In 2008, Achieve released a series of brochures highlighting how advanced mathematics is used across a range of careers – all careers that require some additional education and training beyond high school but less than a four-year degree. The goal of these "Math at Work" brochures was to demonstrate that the mastery of the advanced mathematics embedded in the American Diploma Project benchmarks is both valuable and critical for success in college and careers.[1]

Below are descriptions of the preparation and training necessary for entry into each of the seven career pathways, based on analyses conducted by subject matter experts and interviews with industry leaders on the relevant certifications, on-the-job training and postsecondary coursework aligned with those careers.
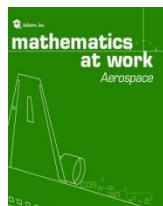
Aerospace / Aircraft Maintenance Technicians

The more than 100,000 aircraft maintenance technicians (AMTs) at work in the public and private sector today have a wide range of talents and skills that keep America's airplane fleet flying safely and smoothly. Although they may have different educational backgrounds and areas of expertise, all AMTs have one thing in common — a solid foundation in mathematics, enabling them to earn the rigorous Federal Aviation Administration (FAA) certification in airframe and power plant maintenance. From fabricating parts and installing hydraulic systems to testing electrical circuits and repairing airplane engines, AMTs possess the highly sought-after mechanical knowledge and skills — grounded in mathematics — that are valued by the airline industry.

To earn FAA certification, applicants must have at least a high school diploma and 18–24 months of specialized postsecondary training, be it on the job, at a community or technical college, or in a specialty occupation in the military. Through a combination of oral and practical exams, the FAA assesses the competency of applicants in handling equipment such as ignition analyzers, riveters and compression checkers. It also tests their familiarity with scientific principles such as basic gas laws and the properties of metals as well as the underlying mathematical concepts that cover many core ADP benchmarks.

For example, the FAA requires that all AMTs understand:
- Measurements with units when replacing and fabricating fuselage parts
- Proportions and ratios when assessing the electrical needs of circuitry
- Solving equations with one or more variables when repairing hydraulic systems
- Calculating volume of spheres, parallelepipeds and cylinders when assessing fuel needs
- Modeling with linear equations when computing the center of gravity (CG) of an aircraft

The FAA certification process tests the understanding future AMTs have of the array of instruments and processes used on a daily basis, thereby evaluating their ability to apply their mathematical skills to the various challenges they face. Given the vital stakes attached to aircraft safety, it also is critical that everyone on the tarmac — pilots, engineers and AMTs — is able to communicate with other members of the team by speaking clearly about an airplane's electronics and mechanics through the universal language of mathematics. Because no two aircraft are exactly the same, AMTs must know when and how to apply particular solutions to unique problems and modify approaches from aircraft to aircraft as appropriate.

For more information on FAA aircraft maintenance certifications, go to www.faa.gov/mechanics/become.

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[1] It is worth noting that the ADP benchmarks have been found to be well aligned with the Common Core State Standards (CCSS). In addition, the Math at Work brochures were used as evidence in the early stages of the CCSS development.
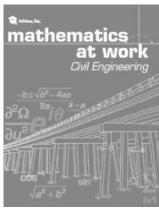
Infrastructure / Civil Engineering Technicians

The vast majority of the 100,000 civil engineering technicians employed in the United States — including the nearly 10,000 workers who will be hired in the next 10 years — will receive associate degrees from community colleges, technical schools or other comparable postsecondary institutions. These two-year programs in civil engineering technology require applicants to have a range of skills and knowledge in math and science.

High school graduates entering these programs need strong foundations in subjects like algebra, geometry, physics and chemistry to succeed in commonly required postsecondary courses such as Precalculus/Trigonometry, Drafting and Design, Topographic Surveying, Soil Mechanics, and Strength of Materials.

It is no surprise that the wide variety of associate degree programs in civil engineering technology share a common core of expectations and learning objectives. ABET, Inc., is the leading accreditor for college and university programs in applied sciences, computing, engineering and engineering technology. ABET — composed of almost 30 professional and technical organizations representing disciplines in applied science, computing, engineering and engineering technology — has developed rigorous criteria for the accreditation of engineering technology programs.

Included within these criteria are learning outcomes for students — what ABET believes are the minimum units of knowledge and skills that every graduate from an accredited associate degree program in civil engineering technology should possess. Among the expectations for graduates are:

- Conducting standardized field and laboratory testing on civil engineering materials (properties of materials, volumes of geometric shapes, physical forces and stresses, measurement, statistics)
- Using modern surveying methods for land measurement and/or construction layout (right triangle trigonometry; geometric figures; powers and square roots; unit conversions for lengths, areas and volumes)
- Determining forces and stresses in elementary structural systems (functions, vectors and matrices; chart interpretations; units and unit conversion)
- Estimating material quantities for technical projects and performing cost estimates (proportions, reading and interpreting charts, equations with multiple variables, interest computations)
- In addition to possessing a range of mathematical skills, today's civil engineering technicians must be able to communicate via written, oral, graphical and electronic media.

Civil engineering technicians must be able to clearly communicate technical concepts not only to their co-workers, but also to clients or customers who may not have technical backgrounds. Teamwork skills also are critical because the civil engineering field relies heavily on team-based approaches to the analysis of complex problems and the design of solutions to those problems. ABET standards for engineering technicians stress the importance of creativity, analysis and the ability to function effectively on teams.
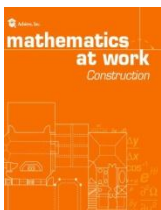
Construction / Contractors

The construction industry is filled with individuals with all sorts of backgrounds and training. The freedom of not being restricted by one specific degree or certification allows anybody with an interest in construction, an ability to work as part of a team and a keen understanding of mathematics to be successful in this field.

Many individuals learn the construction trade as part of a rigorous career and technical education (CTE) program starting in high school. In many communities, high schools and community colleges are joining together to develop integrated programs of study that allow students to master the classroom learning — in particular the advanced mathematics — critical to the construction industry while gaining hands-on experience through work-based learning.

Students can earn a high school diploma while developing an understanding of the construction business from the inside. Some pathways include fully integrated courses that teach advanced mathematics content through construction projects such as building a house for Habitat for Humanity or remodeling a wing of a high school, as well as other rigorous academic and career-oriented courses.

Although there is no mandatory degree or certification that individuals need to enter the construction field, many employers place a premium on such distinctions. The National Center for Construction Education and Research (NCCER), an organization dedicated to addressing the industry shortage of contractors (persons who oversee all project aspects during the construction or development of a property), provides standardized construction and maintenance curricula — the Contren Learning Series — to high schools, community college and individuals. NCCER offers a certification assessment and portable credentials that signal an individual's career readiness. Assessment results are maintained in NCCER's National Registry, through which employers can find qualified employees.

NCCER's curricula run the full spectrum of building competencies, from carpentry and construction technology to other specializations including welding, site layout and even hydro-blasting. Present throughout the curricula's performance objectives are rigorous mathematical concepts and applications. For example:

- Carpentry (e.g., scale factor, isoclines/lines of constant elevation, angular measurement and conversions, calculations with decimals and fractions, converting distance and direction into latitudes and departures)
- Construction Technology (e.g., unit conversions, Pythagorean theorem, sampling methods, right triangle trigonometry, volume of cylinders)
- Site Layout (e.g., angles and geometric figures; powers and square roots; unit conversions for lengths, areas and volumes; interpreting drawings)
- Project Supervision (e.g., bar graphs, network diagrams, rates of productivity)

More than 2,000 schools in the United States use NCCER's curricula, and about half of the states have built these curricula and assessments into their CTE construction pathways. Regardless of whether individuals receive credentials from NCCER, earn an associate degree in a relevant field or learn their trade on the job, they will need a solid foundation in mathematics to truly be prepared for a lifelong career in construction. For more information on NCCER, see www.nccer.org.
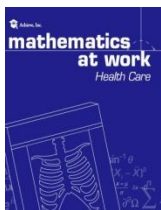
Health Care / Radiologic Technologists
All radiographers — or radiologic technologists — have some form of postsecondary training, typically provided by a two-year college or teaching hospital, before entering the field of diagnostic medicine. The standard curriculum in those programs stresses radiographic procedures, medical imaging, anatomy and physiology, and applied physics.

Beyond knowing how to take X-rays and other images, radiographers are expected to know how radiation works, the potential negative impact of radiation on patients and bystanders, and the radiographer's crucial role as a team member working with physicians and other medical professionals to provide health care to

patients. It is common for these two-year programs, which culminate in certification and/or an associate degree, to require at least college-level algebra or its equivalent.

The American Society of Radiologic Technologists (ASRT) is a membership organization that seeks to foster the professional growth of radiologic technologists. ASRT has been developing and publishing radiography curricula for more than 50 years and offers 10 specific curricula for various professions within this field. For more information on ASRT and its curricula, see www.asrt.org/Content/educators/_educatorsstudents.aspx.

Two other major organizations in this field — the American Registry of Radiologic Technologists (ARRT), which offers voluntary certification; and the Joint Review Committee on Education in Radiologic Technology (JRCERT), which accredits most formal training programs for the field — also support the ASRT curriculum. The objectives for ARRT's voluntary certification exam are well aligned with ASRT's recommended content, and JRCERT urges radiography programs to include the core content in their instruction. JRCERT also considers the alignment of curriculum when evaluating programs to determine whether to approve them and offer them accreditation.

Embedded within ASRT's recommended curriculum are many specific mathematical concepts covering many of the core concepts found in the ADP benchmarks, including:

- Basic Principles of Computed Tomography (e.g., algorithms, ratios, proportions, error in measurement, scale factor)
- Pharmacology and Drug Administration (e.g., ratio and proportion, measurement, exponential decay models)
- Radiation Biology (e.g., interpreting graphs, functions, measurement, probability)
- Radiation Production and Characteristics (e.g., trigonometric functions, scattering theory, direct and inverse variation, periodic functions)
- Radiation Protection (e.g., interpreting graphs, linear and quadratic variation)
- Digital Image Acquisition and Display (e.g., measurement, data acquisition and display, histograms)
- Image Analysis (e.g., data interpretation, problem solving, algorithms)
- Film-Screen Image Acquisition and Processing (e.g., ratios, proportionality, scale factors, graphic representation of functions)

The work of ASRT, ARRT and JRCERT demonstrates that there is a common core of expectations among the radiologic technology community, one that is rooted in a practical and theoretical understanding of mathematics and physics. Although ASRT has revised its curriculum a number of times in the past half-century, understanding the mathematics and science of radiology has remained at the center of its preparatory materials for all future radiographers.
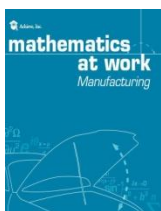
**Information Technology / IT Technicians**
A broad understanding of advanced high school mathematics and its applications is essential for successfully earning certifications from respected industry leaders such as Cisco and the Computing Technology Industry Association (CompTIA). These certifications are highly valued in the marketplace, and some states and school districts build entry-level exams — such as Cisco's Certified Network Associate (CCNA) exam or CompTIA's A+ exam — into high school career pathways to better connect classroom experiences with the world of work.

There also are advanced-level certifications in specific areas, such as networks and security, typically pursued by individuals with on-the-job experience. Key objectives and related mathematical ideas covered in CompTIA's A+ exam and the CCNA exam include:

- IP Addressing (e.g., binary code, exponentials)
- Principles of Wireless Technology (e.g., wavelengths, electromagnetic spectrum)
- Computers and Electronics (e.g., voltage, rates)
- Troubleshooting (e.g., algorithms, logic, Boolean algebra, problem solving)

The specialized certification training that equips network technicians for on-the-job challenges requires a strong background in mathematics and covers many of the core concepts in the ADP benchmarks. Network technicians rely on mathematics to translate bits into bytes using powers, decipher code using multiple variables, calculate the likelihood of an event using permutations and combinations, and construct truth tables to determine outcomes. All these mathematical skills are grounded in a range of advanced high school and entry-level college mathematics courses such as Algebra II, Linear Algebra, Plane Geometry, Statistics, Discrete Mathematics, Calculus and the mathematics found in introductory physics, electrical and mechanical engineering, and finance courses.

For more information on Cisco and CompTIA's exams, see www.cisco.com/web/learning/netacad/index.html and http://certification.comptia.org.
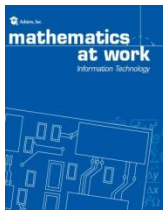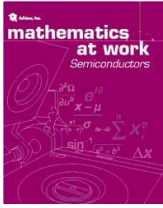
Manufacturing / Manufacturing Technicians

Manufacturing companies like Toyota recognize that the most effective and productive line employees are multiskilled workers who have a sophisticated understanding of electrical and mechanical design as well as fluid power and fabrication applications. Toyota, in fact, has found that the single most important asset possessed by their most talented multiskilled employees — many of whom have only a high school education and some additional training — is a strong foundation in mathematics that is applicable across all manufacturing fields.

Over the years, Toyota has streamlined its training program to maximize its effectiveness so that new hires work through a rigorous sequence of job training courses in only those areas where they lack sufficient background. Many of the courses teach the core concepts covered by the ADP mathematics benchmarks. Key courses include:

- Math Refresher (e.g., computing with rational and real numbers, basic operations with algebraic expressions, modeling, right-triangle trigonometry)
- Electronics (e.g., manipulating linear equations, advanced physics, amplitude and phase shift for sine and cosine)
- Machine Structure (e.g., output-input power, graphical representations of data)
- Fluid Power (e.g., Pascal's law)
- Metric System (e.g., units and measurements: length, mass, time, temperature, pressure and torque)
- Blueprint Reading (e.g., Cartesian and polar coordinates)

The capstone course for manufacturing trainees is Troubleshooting. In this course, technicians must be able to draw on all of the mathematics, physics and engineering concepts they have learned to solve real problems drawn from the factory floor.

Solid math is not the only skill needed to be successful at companies like Toyota. Although the specifics of the technical work may vary from team to team, all skilled line employees are expected to be able to articulate and communicate the complexity of a project, translate their understanding into the language of mathematics, and work together as a team to arrive at the most practical and effective solution to the task at hand.

Semiconductor Manufacturing / Manufacturing Specialists & Technicians
Hires arrive at Texas Instrument – a leader in the manufacturing of semiconductors – with knowledge and skills they learned on the job, in high school or in a specialty occupation in the military, TI ensures that its new employees receive a thorough orientation to the applied mathematics behind the manufacturing process. The entry-level mathematics qualifying exam and subsequent training for manufacturing specialists cover many of the core concepts found in the ADP mathematics benchmarks.

Key concepts on this exam include:
- Measurement systems (e.g., metric and non-metric, calibration studies)
- Statistical analysis (e.g., calculating mean, median, statistical distribution and deviation)
- Probability (e.g., percentages, outcomes)
- Interpreting charts and data (e.g., inputting and reading plotted arrays, interpreting spec and control lines)
- Basic algebra (e.g., one or more variables, multiple calculations)

Employees hired as manufacturing technicians at TI must possess a two-year degree and have additional advanced mathematical training in the areas of:
- Advanced algebra (e.g., power equations)
- Physics (e.g., gases and fluids, basic thermodynamics)
- Geometry (e.g., ergonomic analysis)

The intricacies of building semiconductors require an unprecedented level of mathematical precision and demand that co-workers can communicate flawlessly in the language of mathematics. Semiconductor manufacturing is made possible by workers who have a sophisticated understanding of how math is infused into each and every semiconductor TI produces.