



Career Pathways for STEM Technicians

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Abstract

Science and engineering technicians are needed in emerging technologies by U.S. employers. These technicians are being produced by U.S. community and technical colleges using NSF/ATE-developed curricula and teaching strategies. However, enrollment is low and attrition is high, because there is not an adequate “high school pipeline” to interest and prepare young people to select and be successful in educational programs for these rewarding careers. STEM programs, developed and offered at high schools throughout the country can provide this “pipeline” by recruiting and educating applied learners to graduate and enroll in technology programs at nearby colleges. However, carefully designed (secondary/postsecondary) Career Pathways must be developed and adopted for STEM technologies. NSF/ATE models have been created and are in use.

Introduction

Our country’s technology edge is fading quickly, and the problem will not be solved with just more engineers and scientists. We need more technicians.¹

The history of our country’s emergence, leadership, and prosperity has shown evidence of our values and superiority as we have worked to make our nation a land of opportunity.

- We have shown vision, courage, determination, and a commitment to hard work.
- By creating a public education system that was second to none, we built an environment that supported the personal pursuit of opportunities and rewards.
- As we shifted from agriculture to construction, manufacturing, and services, we mobilized our workforce, infrastructure, and economy.
- As we used our creativity and innovation to advance electronics, automation, energy resources, aerospace, defense, medicine, and information technology, we captured and benefited from technological innovation.

However, over the last thirty years, we have been slipping in our international dominance and leadership because we have lost some of the characteristics that made us great:

- Our educational systems are not developing sufficient globally competitive “human capital.” *Superiority in science, engineering, technology, and innovation are important keys to a globally competitive workforce.*²
- Instead of investing in the future, we are living in—and borrowing on—the past. We’re continuing to rely on the technical and innovative skills and abilities of a generation of workers that is rapidly approaching retirement.
- We are not providing “opportunities for all” to our youth: we are trying to educate everyone the same way, for the same jobs, as if every student had the same limited range of abilities and interests. We’re neglecting students that aren’t performing “at the top”; and this is particularly true in science and engineering.³

What will our nation become if we fail to maintain our edge in technology and innovation? How can we avert this risk?

These questions were the focus of “Rising Above the Gathering Storm,” a 2007 report by the National Academies of Engineering and Sciences (NAE and NAS).⁴ In this very carefully worded, extensive report, technical and corporate experts explained that we as a nation were in deep trouble. If our nation didn’t turn things around, the report said, the United States was on track to become a second rate power—both economically and militarily—and future generations would not enjoy the prosperity and security that we have experienced over the last seventy years. Two recommendations from the report were:

1. *Move the U.S. K–12 education system in science and mathematics to a leading position by global standards.*
2. *Encourage more U.S. citizens to pursue careers in math, science, and engineering.*

Three years later, the National Academies revisited the situation to look for progress on their recommendations. In 2010, the Academies released a new report, “Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5”. The Committee found that little or no progress had been made on K–12 science and math education or in the number of citizens pursuing STEM careers. They concluded that “the outlook for America to compete for quality jobs had deteriorated further over the past five years.”⁵

School districts and technology employers across our nation responded by creating Science, Technology, Engineering, and Mathematics (STEM) programs—often called STEM academies. STEM programs are designed to interest high school students and prepare them to enter postsecondary education in STEM areas. Over 4000 STEM programs are currently operating in America’s high schools. Many of them are using a curriculum that is academically sound and technically valid and that provides the foundation necessary for graduates to enter and be successful in Bachelor of Science programs in science, engineering, information technology (IT), and mathematics. As part of this curriculum, most STEM programs encourage high school students to begin taking higher-level math (pre-calculus and calculus) in their junior and senior years.⁶ *These abstract math courses end up actually deterring many potential STEM students from pursuing STEM careers.* Calculus and pre-calculus courses become a filter that screens out students who are not interested in or successful at abstract math. These students are applied learners who could become the technicians we need.

The Problem and Proposed Solution

Students who fit this description are typically in the middle quartiles of achievement. They are capable of learning math and science at a useful level, but they are “applied learners,” hands-on learners with great spatial abilities. They often ask “What’s this good for?” They are unlikely to pursue baccalaureate studies in math, science, or engineering, but with different options for high school preparation, they may be interested in pursuing Associate of Applied Science (AAS) degrees in STEM fields that U.S. employers so desperately need. *Most high school STEM curricula don’t offer a career pathway to becoming a STEM technician; therefore both students and employers are missing out.*

Today, technicians are working with a wide variety of emerging technologies, such as photonics; nanotechnology; biotechnology; information and communication technology; advanced manufacturing; environmental monitoring; biomedical equipment; and nuclear, solar, wind, and

other alternative energy fields, to name a few. Associate Degree and certificate education programs to prepare technicians are in place in many of our nation's community and technical colleges and are continuously updated, primarily through grants from the National Science Foundation's Advanced Technological Education (ATE) program.⁷ Employers recognize the importance of technicians and readily support technical education programs in their local communities by advising on curriculum and labs, donating useful equipment, providing adjunct faculty and offering student internships.

The Technician Shortage: Low Enrollment Due to Inadequate High School Pipeline

OP-TEC is the NSF/ATE National Science Foundation Center of Excellence for Optics and Photonics Education (www.op-tec.org). The mission of OP-TEC is to encourage and support colleges that prepare photonics (lasers and optics) technicians, to assure that there is an adequate supply of these workers for our nation's industries. We support community and technical colleges by developing skill standards, designing curricula, developing teaching materials, and training faculty to teach new photonics courses. OP-TEC recently commissioned a survey of over four thousand U.S. photonics employers to determine their current and projected needs for technicians.⁸ We also polled the thirty-two existing two-year photonics colleges to estimate the future supply of new technicians.⁹ These surveys unearthed a huge disparity between supply and demand. There is a current and projected need of over 800 new photonics technicians per year, while the colleges are producing less than 300 graduates to fill these jobs.

These are good jobs. Photonics technicians with AAS degrees are earning starting salaries of \$40,000–\$60,000 per year.¹⁰ Because employers can't hire the qualified technicians they need in the United States, some are moving their operations off shore. Others are filling their technician positions with high school graduates and engineers, neither of which are a good fit. Employers prefer to hire educated technicians with AAS degrees, because most high school graduates don't have the necessary math and science background—and most engineers don't have the hands-on skills and spatial abilities. OP-TEC is working with the existing photonics colleges to build their enrollment and reduce attrition to increase the supply of educated/trained photonics technicians. Conditions and attitudes in high schools are preventing the development of strong "high school pipelines" to encourage and prepare grads to enter college programs. OP-TEC's challenge is not unique. The NSF/ATE program is supporting almost forty national and regional centers, as well as many related projects, in nanotechnology, biotechnology, information technology, and other emerging fields.¹¹ Nearly all these centers are experiencing similar low enrollments in the colleges they support.

The problem is that our culture—and our approach to educational reform over the last twenty-five years—has fixated on *one single path* through higher education for *everyone*. High school curricula and teaching strategies are almost totally focused on preparing students to enter and succeed in four-year baccalaureate programs. Accordingly, high schools typically offer only one path toward higher education, and this path requires students to take abstract math courses in their junior or senior year.

Encouraging STEM High Schools to Create Another Career Pathway for Technicians

Gary Hoachlander describes the need and organizing principles for alternate career pathways: *Our challenge as a nation is to help high schools offer a variety of career pathways. Four principles for meeting the challenge of creating new high school pathways are:*

- *A pathway, by design, should prepare students for both college and career. The days are gone when someone could succeed with just a high school diploma. Everyone will need further education and career preparation.*
- *A pathway should prepare students for the full range of postsecondary options. “College” no longer just means a four-year postsecondary opportunity. It also includes community college, apprenticeship, and formal employment training.*
- *A pathway should connect challenging academics to the real world, helping students to better understand what they need to know and why they need to know it. Students deserve thoughtful and truthful answers when they ask, “Why do I need to know this?”*
- *A pathway must produce significant growth in student achievement—in academics to be sure, but also in communications, critical thinking, problem-solving, technological literacy, and other cross-disciplinary areas needed for success in the modern world.¹²*

Build on the STEM Academy Model, but Provide Flexibility to HS STEM Curricula and Experiences that Will Also Include Preparation for Future Technicians

Effective curricula for STEM high schools, or STEM academies, has been tested and used extensively. (Reference: Project Lead the Way, PLTW¹³) The curricula typically involve a core containing four-year sequences of mathematics, science and English courses, in addition to other required courses in history, government, humanities and/or the arts.

- Math courses include Algebra, Geometry, Trigonometry, Statistics, PreCalculus and Calculus.
- Science courses include Biology, Chemistry, Physics, Earth Science and Environmental Science

Added to this core are special (PLTW) elective courses, introducing students to the basic tools and concepts of engineering, biomedical science and technology. In engineering these courses may include engineering/graphics design, engineering strategies to problem-solving, mechanical systems/design and digital electronics. In biomedical science these courses may include human anatomy, biochemistry and biomedical systems. In information and computer technology basic courses may include computer architecture/systems, software, communication networks and programming. These courses are typically offered in the 9th, 10th and 11th grades. Advanced courses in engineering, biomedical science and technology, offered in the 11th and 12th grades are typically designed to lead students into BS programs at universities.

What is in the typical STEM HS curriculum that discourages and/or disinterests potential STEM technician students? How can this be altered?

In the early high school years (9th and 10th grades) two factors can be discouraging to potential technicians:

- Teaching abstract science and mathematics courses with little or no applications.
- Neglecting to show career opportunities for engineering, technology and science technicians.

Curricula and appropriate teacher professional development are available and being used to provide more application-oriented teaching of mathematics and science. NSF/ATE Centers and programs have developed career descriptions and described exemplary models of outstanding technicians in a variety of fields.

Adjustments and interventions can be made to existing STEM programs and courses that will alleviate these issues in the 9th and 10th grades. However, the overriding concern is that middle quartile achievers “are welcomed and encouraged” to participate in the STEM Program.

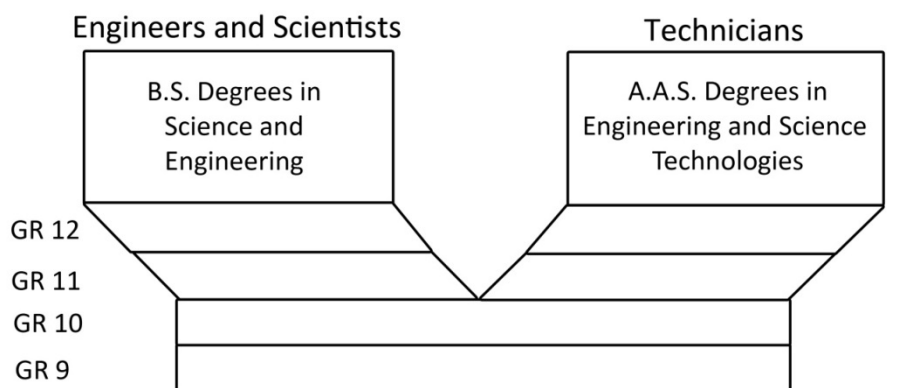
In the 11th and 12th grades two additional factors are present that are not only discouraging, but also are eliminating almost all potential STEM technicians:

- Requiring that STEM students be required to take advanced math courses, including precalculus and possibly calculus in the 11th and/or 12th grades.
- Requiring STEM students to choose advanced courses in the 11th and 12th grades that lead primarily to BS science, engineering and information science programs in colleges or universities.

The logical solution to this issue is to provide alternative 11-12 grade curricula to encourage and prepare potential STEM technicians to articulate into AAS degree STEM programs at community and technical colleges, i.e., *Create Career Pathways for STEM Technicians*.

The curricula for creating these programs of study are neither complicated nor expensive. They require three strategies:

- Teaching Algebra and Geometry in the 9th and 10th grades using problem-solving approaches, using applications that are relevant to scientific and technical fields.
- Offering a sequence of applied mathematics courses in the 11th and 12th grades that are relevant to the technical courses in the AAS degree programs.
- Providing dual-credit technical courses that are currently being taught in the first year of the AAS degree programs.



Alternative Curriculum Pathways For STEM High Schools

PLTW Tier 2 Specialization courses, typically offered in the 11th and 12th grades, are more appropriate to direct and prepare students into one of the BS engineering disciplines.

Instead of using the Tier 2 PLTW courses in the 11-12 grades for technician students, the alternative curriculum consists of 1-3 technical courses that are taught in the first year (freshman) of the AAS degree program of a nearby community or technical college. It is not necessary for technician students to choose the specialty for their AAS while they are in the 11th grade. Usually the AAS degree programs offered by the college are grouped into *clusters*, like electronics cluster (that may support lasers, robotics and instrumentation), or a manufacturing cluster (that may support CAD, automated system controls or CNC), or alternative energy (that may support solar, wind etc.) By selecting an 11th grade course in a cluster, students will still have the option in the 12th grade to select the specialty they may wish to pursue.

Dual-credit courses provide several advantages for the institution and the student.

- For the high school, dual-credit courses eliminate the need to design/develop new courses, and may offer the opportunity to use faculty and laboratories of the articulating college.
- Dual-credit courses offer the students the opportunity to “enter the postsecondary program while they are in high school” which reinforces the career opportunity, eases the anxiety of entering higher education and, most of all provides them postsecondary credits which shortens their time required for Associate degree pursuits and saves a considerable amount of the cost of their college education

Model Secondary-Postsecondary Career Pathways for Engineering Technologies (Possible dual courses shaded)

Soph 2		Elective	Humanities		Technical Core	Technical Specialty	Technical Core
Soph 1	Elective		Social Science		Technical Core	Technical Specialty	Technical Core
Fresh 2	College Algebra			Physical Science	Technical Core	Technical Specialty	Technical Core
Fresh 1		College English		Physical Science	Technical Core	Technical Specialty	Technical Core
12 th Grade	Algebra 2 w/Trig	English 12	Government	Physics	Health	Technical Specialty	Technical Core
11 th Grade	Math Applications	English 11	American History	Chemistry	Physical Education	Technical Core	Digital Electronics
10 th Grade	Geometry	English 10	World History	Biology	Physical Education	Foreign Language	Principles of Engineering
9 th Grade	Algebra 1	English 9	Geography	General Science	Physical Education	Foreign Language	Intro to Engr Design

Examples of Technical Core/Technical Specialty Courses in Eleventh and Twelfth Grades¹⁴

<u>Specialization</u>	<u>Core Courses</u>	<u>Specialty Courses</u>
<i>Photonics (lasers)</i>	DC-AC Electricity Digital Electronics	Fundamentals of Light & Lasers Elements of Photonics
<i>Biotechnology</i>	Quality Assurance Solutions & Biotech Assays	Introductory Biotechnology Biomanufacturing
<i>Advanced Manufacturing</i>	Properties of Materials Digital Electronics	Manufacturing Processes Control Systems
<i>Communications Systems</i>	DC-AC Electricity Introduction to TCP/IP	Communication Systems Unified Networks (Data, Voice and Video Services)
<i>Information Technology</i>	Computer Hardware and Operating Systems Computer Programming	Introduction to TCP/IP
<i>Microsystems (MEMS)</i>	DC-AC Electricity Digital Electronics	Programming for Mobile Devices Introduction to MEMS MEMS Fabrication, Design and Integration
<i>Nanotechnology</i>	Reactions, Forces and Interactions Computer Modeling at the NanoScale	NanoMaterials Nanoscience Applications

Model 4+2 Curriculum for Career Pathways in Photonics¹⁵

Soph2		Elective	Humanities		Laser Devices	Laser Electronics	Laser Measurements
Soph1	Elective		Social Science		Trouble Shooting and Repair Techniques	Laser Technology	Laser Components
Fresh2	College Algebra			Physical Science	Computer Aided Design	Geometric/Wave Optics	Programmable Logic Controllers
Fresh1		College English		Physical Science	Analog Devices	Introduction to Lasers	Electronic Devices
12th Grade	Algebra 2w/Trig	English 12	Government	Physics	Health	Elements of Photonics	AC/DC Circuit Analysis
11th Grade	Math Applications	English 11	American History	Chemistry	Physical Education	Fundamentals of Light and Lasers	Digital Electronics
10th Grade	Geometry	English 10	World History	Biology	Physical Education	Foreign Language	Principles of Engineering
9th Grade	Algebra 1	English 9	Geography	General Science	Physical Education	Foreign Language	Intro to Engr Design

Indian Hills Community College's Early College Program

Indian Hills Community College (IHCC) is one of OP-TEC's Partner Colleges. Its Laser/Electro-Optics program is one of the largest in the country. IHCC photonics graduates are sought by employers throughout the country. In 2011, IHCC received over ninety job opportunities for its eighteen graduates. IHCC's Early College Program is highly successful and fully implemented, and it also demonstrates how a STEM Technician Career Pathway is implemented at the high school level. The curriculum used in this program is an adaption of the model photonics curriculum that has been adjusted to meet the needs of employers. It is a testimony to what can be achieved when educators and employers join forces to provide students opportunities for rewarding careers.

In 2007, IHCC identified a severe national shortage of skilled workers in the advanced manufacturing industry, which is highly dependent on the use of lasers for operations such as welding, cutting, grinding, and precision measurements. Since IHCC had an AAS program in Laser Electro-Optics and Robotics/Automation—both essential to advanced manufacturing—it addressed this labor shortage, most rapidly by decreasing the amount of time it takes for students to complete the AAS degree. Their solution was to develop and implement an early college program.

The IHCC Early College program allows participating high school students to start AAS programs in their junior year of high school and, in a three-year period, graduate with an AAS degree in Laser/Electro-Optics, Electronics Engineering, or Robotics. Thus, the early college program places high school juniors into the workplace one year sooner than a traditional program would.

IHCC Early College Photonics Curriculum (Shaded Courses are Dual-Credit)

Fresh 4					Optical Systems Analysis	Photonics Systems Lab	Photonics Applications
Fresh 3		Communications Elective			Physical Optics	Photonics Troubleshooting	Automated Laser Processing
Fresh 2					Geometric Optics	Laser System Fundamentals	Optical Devices
Fresh 1				Science Elective	Introduction to Solidworks	Introduction to Photonics	Laser Components
12 th Grade	College Algebra	English Elective/ Workplace Communications	Ethics/ Government	Physics	Introduction to Computers	Photonics Concepts	Digital Electronics
					Physical Education	Power Transfer Technology	
11 th Grade	Technical Math	English 11	American History	Chemistry	Physical Education	AC/DC Circuit Analysis	Analog Devices
							Bus. Essentials
10 th Grade	Geometry	English 10	World History	Biology	Physical Education	Foreign Language	Principles of Engineering
9 th Grade	Algebra 1	English 9	Geography	General Science	Physical Education	Computer Applications	Introduction to Engr Design

Since IHCC uses a quarter system, the postsecondary portion of the Early College curriculum is shown as four distinct quarters (Fresh 1—Fresh 4). In addition, this curriculum includes only one year of postsecondary coursework. This is because one full year of courses that are normally

taught at the postsecondary level are now taught as dual-credit offerings in the junior and senior years of high school. Eliminating the need for a second postsecondary year allows students in the Early College program to reduce by one year the time it would normally take to enter the workforce with an AAS in Electro-Optics; this acceleration was one of the main goals of this program. This curriculum also features split boxes that result from the difference in course length of high school and postsecondary courses. Typically, a high school course lasts a full academic year, which is equivalent to two quarters at IHCC.

The IHCC curriculum is an adaptation of the model photonics curriculum presented earlier. Both offer three, Project Lead the Way courses in their high school offerings, and both provide high school students opportunities to complete college-level technical core and specialty courses in photonics. The major adaptation IHCC made to the model photonics curriculum is the addition of technical core courses to the high school portion of the curriculum. These additional courses were needed to meet IHCC's goal of reducing the amount of time it took students to earn their AAS in Laser Electro-optics. This adaptation is an example of how secondary and postsecondary educators can start with the model photonics curriculum and modify it to meet their local and regional needs.

Implementation of this early college curriculum required close coordination between IHCC and high school faculty and administrators. Students take the state-mandated high school courses at their local high schools (which can include the ninth- and tenth-grade tier 1 Project Lead the Way Courses in the model photonics curriculum), but from 8:00 to 10:50 each morning, they take courses at IHCC. These courses, which constitute the Early College program, include Project Lead the Way Digital Electronics, DC Circuit Analysis, AC Circuit Analysis, Analog Circuits, Photonics Concepts, and related mathematics and communications courses. Students who participate in the Early College program in both their junior and senior years complete all requirements in IHCC's electronics core and leave high school with an Electronics Technician diploma. With the electronics core completed, students then enter IHCC full time in the summer term and begin work on any of three technology programs: Laser/Electro-Optics, Electronics Engineering, or Robotics/Automation. Participants who enter the Early College program as juniors are able to complete an AAS degree in one of the three program areas one year after high school graduation. IHCC also gives college credit for the ninth- and tenth-grade Tier 1 Project Lead the Way Courses included in the model photonics curriculum. By adding the credit students earn from completing IHCC's electronics core, to the college credit awarded for the two Project Lead the Way courses, students in the Early College program can graduate from high school with forty-two college credits.

Summary

Educational programs at two-year colleges to prepare technicians for advanced technology careers are mostly under-enrolled and are not providing the numbers of completers that U.S. employers need if we are to maintain and advance our nation's security and economic prosperity. This paper defines the problem, outlines a solution, demonstrates a model of secondary/postsecondary partnership using this strategy and calls for broad scale adoption. This innovation would enable the 4000+ STEM high schools to provide a program of study to recruit

and prepare capable, deserving applied learners who could enter and be successful in AAS-degree technology programs that lead to rewarding technician careers.

Communities need to form partnerships of educators and employers to provide the vision and substantiate the need for STEM career pathways. These leaders will need to design the pathways, encourage and recruit students, cooperate to deliver a secondary-postsecondary sequence of courses, and provide the resources necessary to support and sustain the initiative. This work requires leaders and decision-makers from three vital groups: secondary schools, community/technical colleges, and employers.

Additional information, curriculum plans for other technologies, supporting comments and implementation strategies can be found in the book, *Career Pathways for STEM Technicians*, University of Central Florida, 2012.

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