive CTE programs have been launched or expanded in schools across the nation. As these programs move to larger-scale implementation, they have amazing potential to help many additional students prepare for and pursue careers in STEM areas.

CTE programs and related initiatives provide key advantages in addressing the STEM challenge and securing America's leadership in innovation. CTE programs offer students a deeper understanding of STEM career pathways in order to facilitate student transitions into these areas, build interest in STEM and STEM-related careers by making math and science content more relevant and tangible to students through integration, and help grow the STEM workforce pipeline by encouraging more students from underrepresented populations to enter these career fields.

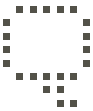
PROVIDING CAREER EXPLORATION AND PATHWAYS

There is a significant challenge in American culture of attracting students to actively pursue STEM careers. According to a recent survey about teen attitudes toward STEM, students are exhibiting a renewed openness toward pursuing STEM professions and showing more interest in developing marketable STEM skills as the nation's economic future becomes more tenuous. However, the survey also indicates that youths' lack of understanding of STEM creates a serious obstacle. "Nearly two-thirds of teens indicated that they may be discouraged from pursuing a career in STEM because they do not know anyone who works in these fields (31 percent) or understand what people in these fields do (28 percent)."[15]

CTE programs, integrated with active career exploration and career advising, help students understand the breadth of careers that have a relationship to STEM and the varied pathways that can lead to those careers. Courses in areas like aviation and aerospace, information technology, engineering, game design, health care, nanotechnology, and simulation and robotics expose students to curricula and careers they may have never even imagined.

Embedded in CTE programs are the support services necessary to help students pursue these rigorous courses and career opportunities, including mentors, career and technical student organizations, and work-based learning opportunities, such as job shadowing and internships, to connect youth with caring adult role models.

STEM-intensive courses are being taught throughout CTE through the use of career clusters, an approach that gives students a broader understanding of the world of careers. There are 16 career clusters containing 81 distinct career pathways.[16] While STEM-related careers exist across the 16 clusters, six are considered STEM intensive: Agriculture, Food and Natural Resources; Health Science; Information Technology; Manufacturing; Science, Technology, Engineering and Mathematics;



"CTE courses, through the thoughtful integration of STEM concepts, can help all students become more STEM literate and increase the chances that these students consider STEM-related careers."

and Transportation, Distribution and Logistics. Within these systems, students can learn more about career options, take personalized career assessments, and better understand the challenging mathematics and science courses they will need to pursue STEM careers.

Through coherent "programs of study," authorized in the federal Carl D. Perkins Career and Technical Education Act, CTE at the secondary level is linked to postsecondary experiences leading to certificates, associate degrees and bachelor's degrees. This is especially critical in STEM fields. While not all STEM professions require bachelor's or more advanced degrees, almost all require some amount of postsecondary education and training.

According to a workforce analysis conducted in 2007, about half of all U.S. jobs fall in the category of "middle skill" jobs—"those that require more than high school, but less than a four-year degree."[17] A large percentage of these middle skill jobs relate directly to STEM.

Through programs of study, CTE students can explore and then enter into a definitive career pathway with the assurance that knowledge and skills will transfer between secondary and postsecondary education, and then into a high-skill, high-wage, high-demand job opportunity. CTE programs put students on a pathway to immediate job opportunities and lifelong career advancement in STEM areas.

ADDING RELEVANCE THROUGH INTEGRATION

Part of the American competitiveness challenge is for all U.S. workers to be able to readily apply the scientific method, cutting-edge technologies, mathematical thinking skills that contribute to innovation and problem solving, and the systems-thinking that undergirds engineering and design to create new services and solutions to meet customer demands. CTE courses, through the thoughtful integration of STEM concepts, can help

Since 1997, when Project Lead the Way (PLTW) was launched as an independent not-for-profit organization with 12 high schools participating, PLTW's pre-engineering program has experienced rapid growth. By 2009, approximately 3,000 middle and high schools were participating in the effort, with 250,000 students enrolled in PLTW courses in engineering and biomedical sciences.[18] This is a significant start on reaching the goal of producing 400,000 scientists and engineers annually.

At Lake Travis High School (LTHS) in Texas, the PLTW curriculum is used as part of the Institute of Math, Engineering & Architecture. LTHS is using an integrated, cohort-based approach to implement PLTW and help more students explore careers in engineering. Ninth-grade students begin the program with the PLTW Introduction to Engineering Design course and continue with the 10th-grade Principles of Engineering course. During the sophomore year, these students take special, engineering-focused academic courses that help them see the relevance of traditional academics to their future career options.

For juniors, the coursework includes Digital Electronics, a course focusing on skills in basic electronics, logical thinking, problem solving and troubleshooting and offering four articulated credits at Austin Community College. Seniors complete the LTHS PLTW program with more in-depth elective engineering courses, as well as internships, capstone projects and college connections.

Much of the expansion and integration of the engineering program at Lake Travis has been made possible by a grant from Siemens Building Technologies. Siemens was looking for a school district to model and disseminate best practices in high school engineering programs. Due to the highly recognized postsecondary engineering programs at Austin Community College and the University of Texas, Lake Travis was selected to participate. The grant has provided business and industry externships for academic and CTE teachers, common planning time to enhance curriculum integration, and partnerships that connect students with the professional STEM community and prepare them for postsecondary success across a wide range of career options.

all students become more STEM literate and increase the chances that these students consider STEM-related careers.

While most students have a strong aptitude for learning, their particular learning styles vary significantly. Many students may have difficulty grasping mathematical concepts and scientific theories if they are presented in an abstract manner devoid of clear applications. CTE courses deliver STEM content in a manner that is far different from the average academic course.

One new approach was developed and examined through the "Math in CTE" project carried out by the National Research Center for CTE. In this project, math and CTE teachers identified the math content already present in various CTE courses and conducted curriculum-alignment activities and created lesson plans to make that content much more explicit and consistent with terminology used in core academic courses. The project's specific methodology demonstrated a positive impact on student learning and test scores, and is being replicated across the country.[19]

Another project aimed at strengthening math and science skills through CTE is the STEM Transitions Initiative, led by the Center for Occupational Research and Development (CORD) and funded by the U.S. Department of Education. The STEM Transitions Initiative developed 61 curriculum projects that integrate core academic content into rigorous CTE applications.[20] Curriculum resources are organized within the six STEM-intensive career clusters. The context-based instructional materials provide faculty with teaching resources that will boost both the academic and career-related skills of their students by integrating math and science instruction within the context of a technical discipline.

Other innovative projects are also underway all across the country. The Ford Partnership for Advanced Studies (Ford PAS) curriculum modules, developed by Ford Motor Company Fund, a leader in the CTE career academy movement, in collaboration with Education Development Center, Inc., utilize a similar approach to helping students apply, and deeply learn, math and science content. The FORD PAS module "Putting Math to Work" involves teaching and reinforcing algebraic and statistical mathematics standards through personal financial planning, creating a business plan and applying statistical methodology for quality control processes.[21]

In January 2008, Virginia Governor Timothy Kaine announced grants to establish the commonwealth's first "Governor's Career and Technical Academies."[22] The academies are placed throughout the commonwealth and provide instruction in science, technology, engineering and mathematics while helping students explore careers. They were developed as partnerships among schools, employers, business organizations, and colleges and universities. This initiative demonstrates clearly how CTE programs can strengthen student learning in STEM-related fields and expand the high-tech workforce of Virginia.

"These academies will combine programs based on local and state economic and employment needs with rigorous academics and opportunities for applied learning in science, technology, engineering and mathematics," said Governor Kaine. "The academies will prepare young men and women for rewarding careers while ensuring that communities have the highly skilled workers necessary to compete in the global economy."[23]

Each of the original six partnerships (more have been added without state funding) received a $20,000 planning grant, followed by a $100,000 implementation award upon program approval by the Board of Education and the State Council of Higher Education. The academies are building on existing programs at the high school and postsecondary levels and aligning instruction in science, technology, engineering and mathematics with postsecondary and 21st century workplace expectations.

Programs across the partnerships are offered in diverse areas, including modeling and simulation, interactive media, natural resource systems, biotechnology, mechanical engineering, emergency medical services, and automotive technologies. Business partners like NASA's Langley Research Center, the Appalachian Electric Power Company, GEICO and Northrup Grumman Corporation have been involved in the efforts and offer students work-based learning opportunities like mentorships, job shadowing, cooperative education and internships.

The planning and start-up funding for the academies was provided through a $500,000 grant from the National Governors Association Center for Best Practices, which was supported by the Bill & Melinda Gates Foundation and Intel Corporation.

In the realm of physics, students from Eau Claire North High School in Wisconsin participated in the Annual High Mileage Vehicle Challenge held at the University of Wisconsin-Stout.[24] Like other participating schools, Eau Claire North High School students produced a fuel-efficient hybrid car for the race. Built in their Electronics 3 CTE course, the car made from aluminum and shrink wrap by Eau Claire students averaged 1,610 miles per gallon of gasoline and helped them integrate a wide variety of STEM skills.

CTE courses demonstrate to students in a vivid way the direct applicability of STEM concepts to authentic situations and show that these knowledge and skills have value in solving interesting and engaging real-world problems.

ENCOURAGING UNDER-REPRESENTED POPULATIONS

If the United States is going to successfully get the number of additional students needed to secure the country's economic future interested in and able to pursue STEM-related careers, all population groups must be included in this effort—even those currently underrepresented in STEM areas. Females, who earn significantly fewer bachelor's and associate degrees in STEM fields like engineering,[25] and African-American and Latino students who, as a group, have significantly lower achievement levels in math and science and who have been declining as a percent of the degrees earned in STEM fields,[26] are key to the future of the STEM workforce.

CTE programs across the country are taking great strides in both areas. To help increase the number of women in STEM careers, the Carl D. Perkins Career and Technical Education Act of 2006 continues to require that CTE programs work to recruit students to programs considered "nontraditional" and holds them accountable for participation and completion rates. Nontraditional programs are defined as those that prepare students for careers in which one gender constitutes less than 25 percent of the total employment in that field. For females, many STEM-related programs fall into this category.

The National Alliance for Partnerships in Equity, through its STEM Equity Pipeline Project, has identified a series of research-based root causes across the areas of education, career infor-

At Francis Tuttle Technology Center in Oklahoma, the GirlTech program was created to attract more girls into STEM career areas and encourage them to complete CTE programs. The mission of the GirlTech program is to equip female students (ninth grade to adult) with skills to pursue careers in information technology, scientific research and engineering.

GirlTech adds the essential ingredient of relationships to rigorous STEM-related CTE programs by providing female students with mentors and role models who give them assurance that they can succeed. Up to 25 female students per year who are enrolled in predominately male CTE programs apply to the program and are selected to participate. These students are matched with a volunteer professional mentor who meets with them, in person and electronically, throughout the year to ensure they understand the challenges they will face in this nontraditional career.

While participation is concentrated in Francis Tuttle's pre-engineering academy, girls from precision machining, automotive services, carpentry, bioscience and medicine, CADD, and cyber security and network technology programs have participated. Mentors from leading science and technology companies like Boeing correspond with students by e-mail once a week; participate in three group workshops on topics like assertiveness, networking and communications, job interviewing, and resume writing; provide opportunities for mentees to job shadow; and provide general guidance and advisement on a broad range of issues, from difficult homework assignments to college and career plans.

The GirlTech program has successfully increased the number of girls enrolled in the pre-engineering academy to an all-time high and encouraged these students to pursue careers in STEM areas. Of the 22 GirlTech participants who graduated from the pre-engineering academy from 2006 to 2008, 21 went on to declare a STEM field as their college major. Shanee Watson, a 2005 GirlTech graduate, attributes her mentor with confirming her decision to become a chemical engineer and inspiring her to apply for entrance to the Massachusetts Institute of Technology (MIT). Watson has completed her third year at MIT on a full scholarship and still maintains her relationship with her mentor.[27]

"CTE courses demonstrate to students in a vivid way the direct applicability of STEM concepts to authentic situations and show that these knowledge and skills have value in solving interesting and engaging real-world problems."

mation, families, individuals and society that discourage girls from entering STEM careers, as well as corresponding strategies for addressing those issues.[28] CTE programs have implemented a number of these successful strategies, including:

- strong career guidance and counseling and career exploration activities for all students
- role models and mentors to better connect students to STEM careers
- ongoing gender equity and non-discrimination training for faculty and staff
- hand-on activities to engage students and connect programs to the real world
- business and community involvement
- cohort-based activities that create a more positive school climate

While single strategies alone may not be enough to address the myriad challenges in this area, comprehensive programs have had success. Since 2000, the Inspiring Girls Now In Technology Evolution (IGNITE) program has connected more than 10,000 high school girls from Seattle Public Schools with technology careers. This has resulted in dramatic increases in female enrollment in technology courses. Through strong partnerships with local companies like CISCO and Microsoft, the program provides girls with corporate field trips, job shadowing and internships, as well as women-in-technology guest speakers and mentors.[29]

To encourage minorities to enter STEM career fields and better prepare these students to overcome current achievement gaps, CTE programs are expanding into urban areas and focusing on low-income and minority students.

In the Los Angeles Unified School District, a program funded by the National Science Foundation has focused on encouraging more students to enroll in computer technology programs.[30] The program has doubled the number of African-American students and tripled the number of Latinos enrolled in AP Computer Science by changing student perspectives and showing them how they already relate to technology in their everyday lives, upgrading curriculum, and providing professional development to teachers. Another high school in Los Angeles, with a population 61 percent Latino and 17 percent African-American, has recently opened a new Academy of Engineering, sponsored by the Gates Foundation, National Academy Foundation, Project Lead the Way, Motorola, Verizon, Xerox and other high-tech companies.[31]

Urban agriculture education, like the agriculture and environmental sciences program at Uniondale High School on Long Island, is rapidly expanding to draw an increasingly diverse population. Students in the Uniondale program connect to science through agriculture projects that address community needs, such as examining how to make contaminated soil useful again and regulating plant growth. Students even competed in the 2008 INTEL International Science and Engineering Fair with research projects related to pest management.[32]

Conclusion

In an always-growing, flattening, globalizing economy, the United States is facing strong international competition from nations that are "increasing the skills of their citizens in the science, technology, engineering and mathematics (STEM) subjects—areas key to success in a high-tech world."[33]

Fortunately, schools and colleges in the United States are rising to the challenge by offering rigorous, relevant CTE programs with content strong in science, technology, engineering and mathematics. The nation's economic leadership, inherently linked to STEM achievement, will not be maintained without support for critical CTE programs that build student interest and skills in STEM areas.

Through the thoughtful investment in STEM-intensive CTE programs, America can readily increase its supply of motivated and prepared students entering STEM-related fields and strengthen the general STEM literacy of the emerging U.S. workforce.

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Photo courtesy of Miami Valley Career Technology Center in Clayton, Ohio. Casey Whitaker prepares samples for the Biotechnology Tech Prep program.

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