Engineering and Science Technologies and Manufacturing Technologies

CAREER FIELD TECHNICAL CONTENT STANDARDS

2013

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Foreword

The Career Field Technical Content Standards serve as the curricular framework for Ohio's career-technical education pathway programs as outlined in Ohio Administrative Code 3301-61-03 (Criteria for Secondary Workforce Development Programs).

Career Field Technical Content Standards outline the knowledge and skills needed for success in careers across multiple pathways. Validated by Ohio business and industry representatives in conjunction with Ohio educators, these standards form the basis for developing educational programming in Ohio secondary schools. The standards also serve as the framework for developing strong career pathways that connect secondary education with postsecondary education systems and the workplace.

This version of Career Field Technical Content Standards is intended to support the ongoing evolution of career technical education pathway programs. The standards tend to be somewhat broader than previous versions and are not repeated for individual pathways or occupational areas. The broader and non-duplicated statements are intended to capture the knowledge and skills that can be applied across any number of occupations in a pathway rather than focusing on the requirement of a single occupation. After all, the intent of a pathway program is to prepare a student for a range of educational and career opportunities following high school.

Pathway programs prepare students to combine broad knowledge, insight and understanding of business processes, academic attainment and workplace readiness with depth of knowledge and expertise in a technical area. Knowing that many careers will require some level of postsecondary education, the content standards also delineate the knowledge and skills necessary to seamlessly transition to postsecondary educational programs.

This document seeks to provide the basis for educational programming that will provide the employee with fundamental skill-sets that employers demand. This ensures that Ohio's workforce of tomorrow is competitive in a global environment. An environment that requires knowledge and skills can be applied in a broader context, aimed at innovation to support new products and services in an ever-changing economy.

In addition to the extensive engagement of secondary and postsecondary educators and business/industry professionals, development of these standards represents a collaborative effort of the following professional partners: the Ohio Department of Education's Office of Career-Technical Education; the Ohio Board of Regents Secondary Career-Technical Alignment Initiative; and CETE, known as the Center on Education and Training for Employment, at The Ohio State University.

Isaac Kershaw, PhD, Assistant Director
Office of Career-Technical Education
Ohio Department of Education

Acknowledgements

A number of individuals contributed their time and expertise to this development. Special thanks go to all the business representatives and educators named in this document.

Further acknowledgement is due to:

- Steve Gratz, Director, Office of Career-Technical Education, Ohio Department of Education;
- Isaac Kershaw, Assistant Director, Office of Career-Technical Education, Ohio Department of Education;
- Linda O'Connor, Assistant Director, Office of Career-Technical Education, Ohio Department of Education;
- Cyndi Brill, Career-Technical Education (CTE) Academic Content Expert, Educational Consultant, Office of Career-Technical Education, Ohio Department of Education;
- James Ruble, Consultant for Engineering and Science Technologies and Manufacturing Technologies, Office of Career-Technical Education, Ohio Department of Education;
- Paula Compton, Associate Vice Chancellor, Articulation and Transfer, Ohio Board of Regents;
- Jamilah Jones Tucker, Director for Career-Technical Initiatives, Ohio Articulation and Transfer Network, Ohio Board of Regents;
- Robert Speckert, Consultant, Ohio Board of Regents;
- Wendi Howell, Project Manager, CETE at The Ohio State University;
- Mike Wonacott, Content Development Manager, CETE at The Ohio State University; and
- Alicia Willis, Program Coordinator - Editorial Projects, CETE at The Ohio State University.

Those listed above provided vision and implementation support for the Engineering and Science Technologies and Manufacturing Technologies Career Field Technical Content Standards and Ohio's Engineering and Science Technologies and Manufacturing Technologies educational programs.

Philosophy and Principles for Implementation

Ohio Career Field Initiative

The overarching framework for Ohio career-technical education is outlined in the Ohio Revised Code and subsequent administrative rules, which specify career-technical programming based on 16 career fields. To view the full text of Administrative Rule 3301-61-03 (Criteria for Secondary Workforce Development Programs), go to: http://education.ohio.gov/Topics/Career-Tech/Career-Development-OCIS/CTE-Administrative-Rules-Update. These 16 fields provide the framework for an Ohio career field initiative that seeks to foster the educational shift necessary to respond to the needs of a rapidly changing global environment.

A career field is a "group of occupations and broad industries based on common characteristics" (see www.careertech.org). Career fields are the basis for developing both broad and specialized technical content standards that serve as a framework for curriculum, instruction, assessment and program design, addressing the needs of an entire industry and business sector. Ohio's 16 career fields align with national efforts to broaden career-technical education, integrate career-technical with academic study and reflect the workforce needs of today and tomorrow. For today's students to be adequately prepared for tomorrow's workforce, they must have an education that:

- **Incorporates a broad, long-term conception of work in combination with the depth of specialization skills;**
  Employees need a comprehensive understanding beyond a single occupational area. Career-technical programming needs to be provided in a larger context, so students can generalize learning, make connections between education and work and adapt to changes in their careers. Workplace knowledge and skills are needed to prepare employees for collaborating and problem solving while contributing to the broader business process.
- **Emphasizes the acquisition of strong academic knowledge and skills; and**
  Academic skills provide the foundation for career success. The integration of academic content standards with career field technical content standards helps to contextualize learning for students, making English language arts, mathematics, social studies and science relevant to students as a means to an important end—success at work and in life.
- **Facilitates high-school-to-postsecondary transitions.**
  A lifetime of change means a lifetime of learning, including postsecondary education. Students need knowledge and skills for success in a variety of postsecondary options, including apprenticeships, industry credentialing through adult education, two- and four-year college degree programs and graduate school.

Career Pathways

A key component of the Ohio Career Field Initiative is a career pathway, which is a coherent, articulated sequence of rigorous academic and career-technical coursework commencing in the ninth grade and leading to an associate degree, baccalaureate degree and beyond–an industry-recognized certificate and/or licensure. Pathways facilitate a seamless transition from high school to postsecondary education (including apprenticeships, adult education, two- and four-year colleges and graduate school) and from postsecondary education to the workplace. The career pathway is developed, implemented and maintained in partnership among secondary and postsecondary education, business and employers. Career pathways are available to all students, including adult learners and lead to rewarding careers.

To effectively facilitate the transition from secondary to postsecondary education and a career, high school career pathways should encompass:

1. Challenging technical coursework in a chosen career field based on career field technical content standards;
2. Rigorous academics that meet Ohio's academic content standards and grade-level expectations;
3. Electives that relate to career objectives;
4. Instructional enhancements such as experiential and authentic learning opportunities (e.g., work-based learning, mentorships, internships) and career-technical student organization participation;
5. Opportunities (when appropriate) for program and student certification and licensure;
6. Preparation for transition to further study that includes college readiness and opportunities to earn college credit while in high school;
7. Preparation for transition to employment with advancement opportunities;
8. Performance targets that include high school academic and technical testing/exit and postsecondary entry/placement requirements;
9. Various sector(s) within an industry or encompass a function that crosses industry sectors;
10. The scope of opportunities in the related industry and available college programs;
11. Opportunities to prepare for a range of careers, including
    a. multiple employment opportunities after high school and
    b. opportunities for students to enter and succeed in postsecondary and continuing education programs;
12. Transferable skills required for employment in the range of occupations aligned to the pathway; and
13. Opportunities to learn skills across the pathway as well as in specialized areas.

For additional information on the Career Field Initiative, including Ohio Career Field Technical Content Standards and Career Pathways, go to http://education.ohio.gov/Topics/Career-Tech/Career-Fields.

Structure and Format

The Career Field Technical Content Standards document is composed of a series of strands comprised of outcomes that each contain a set of competencies.

- A strand is a large content area under which multiple outcomes are organized, regardless of the pathway. It includes a title and a concise description with statements that capture multiple, broad areas of learner knowledge and skills expected across all outcomes in the strand. There are approximately six strands of content per career field. Strand 1, Business Operations/21st Century Skills (employability skills, leadership and communications, business ethics and law, knowledge management and information technology, global environment, business literacy, entrepreneurship/entrepreneurs, operations management, financial management, sales and marketing and principles of business economics), is the same for all career-technical education career fields.
- An outcome is an overarching statement that summarizes the knowledge and skills described in a set of individual competencies to be learned by the end of the 12th grade. There are usually 5–15 outcomes within a strand, depending on the breadth of content to be addressed.
- A competency is a specific statement of essential knowledge or skill to be learned in the pathway program. There are usually 5–12 competencies under an outcome.

Each set of outcomes and competencies is included in one or more pathways in the career field. Outcomes and competencies form the basis for developing secondary courses, programs, instruction and assessment, facilitating transition from one educational level to the next and to the workplace. This supports career readiness and long-term career success by:

- Providing the basis for effective collaboration, teamwork and communication across pathways;
- Laying the groundwork for successful transfer of knowledge and skills across pathways, thereby facilitating horizontal and vertical career success and
- Equipping students and workers with the skills needed to transition to new and emerging careers throughout a working lifetime.

All outcomes and competencies in the Career Field Technical Content Standards have been verified as essential by business and labor representatives within the pathway or pathways specified.

These essential outcomes and competencies specify industry-based knowledge or hands-on skills that CTE students need by the end of the 12th grade to be successful in their selected career pathway and on-going learning (such as college, apprenticeships and military opportunities).

Development of Engineering and Science Technologies and Manufacturing Technologies Career Field Technical Content Standards

The process for the development of the Engineering and Science Technologies and Manufacturing Technologies Career Field Technical Content Standards began in February 2012 and culminated in June 2013. Over the course of 2012–2013, numerous business and industry representatives as well as secondary and postsecondary educators from across the state of Ohio took part in the formal development process. The following summarizes the various stages of the development process.

Research and Development

The involvement of subject matter experts, including educators, was critical to the completion of the draft revision of the document. Development was also informed by consulting the following sources of information:

- National Association of State Directors of Career Technical Education Consortium (NASDCTEc) Common Career Technical Core (CCTC) standards and Programs of Study;
- Industry-based certifications/standards;
    - National Center for Construction Education and Research (NCCER);
    - American Welding Society (AWS);
- Department of Education, Office of Career-Technical Education in Oklahoma, Virginia, Texas and Florida;
- SkillsUSA;
- Partnership for 21st Century Skills;
- Career-Technical Transfer Assurance Guides (CTAGs);
- University System of Ohio Academic Program Guide; and
- Ohio Industry Employment Projections Report, 2008-18.

Futuring Panel

On February 22 and May 2, 2012, the Engineering and Science Technologies and Manufacturing Technologies futuring panels brought together key business and industry representatives from across the state to advise the Ohio Department of Education on trends impacting the Engineering and Science Technologies and Manufacturing Technologies career field. The participants were asked to share their perceptions on changes in the workplace, employment trends, changes in technical skill requirements, needed workplace readiness skills and available industry-recognized standards and credentials. This feedback was used to develop and streamline the standards document into what is most demanded by the labor market.

Validation Panel

On December 4, 2012, and January 23, 2013, a diverse group of Ohio business and industry representatives participated in panels to validate and rate the importance of the work-related competencies in the draft standards document. Drawn from various sectors and regions of the state, the panels identified what employees should know and be able to do in the two Engineering and Science Technologies and Manufacturing Technologies pathways. Secondary and postsecondary education representatives participated on the panels to gain an understanding of the standards development process as well as to provide their perspective to the business representatives, when needed.

Postsecondary Alignment

The goal of the Secondary Career-Technical Alignment Initiative (SCTAI) was to develop new statewide Career-Technical Assurance Guides (CTAGs) for secondary career-technical institutions using the combined process of the Ohio Board of Regents' CTAG development process with the Ohio Department of Education's Career Field Technical Content Standards development process. The result of this collaboration was a tighter alignment between secondary career-technical and postsecondary content and the development of pathways that encourage college-going and increase statewide postsecondary options for career technical students. For more information on CTAGs and opportunities for statewide postsecondary articulated transfer credit, visit https://student-transfer.ohiohighered.org.

Futuring Panel Contributors

February 22 and May 2, 2012

Design

Jennifer Brubaker
Business and Industry Coordinator
Ohio Hi-Point Career Center
Bellefontaine, OH

Marty Griffith
Founder, Chief Executive Officer
Franklinton Preparatory Academy
Columbus, OH

Tonya Kessinger
Director, Agriculture, Construction,
and Engineering Technology
Toledo Public Schools
Toledo, OH

Scot McLemore
Unit Manager, Technical Development
Honda of America Manufacturing
Marysville, OH

Rick Pridemore
Director of Satellite Operations
Greene County Career Center
Xenia, OH

Ryan Reed
Technology Instructor
Northview High School
Sylvania, OH

Tom Schumann
General Manager
E.C. Kitzel and Sons, Inc.
Cleveland, OH

Rob Smith
Educational Consultant
DEPCO, LLC
Lexington, OH

Gary Wimer
Electronic and Computer Technology
Instructor
Wayne County Schools Career Center
Smithville, OH

Operations

Sandra Chamberlain
Consultant
Dublin, OH

Jason Keys
District Manager
The Lincoln Electric Company
Columbus, OH

Earl LeVan
Consultant
Honda of America Manufacturing
Bellefontaine, OH

Toni Neary
Business Development
Government and Education Group
ToolingU
Cleveland, OH

Todd Tracey
Mastercam Distribution, Sales,
Support and Training
FASTech, Inc.
Findlay, OH

Shannon Wagner
Education Services Specialist
United States Army Recruiting Battalion
Columbus, OH

Education Leaders

Ayodele Abatan
Department Chair and Professor
Miami University
Hamilton, OH

Michelle Blaney
Ohio Board of Regents
Columbus, OH

Julie Clemens
Ohio Board of Regents
Columbus, OH

April Carpenter
Sinclair Community College
Dayton, OH

Stephanie McCann
Ohio Board of Regents
Columbus, OH

Robert Speckert
Professor and Assistant Chair
Department of Engineering Technology
Miami University
Hamilton, OH

Jeffrey Woodson
Professor
Columbus State Community College
Columbus, OH

Development Contributors

Design

Kimberly Barr
Mechanical Engineer
Roger D. Fields and Associates
Columbus, OH

Frank Gibson
Program Manager
Alber Enterprise Center
Marion, OH

Matt Hanning
Instructor
Pioneer Career and Technology Center
Shelby, OH

Jason Hoffman
Buckeye Educational Systems
Lexington, OH

Robert Hurley
Engineer
Stanley Electric U.S. Co.
London, OH

Kristina Kennedy
Program Manager
Ohio Manufacturing Institute
Columbus, OH

Jim Mastoros
Coordinator
Stanley Electric U.S. Co.
London, OH

Scot McLemore
Unit Manager, Technical Development
Honda of America Manufacturing
Marysville, OH

Aaron Patrick
Manager
Stanley Electric U.S. Co.
London, OH

Brad Schneider
Manager, Training and Development
Ariel Corporation
Mount Vernon, OH

Robert Sintobin
Instructor/Department Chair
Toledo Technology Academy
Toledo, OH

Robert Speckert
Professor and Assistant Chair
Department of Engineering Technology
Miami University
Hamilton, OH

Ryan Reed
Engineering Instructor
Northview High School
Sylvania, OH

Jeffrey Woodson
Professor
Columbus State Community College
Columbus, OH

Operations

April Carpenter
Instructor
Sinclair Community College
Dayton, OH

Sandra Chamberlain
Consultant
Dublin, OH

Chris Conrardy
Chief Technology Officer
Edison Welding Institute
Columbus, OH

Frank Gibson
Program Manager
Alber Enterprise Center
Marion, OH

Chris Karl
Instructor
Pioneer Career and Technology Center
Shelby, OH

Jason Keys
District Manager
Lincoln Electric Co.
Columbus, OH

Dave Lord
Project Lead the Way (PTLW)
Engineering Instructor
Kettering Fairmont High School
Kettering, OH

Dave McGrough
Instructor
Knox County Career Center
Mount Vernon, OH

Bill Pencil
Instructor
Tolles Career and Technical Center
Plain City, OH

Richard Parrott
Cuyahoga Valley Career Center
Brecksville, OH

Kip Stevens
Welding Instructor
Pioneer Career and Technology Center
Shelby, OH

Rick Stringer
Instructor
Scioto County Career Technical Center
Lucasville, OH

Brian Timmerman
Assistant Die Mold Manager
Stanley Electric U.S. Co.
London, OH

Rick Pridemore
Director of Satellite Operations
Greene County Career Center
Xenia, OH

Validation Panel Contributors

December 4, 2012, and January 23, 2013

Design

Kimberly Barr
Mechanical Engineer
Roger D. Fields and Associates
Columbus, OH

Kyle Cramer
Mechanical Engineer
MTD Products Inc.
Cleveland, OH

Sharon Emmer
Human Resources Manager
Voisard Manufacturing
Shiloh, OH

Todd Garber
Sales Representative
OE Meyer Co.
Galion, OH

Brandon Hall
Supervisor
The Gorman-Rupp Company
Mansfield, OH

Luke Keinath
Engineer
Emerson Process Management
Mansfield, OH

Scott King
Supervisor
The Gorman-Rupp Company
Mansfield, OH

Scot McLemore
Unit Manager, Technical Development
Honda of America Manufacturing
Marysville, OH

Brian White
Project Engineer
Mansfield Engineered Components
Mansfield, OH

Operations

Sandra Chamberlain
Consultant
Dublin, OH

Chris Conrardy
Chief Technology Officer
Edison Welding Institute
Columbus, OH

Jason Keys
District Manager
Lincoln Electric Co.
Columbus, OH

Jason Scales
Technical Trainer
Lincoln Electric Co.
Cleveland, OH

Shannon Wagner
Education Services Specialist
United States Army
Columbus, OH

Education Leaders

Ayodele Abatan
Department Chair and Professor
Miami University
Hamilton, OH

Dick Bickerstaff
Dean
Columbus State Community College
Columbus, OH

Matt Hanning
Instructor
Pioneer Career and Technology Center
Shelby, OH

Carl Hilgarth
Professor
Shawnee State University
Portsmouth, OH

Chris Karl
Instructor
Pioneer Career and Technology Center
Shelby, OH

Tim Keller
Ohio Board of Regents
Columbus, OH

Dave McGrough
Instructor
Knox County Career Center
Mount Vernon, OH

Bob Oehler
PTLW Pre-Engineering Instructor
Collins Career Center
Chesapeake, OH

Jay Osborne
Welding Instructor
Pike County Career Technical Center
Piketon, OH

Ryan Reed
Engineering Instructor
Northview High School
Sylvania, OH

Kip Stevens
Welding Instructor
Pioneer Career and Technology Center
Shelby, OH

Jeff Williams
Instructor
Collins Career Center
Shelby, OH

Kim Williams
Instructor
Collins Career Center
Shelby, OH

Jeffrey Woodson
Professor
Columbus State Community College
Columbus, OH

Career Pathways Definitions

The Engineering and Science Technologies and Manufacturing Technologies Career Field prepares students for careers in design, operations, manufacturing and STEM (Science, Technology, Engineering and Math).

Design

Design program areas will provide students with the necessary technical and academic skills to research and create product models with features/functions that meet the needs of the customer, manufacturing, quality and the overall business.

Careers for which this pathway prepares students include:

Computer Aided Drafting Technician (CAD)
Engineer
Engineering Technician
Line Operator
Maintenance Technician
Quality Technician

Postsecondary majors for which this pathway prepares students include:

Drafting and Design Technology
Engineering – Aeronautical/Aerospace, Electrical, Industrial, Manufacturing, Materials
Quality Control and Safety Technology
Robotics Technology

Operations

Operations program areas will provide students with the necessary technical and academic skills to administer the manufacturing process, including equipment, installation, tools and dies, logistics, inventory control, assembly, repair, quality and safety.

Careers for which this pathway prepares students include:

Computer Numeric Control Technician (CNC)
Forming Machine Setter
Machine Tool Cutting Setter
Machinist
Welder

Postsecondary majors for which this pathway prepares students include:

Computer Numerically Controlled (CNC) Machinist Technology
Metallurgical Technology
Precision Metal Working
Tool and Die Technology
Welding Technology

Strand/Outcome Pathway Chart

An “X” indicates that the pathway applies to the outcome.

Outcome	Pathway	
	Design	Operations
Strand 1: Business Operations/21st Century Skills page 2		
Outcome 1.1: Employability Skills	X	X
Outcome 1.2: Leadership and Communications	X	X
Outcome 1.3: Business Ethics and Law	X	X
Outcome 1.4: Knowledge Management and Information Technology	X	X
Outcome 1.5: Global Environment	X	X
Outcome 1.6: Business Literacy	X	X
Outcome 1.7: Entrepreneurship/Entrepreneurs	X	X
Outcome 1.8: Operations Management	X	X
Outcome 1.9: Financial Management	X	X
Outcome 1.10: Sales and Marketing	X	X
Outcome 1.11: Principles of Business Economics	X	X
Strand 2: Electrical/Electronics page 12		
Outcome 2.1: Electronic Theory	X	
Outcome 2.2: Circuits	X	
Outcome 2.3: Codes and Regulations	X	
Outcome 2.4: Electronic Components	X	
Outcome 2.5: Electronic Soldering Connections	X	
Outcome 2.6: Digital Electronics	X	
Outcome 2.7: Cabling and Wiring	X	
Outcome 2.8: Power Supplies	X	
Outcome 2.9: Motors and Power	X	
Strand 3: Computer Integrated Manufacturing page 17		
Outcome 3.1: Computer Numerical Control (CNC)	X	X
Outcome 3.2: Robotics	X	X
Outcome 3.3: Programmable Logic Controllers (PLCs)	X	X
Outcome 3.4: Power Technologies	X	X
Outcome 3.5: Pumping Systems	X	X
Outcome 3.6: Transmission Systems	X	X
Strand 4: Materials Joining page 21		
Outcome 4.1: Physics of Welding		X
Outcome 4.2: Metallurgy of Welding		X

Outcome	Pathway	
	Design	Operations
Outcome 4.3: Arc Welding Processes		X
Outcome 4.4: Non-Arc Welding Processes		X
Outcome 4.5: Testing and Inspection		X
Outcome 4.6: Thermal Cutting		X
Strand 5: Pre-Engineering: Design and Development page 25		
Outcome 5.1: The Design Process	X	X
Outcome 5.2: Sketching and Visualization	X	X
Outcome 5.3: Computer-Aided Modeling	X	X
Outcome 5.4: Computer-Aided Drafting	X	X
Outcome 5.5: Materials	X	X
Outcome 5.6: Production and Process Design	X	X
Strand 6: Precision Machining page 28		
Outcome 6.1: Measurement and Interpretation	X	X
Outcome 6.2: Layout and Planning	X	X
Outcome 6.3: Cutting	X	X
Outcome 6.4: Drilling	X	X
Outcome 6.5: Turning	X	X
Outcome 6.6: Milling	X	X
Outcome 6.7: Grinding	X	X
Outcome 6.8: Maintenance	X	X
Strand 7: Safety, Tools and Equipment page 32		
Outcome 7.1: Site Safety	X	X
Outcome 7.2: Personal Safety	X	X
Total Outcomes by Pathway:	42	39
Total Outcomes:	48	

ENGINEERING AND SCIENCE TECHNOLOGIES AND MANUFACTURING TECHNOLOGIES

CAREER FIELD TECHNICAL CONTENT STANDARDS

STRANDS 1-7

Strand 1. Business Operations/21st Century Skills

Learners apply principles of economics, business management, marketing and employability in an entrepreneur, manager and employee role to the leadership, planning, developing and analyzing of business enterprises related to the career field.

Outcome 1.1. Employability Skills

Develop career awareness and employability skills (e.g., face-to-face, online) needed for gaining and maintaining employment in diverse business settings.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

1.1.1. Identify the knowledge, skills and abilities necessary to succeed in careers.
1.1.2. Identify the scope of career opportunities and the requirements for education, training, certification, licensure and experience.
1.1.3. Develop a career plan that reflects career interests, pathways and secondary and postsecondary options.
1.1.4. Describe the role and function of professional organizations, industry associations and organized labor and use networking techniques to develop and maintain professional relationships.
1.1.5. Develop strategies for self-promotion in the hiring process (e.g., filling out job applications, resumé writing, interviewing skills, portfolio development).
1.1.6. Explain the importance of work ethic, accountability and responsibility and demonstrate associated behaviors in fulfilling personal, community and workplace roles.
1.1.7. Apply problem-solving and critical-thinking skills to work-related issues when making decisions and formulating solutions.
1.1.8. Identify the correlation between emotions, behavior and appearance and manage those to establish and maintain professionalism.
1.1.9. Give and receive constructive feedback to improve work habits.
1.1.10. Adapt personal coping skills to adjust to taxing workplace demands.
1.1.11. Recognize different cultural beliefs and practices in the workplace and demonstrate respect for them.
1.1.12. Identify healthy lifestyles that reduce the risk of chronic disease, unsafe habits and abusive behavior.

Outcome 1.2. Leadership and Communications

Process, maintain, evaluate and disseminate information in a business. Develop leadership and team building to promote collaboration.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

1.2.1. Extract relevant, valid information from materials and cite sources of information.
1.2.2. Deliver formal and informal presentations.
1.2.3. Identify and use verbal, nonverbal and active listening skills to communicate effectively.
1.2.4. Use negotiation and conflict-resolution skills to reach solutions.
1.2.5. Communicate information (e.g., directions, ideas, vision, workplace expectations) for an intended audience and purpose.
1.2.6. Use proper grammar and expression in all aspects of communication.
1.2.7. Use problem-solving and consensus-building techniques to draw conclusions and determine next steps.
1.2.8. Identify the strengths, weaknesses and characteristics of leadership styles that influence internal and external workplace relationships.
1.2.9. Identify advantages and disadvantages involving digital and/or electronic communications (e.g., common content for large audience, control of tone, speed, cost, lack of non-verbal cues, potential for forwarding information, longevity).
1.2.10. Use interpersonal skills to provide group leadership, promote collaboration and work in a team.
1.2.11. Write professional correspondence, documents, job applications and resumés.
1.2.12. Use technical writing skills to complete forms and create reports.
1.2.13. Identify stakeholders and solicit their opinions.
1.2.14. Use motivational strategies to accomplish goals.

Outcome 1.3. Business Ethics and Law

Analyze how professional, ethical and legal behavior contributes to continuous improvement in organizational performance and regulatory compliance.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

1.3.1. Analyze how regulatory compliance affects business operations and organizational performance.

1.3.2. Follow protocols and practices necessary to maintain a clean, safe and healthy work environment.

1.3.3. Use ethical character traits consistent with workplace standards (e.g., honesty, personal integrity, compassion, justice).

1.3.4. Identify how federal and state consumer protection laws affect products and services.

1.3.5. Access and implement safety compliance measures (e.g., quality assurance information, safety data sheets [SDSs], product safety data sheets [PSDSs], United States Environmental Protection Agency [EPA], United States Occupational Safety and Health Administration [OSHA]) that contribute to the continuous improvement of the organization.

1.3.6. Identify deceptive practices (e.g., bait and switch, identity theft, unlawful door-to-door sales, deceptive service estimates, fraudulent misrepresentations) and their overall impact on organizational performance.

1.3.7. Identify the labor laws that affect employment and the consequences of noncompliance for both employee and employer (e.g., harassment, labor, employment, employment interview, testing, minor labor laws, Americans with Disabilities Act, Fair Labor Standards Acts, Equal Employment Opportunity Commission [EEOC]).

1.3.8. Verify compliance with computer and intellectual property laws and regulations.

1.3.9. Identify potential conflicts of interest (e.g., personal gain, project bidding) between personal, organizational and professional ethical standards.

Outcome 1.4. Knowledge Management and Information Technology

Demonstrate current and emerging strategies and technologies used to collect, analyze, record and share information in business operations.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

1.4.1. Use office equipment to communicate (e.g., phone, radio equipment, fax machine, scanner, public address systems).
1.4.2. Select and use software applications to locate, record, analyze and present information (e.g., word processing, e-mail, spreadsheet, databases, presentation, Internet search engines).
1.4.3. Verify compliance with security rules, regulations and codes (e.g., property, privacy, access, accuracy issues, client and patient record confidentiality) pertaining to technology specific to the industry pathway.
1.4.4. Use system hardware to support software applications.
1.4.5. Use information technology tools to maintain, secure and monitor business records.
1.4.6. Use an electronic database to access and create business and technical information.
1.4.7. Use personal information management and productivity applications to optimize assigned tasks (e.g., lists, calendars, address books).
1.4.8. Use electronic media to communicate and follow network etiquette guidelines.

Outcome 1.5. Global Environment

Evaluate how beliefs, values, attitudes and behaviors influence organizational strategies and goals.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

1.5.1. Describe how cultural understanding, cultural intelligence skills and continual awareness are interdependent.
1.5.2. Describe how cultural intelligence skills influence the overall success and survival of an organization.
1.5.3. Use cultural intelligence to interact with individuals from diverse cultural settings.
1.5.4. Recognize barriers in cross-cultural relationships and implement behavioral adjustments.
1.5.5. Recognize the ways in which bias and discrimination may influence productivity and profitability.
1.5.6. Analyze work tasks for understanding and interpretation from a different cultural perspective.
1.5.7. Use intercultural communication skills to exchange ideas and create meaning.
1.5.8. Identify how multicultural teaming and globalization can foster development of new and improved products and services and recognition of new opportunities.

Outcome 1.6. Business Literacy

Develop foundational skills and knowledge in entrepreneurship, financial literacy and business operations.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

1.6.1. Identify business opportunities.
1.6.2. Assess the reality of becoming an entrepreneur, including advantages and disadvantages (e.g., risk versus reward, reasons for success and failure).
1.6.3. Explain the importance of planning your business.
1.6.4. Identify types of businesses, ownership and entities (i.e., individual proprietorships, partnerships, corporations, cooperatives, public, private, profit, not-for-profit).
1.6.5. Describe organizational structure, chain of command, the roles and responsibilities of the organizational departments and interdepartmental interactions.
1.6.6. Identify the target market served by the organization, the niche that the organization fills and an outlook of the industry.
1.6.7. Identify the effect of supply and demand on products and services.
1.6.8. Identify the features and benefits that make an organization's product or service competitive.
1.6.9. Explain how the performance of an employee, a department and an organization is assessed.
1.6.10. Describe the impact of globalization on an enterprise or organization.
1.6.11. Describe how all business activities of an organization work within the parameters of a budget.
1.6.12. Describe classifications of employee benefits, rights, deductions and compensations.

Outcome 1.7. Entrepreneurship/Entrepreneurs

Analyze the environment in which a business operates and the economic factors and opportunities associated with self-employment.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

1.7.1. Compare and contrast the four types of business ownership (i.e., individual proprietorships, partnerships, corporations, cooperatives).
1.7.2. Explain the role of profit as the incentive to entrepreneurs in a market economy.
1.7.3. Identify the factors that contribute to the success and failure of entrepreneurial ventures.
1.7.4. Assess the roles of nonprofit and for-profit businesses.
1.7.5. Develop a business plan.
1.7.6. Describe life cycles of an entrepreneurial business and an entrepreneur.
1.7.7. Create a list of personal strengths, weaknesses, skills and abilities needed to be successful as an entrepreneur.
1.7.8. Explain pathways used to become an entrepreneur.
1.7.9. Conduct a self-assessment to determine entrepreneurial potential.
1.7.10. Describe techniques for obtaining experience (e.g., apprenticeship, co-operative [co-op] education, work placement, internship, job shadowing) related to an entrepreneurial objective.
1.7.11. Identify initial steps in establishing a business (e.g., limited liability company [LLC], tax ID, permits, insurance, licensing).
1.7.12. Identify resources available to entrepreneurs (e.g., Small Business Administration, mentors, information resources, educational opportunities).
1.7.13. Protect intellectual property and knowledge (e.g., copyright, patent, trademark, trade secrets, processes).

Outcome 1.8. Operations Management

Plan, organize and monitor an organization or department to maximize contribution to organizational goals and objectives.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

1.8.1. Forecast future resources and budgetary needs using financial documents (e.g., balance sheet, demand forecasting, financial ratios).
1.8.2. Select and organize resources to develop a product or a service.
1.8.3. Analyze the performance of organizational activities and reallocate resources to achieve established goals.
1.8.4. Identify alternative actions to take when goals are not met (e.g., changing goals, changing strategies, efficiencies).
1.8.5. Use inventory and control systems to purchase materials, supplies and equipment (e.g., Last In, First Out [LIFO]; First In, First Out [FIFO]; Just in Time [JIT]; LEAN).
1.8.6. Identify the advantages and disadvantages of carrying cost and Just-in-Time (JIT) production systems and the effects of maintaining inventory (e.g., perishable, shrinkage, insurance) on profitability.
1.8.7. Collect information and feedback to help assess the organization's strategic planning and policymaking processes.
1.8.8. Identify routine activities for maintaining business facilities and equipment.
1.8.9. Develop a budget that reflects the strategies and goals of the organization.
1.8.10. Analyze how business management and environmental management systems (e.g., health, safety) contribute to continuous improvement and sustainability.

Outcome 1.9. Financial Management

Use financial tools, strategies and systems to develop, monitor and control the use of financial resources to ensure personal and business financial well-being.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

1.9.1. Create, analyze and interpret financial documents (e.g., budgets, income statements).
1.9.2. Identify tax obligations.
1.9.3. Review and summarize savings, investment strategies and purchasing options (e.g., cash, lease, finance, stocks, bonds).
1.9.4. Identify credit types and their uses in order to establish credit.
1.9.5. Identify ways to avoid or correct debt problems.
1.9.6. Explain how credit ratings and the criteria lenders use to evaluate repayment capacity affect access to loans.
1.9.7. Review and summarize categories (types) of insurance and identify how insurances can reduce financial risk.
1.9.8. Identify income sources and expenditures.
1.9.9. Compare and contrast different banking services available through financial institutions.
1.9.10. Identify the role of depreciation in tax planning and liability.

Outcome 1.10. Sales and Marketing

Manage pricing, place, promotion, packaging, positioning and public relations to improve quality customer service.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

1.10.1. Identify how the roles of sales, advertising and public relations contribute to a company's brand.
1.10.2. Determine the customer's needs and identify solutions.
1.10.3. Communicate features, benefits and warranties of a product or service to the customer.
1.10.4. Identify the company policies and procedures for initiating product and service improvements.
1.10.5. Monitor customer expectations and determine product/services satisfaction by using measurement tools.
1.10.6. Discuss the importance of correct pricing to support a product's or service's positioning in the marketing mix.
1.10.7. Describe the importance and diversity of distribution channels (i.e., direct, indirect) to sell a product.
1.10.8. Use promotional techniques to maximize sales revenues (e.g., advertising, sales promotions, publicity, public relations).
1.10.9. Describe how product mix (e.g., product line, product items) maximize sales revenues, market, share and profit margin.
1.10.10. Demonstrate sales techniques.

Outcome 1.11. Principles of Business Economics

Examine and employ economic principles, concepts and policies to accomplish organizational goals and objectives.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

1.11.1. Identify the economic principles that guide geographic location of an industry's facilities (e.g., relative scarcity, price, quantity of products and services).

1.11.2. Identify the difference between monetary and nonmonetary incentives and explain how changes in incentives cause changes in behavior.

1.11.3. Use economic indicators to identify economic trends and conditions (e.g., inflation, interest rate fluctuations, unemployment rates).

1.11.4. Determine how the quality, quantity and pricing of goods and services are affected by domestic and international competition in a market economy.

1.11.5. Analyze factors that affect currency and exchange rates.

1.11.6. Explain how financial markets and government policies influence interest rates (credit ratings/debt ceiling), trade deficits and unemployment.

1.11.7. Describe how economic performance and culture are interdependent.

1.11.8. Identify the relationships between economy, society and environment that lead to sustainability.

1.11.9. Describe how laws and regulations influence domestic and international trade.

Strand 2. Electrical/Electronics

Learners apply principles of electricity and electronics related to electronic theory, alternating and direct current, electronic components, electronic skills, digital electronics and power supplies. Knowledge and skills may be applied to fundamentals of electricity, analyzing and evaluating circuits, assembling components into electrical circuits, creating circuits to perform tasks and operations, wiring components to construct a communications system and providing power to an electrical system.

Outcome 2.1. Electronic Theory

Explain electrical principles and theories.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	

Competencies

2.1.1. Describe the structure of atoms and their relationship to electricity.
2.1.2. Compare and contrast electrical and electromagnetic effect.
2.1.3. Explain methods of producing electrical current.
2.1.4. Explain how batteries store and disperse energy.
2.1.5. Compare and contrast alternating current (AC) and direct current (DC).
2.1.6. Define the units of measurement for voltage, current, power and resistance.
2.1.7. Describe the relationships between voltage, current, resistance and power in circuits.
2.1.8. Determine voltage, current, resistance and power in circuits using Ohm's Law, Kirchhoff's Law and Watt's Law.
2.1.9. Describe the purpose of grounding and common methods used for grounding.
2.1.10. Evaluate frequency and phase.
2.1.11. Identify methods of varying capacitance.
2.1.12. Calculate true power, apparent power, reactive power and power factor.
2.1.13. Determine impedance.
2.1.14. Compare peak (PK), root mean square (RMS) and average voltage.

Outcome 2.2. Circuits

Construct and analyze alternating current (AC) circuits and direct current (DC) circuits.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	

Competencies

2.2.1. Compare and contrast conductors and insulators.
2.2.2. Identify common types of transformers and list uses for each.
2.2.3. Explain step-up/step-down voltage methods.
2.2.4. Describe lamination and explain why laminations are used.
2.2.5. Identify types of capacitors and common usages for each.
2.2.6. Identify types of inductors and explain the purposes of different core materials.
2.2.7. Identify the function of inductors and capacitors in series and parallel circuits.
2.2.8. Explain the uses of series, parallel and series-parallel circuits.
2.2.9. Construct and troubleshoot series, parallel and series-parallel circuits.
2.2.10. Analyze wiring schematics and diagrams for accuracy and function.

Outcome 2.3. Codes and Regulations

Explain and apply the National Electrical Code (NEC) and other building codes.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	

Competencies

2.3.1. Explain the role of Underwriters Laboratory (UL), Canadian Standards Association (CSA) and Intertek Testing Service/Edison Testing Laboratory (ITS/ETL).
2.3.2. Locate and apply the information in articles of the NEC and other applicable codes (i.e., Building Officials and Code Administrators [BOCA], Ohio Building Code [OBC], Life Safety Codes) and explain how they impact job requirements (e.g., service conductors, feeders, branch circuits, overload protection, grounding, bonding requirements).
2.3.3. Utilize National Fire Protection Association (NFPA) procedures for NFPA 70E-arc flash boundaries, current-limiting fuses, live work power permits, electrically safe work conditions, emergency worker safety programs, scheduling, energized circuits and training.

Outcome 2.4. Electronic Components

Describe electronic components and their functions and purpose.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	

Competencies

2.4.1. Identify resistor values from color codes or other marks.
2.4.2. Compare and contrast resistor compositions and their uses.
2.4.3. Identify symbols for electronic components.
2.4.4. Compare and contrast negative positive negative (NPN) and positive negative positive (PNP) transistors.
2.4.5. Identify types of transistors and explain their uses (i.e., Darlington pairs, unijunction transistors, Gunn diodes, field effect transistors [FETs] and metal-oxide semiconductor field-effect transistor [MOSFETs], N- and P- channel junction field effect transistors [JFETs]).
2.4.6. Compare and contrast the purpose and function of thyristors (diacs, triacs, varisters and thermistors).
2.4.7. Describe the purpose and operation of zener diodes.
2.4.8. Describe the purpose and operation of common optical devices (e.g., light emitting diodes [LEDs], liquid crystal displays [LCDs]).
2.4.9. Describe the purpose and operation of photovoltaic cells.
2.4.10. Describe the purpose, composition and operation of photo resistors, photodiodes and phototransistors.
2.4.11. Define surface mount components.
2.4.12. Describe the purpose and operation of audio amplifiers and their frequency response.
2.4.13. Explain the purpose and operation of common emitter (CE) amplifiers, common base (CB) amplifiers and common collector (CC) or emitter follower amplifiers.

Outcome 2.5. Electronic Soldering Connections

Connect individual components into an electrical unit.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	

Competencies

2.5.1 Define the purpose of a connection and the differences between a good and bad connection.
2.5.2 Select types of solder.
2.5.3 Describe methods for soldering and desoldering and the purpose for each method.
2.5.4 Protect circuit boards from electrostatic discharge (ESD).
2.5.5 Solder and desolder components.
2.5.6 Combine components per wiring prints, schematics and block diagrams.

Outcome 2.6. Digital Electronics

Create circuits to perform tasks and operations.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	

Competencies

2.6.1 Determine the output frequency of circuits.
2.6.2 Describe the purpose and use of logic gates (e.g., discrete and medium scale integration [MSI] gates, latches, flip-flops).
2.6.3 Design a paradigm for combinational logic problems.
2.6.4 Design a specific MSI gate application.
2.6.5 Describe the purpose and operation of programmable logic devices (PLDs) and complex programmable logic devices (CPLDs).
2.6.6 Describe the purpose and use of asynchronous and synchronous counters.
2.6.7 Determine fan-out and propagation delays.
2.6.8 Explain the purpose and use of a digital bus.
2.6.9 Explain the purpose and use of pulsers and logic probes.
2.6.10 Identify the numbering systems, codes, arithmetic operations, Boolean operations and simplification methods used in digital electronics.
2.6.11 Describe the purpose and use of digital-to-analog and analog-to-digital circuits.
2.6.12 Design a schematic for a digital circuit.
2.6.13 Utilize a counter in a circuit.
2.6.14 Utilize memory in a control system.
2.6.15 Construct a digital circuit based on the schematic using solder and solderless techniques.
2.6.16 Test circuit function.
2.6.17 Use schematics and test points to locate subsystem, component and wiring failures in electronics products.

Outcome 2.7. Cabling and Wiring

Connect components to construct low-voltage, data and communication systems using coaxial or fiber optic cables and twisted pair or balanced wires.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	

Competencies

2.7.1. Describe the types, purposes and uses of cables and wires.
2.7.2. Identify the construction, impedance characteristics and use of cables and wires.
2.7.3. Explain how the characteristics of cables and wires cause impedance.
2.7.4. Select methods for splicing and terminating cables and wires.
2.7.5. Splice and terminate cables and wires.
2.7.6. Test cables and wires.

Outcome 2.8. Power Supplies

Provide power to electrical circuits.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	

Competencies

2.8.1 Identify the differences between transformer-powered supplies and line-connected supplies.
2.8.2 Select a battery based on composition, environment and circuit characteristics.
2.8.3 Select and install filters.
2.8.4 Construct and install regulated power supplies.
2.8.5 Select and install fuses and circuit breakers.
2.8.6 Select and construct half-wave, full-wave and bridge rectifiers.
2.8.7 Select and install power conditioning, isolation transformers, surge suppressors and uninterruptible power supplies.

Outcome 2.9. Motors and Power

Install motors and power wiring in accordance with the National Electrical Code (NEC).

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	

Competencies

2.9.1 Identify types and components of single phase and three phase motors.
2.9.2 Interpret motor nameplate information and motor specifications.
2.9.3 Calculate motor loads.
2.9.4 Determine motor rotation needed for the installed load and explain the process for reversing rotation (i.e., three phase and single phase).
2.9.5 Interpret schematics and control diagrams for building a motor circuit.
2.9.6 Wire single phase and three phase circuits and install motor control devices (i.e., contactors, starters, variable frequency and motor speed controls).
2.9.7 Explain the starting sequence of motor components within a given circuit.
2.9.8 Troubleshoot and repair motor starting systems to verify operation according to schematics and control diagrams.
2.9.9 Describe how programmable controllers can be used in single phase and three phase circuits.

Strand 3. Computer Integrated Manufacturing

Learners apply the principles of computer integrated manufacturing related to computer numerical control, robotics, programmable logic controllers and power systems.

Outcome 3.1. Computer Numerical Control (CNC)

Apply standard practices of CNC operations and part inspection.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

3.1.1. Maintain CNC milling/turning machine components and controllers.
3.1.2. Plan a CNC production process for jobs in a machining cell.
3.1.3. Create and edit CNC programs (e.g., G-code, computer-aided manufacturing [CAM]) for milling/turning machine operations according to job specifications, dimensions and tolerances.
3.1.4. Create a tool setup sheet.
3.1.5. Work from a process sheet and part print.
3.1.6. Set up and operate CNC milling/turning machines.
3.1.7. Monitor the operations of a machining cell and troubleshoot problems that arise.
3.1.8. Verify part quality against job specifications.

Outcome 3.2. Robotics

Plan and operate robotics production processes.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

3.2.1. Identify the components of a robot system and explain their roles in the robot's operation cycle.
3.2.2. Maintain robot components and controllers.
3.2.3. Use the robotic systems classification scheme to select an industrial robot.
3.2.4. Use job specifications to create programs for robot operations, sensors and feeder systems.
3.2.5. Plan, program and test a robotic work cell using teach pendant and simulation software.
3.2.6. Identify the robot's payload and identify the concepts of payload weight and moment of inertia to select an appropriate robot.
3.2.7. Use robot speed specifications to calculate estimated cycle times for sample tasks.
3.2.8. Identify home position (fixed and floating zero) using absolute and incremental coordinates.
3.2.9. Compare and contrast various robotic applications and processes (e.g., pick and place, welding).
3.2.10. Identify the robot's work envelope and apply the concepts of reach and articulation to evaluate whether a robot is suited to an application.
3.2.11. Analyze the performance and troubleshoot the operation of a robotic cell.

Outcome 3.3. Programmable Logic Controllers (PLCs)

Program digital computers used for automation of electromechanical processes to perform tasks.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

3.3.1. Identify PLCs.
3.3.2. Design a PLC program.
3.3.3. Describe the use of PLCs in manufacturing automation.
3.3.4. Apply and execute a ladder logic program.
3.3.5. Design a motor control program using manual and automatic modes.
3.3.6. Monitor and troubleshoot a hard-wired system with a PLC.
3.3.7. Monitor PLC operation using systems control dialog.

Outcome 3.4. Power Technologies

Install, maintain and troubleshoot fluid power systems.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

3.4.1. Calculate the pressure and flow of a fluid and describe how it relates to the functioning of a hydraulic and pneumatic actuator.
3.4.2. Describe the relationship between force, pressure and power.
3.4.3. Calculate the efficiency of system components and energy loss due to friction, slippage and leakage.
3.4.4. Determine the effect of energy storage on efficiency and size of power units.
3.4.5. Predict the performance of an actuator under meter-in and meter-out conditions.
3.4.6. Read and interpret hydraulic, pneumatic and vacuum schematics and model codes.
3.4.7. Select a fluid power system based on project needs (e.g., pressure, flow, temperature, dissipation, filtration, fluid, maintenance).
3.4.8. Explain the fundamental principles of pneumatics, hydraulics and vacuum technology.
3.4.9. Troubleshoot power loss within a system.
3.4.10. Select the O-ring size, material and oil capacity for a specified application.
3.4.11. Use directional and proportional controls.
3.4.12. Compare and contrast electromechanical, pneumatic and hydraulic actuation.
3.4.13. Perform general maintenance on pneumatics, hydraulics and vacuum systems.
3.4.14. De-energize pneumatics, hydraulics and vacuum systems.
3.4.15. Compare and contrast types and functions of compressors.

Outcome 3.5. Pumping Systems

Analyze pumps and pumping systems.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

3.5.1. Compare and contrast types of positive and non-positive displacement pumps and their respective functions.
3.5.2. Calculate flow, head/pressure and efficiency.
3.5.3. Interpret pump curves.
3.5.4. Align precision and non-precision couplings.
3.5.5. Disassemble and assemble pumping stations.
3.5.6. Troubleshoot pump system failure conditions (e.g., cavitation).

Outcome 3.6. Transmission Systems

Analyze power transmission systems.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

3.6.1. Perform shaft alignment on rotating equipment.

3.6.2. Install, maintain, monitor and troubleshoot power transmissions systems.

3.6.3. Compare and contrast types of gears, couplings, belts and chains used in the transmission of power.

3.6.4. Select bearings for specific applications.

3.6.5. Calculate or obtain speed and torque ratios for belt and chain drives per design specifications.

Strand 4. Materials Joining

Learners apply principles of physics and metallurgy to join materials and test joints. Knowledge and skills may be applied to arc welding processes, non-arc welding processes, testing and inspection and thermal cutting.

Outcome 4.1. Physics of Welding

Apply the physics of arc welding to the process of joining metal.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
	X

Competencies

4.1.1. Explain how the welding arc produces a weld.
4.1.2. Identify the factors that affect heat transfer.
4.1.3. Identify the factors that affect melting.
4.1.4. Describe the effects of arc length and shielding gases on the arc.
4.1.5. Identify key variables that determine the type of metal transfers.
4.1.6. Identify how metal transfers in different welding processes (i.e., short circuit, globular, spray transfer, pulsed spray transfer).
4.1.7. Explain the characteristics of different transfer modes (i.e., short circuit, globular, spray transfer, pulsed spray transfer).
4.1.8. Describe the relationship between wire feed speed and welding current.
4.1.9. Describe pulsed arc transfer mode.
4.1.10. Describe the effects of wire size on deposition rate and current ranges.
4.1.11. Identify the characteristics of a stable arc position.
4.1.12. Describe constant current and constant voltage power sources and how they relate to the self-regulation of arcs.
4.1.13. Explain conditions when arc blow occurs and how to reduce arc blow.

Outcome 4.2. Metallurgy of Welding

Apply the metallurgy of welding to the processes of joining metal.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
	X

Competencies

4.2.1. Explain phases of matter and phase changes during solidification.
4.2.2. Explain how the common crystal structure in metallic materials affects welds.
4.2.3. Explain point, line and surface imperfection in metal crystal structure.
4.2.4. Explain the types of weld imperfections and indicate their effects on material properties.
4.2.5. Explain grain boundaries.
4.2.6. Explain allotropic phase changes as a function of temperature.
4.2.7. Explain the production of ferrous and nonferrous alloys.
4.2.8. Explain an equilibrium phase diagram for alloys.
4.2.9. Explain how the constituent structure of eutectoid steel changes when it is slowly cooled from austenite to pearlite and when it is rapidly cooled from austenite to martensite.
4.2.10. Explain the tie line concept for calculating percent of a phase in the two-phase region of equilibrium diagrams.
4.2.11. Identify the phases present in the two-phase pro-eutectoid ferrite region.
4.2.12. Explain transformation strengthening, deformation strengthening and precipitation strengthening.

Outcome 4.3. Arc Welding Processes

Perform all types of welds in all positions up to overhead using arc welding processes.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
	X

Competencies

4.3.1. Identify types of ferrous and nonferrous materials to be joined.
4.3.2. Select the types of weld (e.g., flat welds, butt welds, tack welds) required for product specifications.
4.3.3. Explain electrode and filler metal classification systems and procedures for handling and storing.
4.3.4. Select an arc welding process based on product specifications.
4.3.5. Join materials using the shielded metal arc welding (SMAW) process.
4.3.6. Join materials using the gas metal arc welding (GMAW) process.
4.3.7. Join materials using the flux core arc welding (FCAW) process.
4.3.8. Join materials using the submerged arc welding (SAW) process.
4.3.9. Join materials using the gas tungsten arc welding (GTAW) process.
4.3.10. Join materials using the arc stud welding process.

Outcome 4.4. Non-Arc Welding Processes

Perform all types of welds in all positions.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
	X

Competencies

4.4.1. Identify types of ferrous and nonferrous metals (e.g., mild steel, stainless steel, aluminum) and plastics to be joined.
4.4.2. Select the types of welds (e.g., flat welds, butt welds, tack welds) required for product specifications.
4.4.3. Select non-arc welding processes based on product specifications.
4.4.4. Join materials using the resistance welding (RW) process.
4.4.5. Join materials using the oxy-fuel gas welding process.
4.4.6. Describe the types and applications of solid state bonding processes.
4.4.7. Join materials using the ultrasonic process.
4.4.8. Join materials using the friction stir process.
4.4.9. Join materials using the high energy density fusion welding processes.
4.4.10. Join materials using the brazing and soldering processes.
4.4.11. Join materials using the processes for joining plastics.
4.4.12. Join materials using the adhesive bonding of parts technique.

Outcome 4.5. Testing and Inspection

Test and inspect joints and weld structures.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
	X

Competencies

4.5.1. Identify the factors considered in weld quality.
4.5.2. Conduct a visual defect examination.
4.5.3. Conduct destructive weldment testing.
4.5.4. Conduct dye penetrant examination.
4.5.5. Conduct radiographic examination.
4.5.6. Conduct eddy current examination.
4.5.7. Analyze weld structure test results to determine weld quality.

Outcome 4.6. Thermal Cutting

Cut materials using thermal cutting processes.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
	X

Competencies

4.6.1. Identify types of materials (ferrous and nonferrous) to be cut.
4.6.2. Identify the characteristics of the cut required.
4.6.3. Select a cutting process based on product specifications.
4.6.4. Cut metals using the plasma arc cutting (PAC) process.
4.6.5. Cut and gouge metals using the air carbon arc (CAC-A) process.
4.6.6. Cut metals using manual and machine-guided oxy-fuel processes.
4.6.7. Cut metals using advanced cutting systems (e.g., plasma computer-aided controls, computer numeric controls [CNC], laser).

Strand 5. Pre-Engineering: Design and Development

Learners apply principles of design and development related to the design process, sketching and visualization, modeling, drafting, materials and production and process design.

Outcome 5.1. The Design Process

Use the engineering design process and quality assurance principles to analyze and solve design problems.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

5.1.1. Describe the role of research, development and experimentation in design problem solving.
5.1.2. Conduct an investigation to identify customer needs, constraints and criteria.
5.1.3. Develop multiple solutions and select an approach.
5.1.4. Develop a design proposal and make a model/prototype.
5.1.5. Evaluate and redesign a prototype using collected data.
5.1.6. Utilize process planning and improvement tools to manage the life cycle of a product.
5.1.7. Compare and contrast design considerations for product recycling or disposal for the end of a product's life cycle.
5.1.8. Maintain an engineering journal to document progress and capture ideas during the development phase.

Outcome 5.2. Sketching and Visualization

Conceptualize and sketch design projects and components.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

5.2.1. Compare and contrast technical sketching and drawing.
5.2.2. Sketch possible solutions to an existing design problem.
5.2.3. Use tolerancing techniques when dimensioning.
5.2.4. Apply annotations on sketches and drawings.
5.2.5. Create sketches using integration sketching techniques and styles.
5.2.6. Apply coordinate systems (e.g., absolute, relative, user, cylindrical, Cartesian).
5.2.7. Sketch geometric forms and shapes.
5.2.8. Describe geometric constraints.
5.2.9. Select a view to graphically communicate a design solution.

Outcome 5.3. Computer-Aided Modeling

Create models to illustrate the design of projects and components.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

5.3.1. Apply manufacturing processes (e.g., casting, molding, forming, separating, conditioning, assembling, finishing, rapid prototyping).
5.3.2. Evaluate a sketch and generate a model utilizing three-dimensional modeling software and techniques.
5.3.3. Compare and contrast conceptual, physical and mathematical design models used to check proper design.
5.3.4. Perform part manipulation during the creation of an assembly model.
5.3.5. Analyze assembly constraints to successfully construct a multipart object.
5.3.6. Utilize part libraries effectively during the assembly modeling process.
5.3.7. Employ subassemblies during the production of assemblies.
5.3.8. Verify drive constraints that simulate the motion of parts in assemblies.
5.3.9. Apply adaptive design concepts during the development of sketches, features, parts and assemblies.
5.3.10. Translate a three-dimensional drawing or model into corresponding orthographic drawing views.
5.3.11. Evaluate the accuracy of mass properties calculations.
5.3.12. Evaluate a model for design imperfections.

Outcome 5.4. Computer-Aided Drafting

Interpret and prepare technical drawings.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

5.4.1. Create and interpret auxiliary views, orthographic projections, isometric drawings, oblique drawings and perspective drawings.
5.4.2. Create a sectional view drawing.
5.4.3. Illustrate the types of breaks and symbols used in drawing sectional views.
5.4.4. Produce a reverse-engineered drawing from a solid object.
5.4.5. Add technical elements (e.g., parts lists, titles, finishes, tolerances, specifications, hidden surfaces) to drawings.

Outcome 5.5. Materials

Select materials for design projects and components.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

5.5.1. Compare and contrast the advantages and disadvantages of organic materials, metals, polymers, ceramics and composites based on physical properties.
5.5.2. Determine the production processes used to create products from categories of materials.
5.5.3. Evaluate the types and magnitude of stresses and forces.
5.5.4. Analyze material properties by destructive and nondestructive tests.
5.5.5. Select materials for a given application based on specified criteria (e.g., cost, availability, manufacturability).
5.5.6. Analyze the strength of a design using simulation modeling software (e.g., finite element analysis).

Outcome 5.6. Production and Process Design

Plan, set up, monitor, analyze and control integrated systems.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

5.6.1. Identify the planning and process procedures for production (e.g., corrective preventive actions, audit documentation, Process Failure Mode Effect Analysis [PFMEA]).
5.6.2. Use process planning and improvement tools (e.g., flowcharts, diagrams, design for manufacturability [DFM]).
5.6.3. Employ project scheduling techniques (e.g., critical path methodology [CPM], project evaluation and review technique [PERT]).
5.6.4. Identify criteria and constraints and determine how those will affect the design of the production process.
5.6.5. Estimate time, tooling, product packaging and material costs.
5.6.6. Monitor performance against time, tool and material cost estimates.
5.6.7. Set capacity to account for fluctuation in demand.
5.6.8. Adjust the plan as necessary to respond to variations (e.g., process, demand, material).
5.6.9. Evaluate final solutions and communicate observations, processes and results.
5.6.10. Develop a packaging design that prepares a product for shipping.

Strand 6. Precision Machining

Learners apply principles of precision machining to measuring work pieces, drawing interpretation, inspection, bench work and layout, power saws, drilling machines, lathes and turning machines, milling machines and grinding machines.

Outcome 6.1. Measurement and Interpretation

Interpret drawings and documentation and perform measurements.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

6.1.1. Identify measuring tools and gradations used in precision machining and their purposes.
6.1.2. Identify typical measurements in precision machining (e.g., angles, diameter, hardness).
6.1.3. Identify measuring systems and convert between systems.
6.1.4. Measure and inspect work pieces according to product specifications.
6.1.5. Identify information and symbols typically provided in drawings and specifications.

Outcome 6.2. Layout and Planning

Plan a machining process.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

6.2.1. Determine product requirements, dimensions and tolerances from drawing and specifications.
6.2.2. Determine process steps (e.g., cut, drill, turn, mill, grind, heat treat).
6.2.3. Plan individual process steps based on industry standards (e.g., manufacturers' specifications, machining standards).
6.2.4. Schedule machining equipment as required.

Outcome 6.3. Cutting

Cut materials.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

6.3.1. Identify the type of material and cuts required in product specifications.
6.3.2. Select cutting equipment, work-holding devices, speeds, feeds and cutting fluids.
6.3.3. Configure the cutting equipment.
6.3.4. Prepare work pieces for cutting.
6.3.5. Cut the materials.
6.3.6. Inspect the work to meet requirements.

Outcome 6.4. Drilling

Drill materials.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

6.4.1. Identify the type of material and apertures required in product specifications.
6.4.2. Select drill, bit, work-holding devices, speeds, feeds and cutting fluids.
6.4.3. Configure the drilling equipment.
6.4.4. Prepare work pieces for drilling.
6.4.5. Drill the materials.
6.4.6. Inspect the work to meet requirements.

Outcome 6.5. Turning

Turn materials.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

6.5.1. Identify the type of material and turning required in product specifications.
6.5.2. Select turning machine, bit, chucks, speeds and cutting fluids.
6.5.3. Configure the turning equipment.
6.5.4. Prepare work pieces for turning.
6.5.5. Turn the materials.
6.5.6. Inspect the work to meet requirements.

Outcome 6.6. Milling

Mill materials.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

6.6.1. Identify the type of material and milling required in product specifications.
6.6.2. Select milling machine, bit, chucks, speeds and cutting fluids.
6.6.3. Configure the milling equipment.
6.6.4. Prepare work pieces for milling.
6.6.5. Mill the materials.
6.6.6. Inspect the work to meet requirements.

Outcome 6.7. Grinding

Grind materials.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

6.7.1. Identify the type of material and grinding required in product specifications.
6.7.2. Select grinding machine, wheels, work-holding devices, speeds and cutting fluids.
6.7.3. Configure the grinding equipment.
6.7.4. Prepare work pieces for grinding.
6.7.5. Grind the materials.
6.7.6. Inspect the work to meet requirements.

Outcome 6.8. Maintenance

Maintain tools and equipment in working condition.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

6.8.1. Identify equipment maintenance requirements in the equipment manufacturer's documentation.

6.8.2. Identify maintenance tasks required (e.g., inspecting, grinding, sharpening, dressing, lubricating, cleaning).

6.8.3. Verify measuring tool accuracy and recalibrate as needed.

6.8.4. Develop a preventive maintenance schedule.

6.8.5. Monitor equipment performance during use.

6.8.6. Repair or replace equipment and accessories as needed.

Strand 7. Safety, Tools and Equipment

Learners apply principles of protection, prevention and mitigation to create and maintain safe working conditions at manufacturing sites. Knowledge and skills may be applied in all aspects of personal and site safety, including handling materials, using tools and equipment, working with and around electricity and using personal protective equipment.

Outcome 7.1. Site Safety

Handle materials, prevent accidents and mitigate hazards.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

7.1.1. Use Occupational Safety and Health Administration (OSHA)-defined procedures for identifying employer and employee responsibilities, working in confined spaces, managing worker safety programs, using ground fault circuit interrupters (GFCIs), maintaining clearance and boundaries and labeling.

7.1.2. Identify and rectify or mitigate hazards associated with walking surfaces, working surfaces and lighting.

7.1.3. Calculate example of load factors for constructing scaffolding, railings, ladders and temporary structures.

7.1.4. Apply inspection, rejection criteria, hitch configurations and load-handling practices to slings and rigging hardware.

7.1.5. Demonstrate proper use of American National Standards Institute (ANSI) hand signals.

7.1.6. Identify source of electrical and mechanical hazards and use shut-down and established lock out/tag-out procedures.

7.1.7. Identify and eliminate worksite clutter in accordance with standards for cleanliness and safety.

7.1.8. Identify procedures for the handling, storage and disposal of hazardous materials.

7.1.9. Identify the location of emergency flush showers, eyewash fountains, Safety Data Sheets (SDSs), fire alarms and exits.

7.1.10. Select and operate fire extinguishers based on the class of fire.

7.1.11. Identify the components of a hazardous materials safety plan.

7.1.12. Create a hazardous materials safety plan.

7.1.13. Set up for ergonomic workflow.

7.1.14. Describe the interactions of incompatible substances when measuring and mixing chemicals.

Outcome 7.2. Personal Safety

Practice personal safety.

An "X" indicates that the pathway applies to the outcome.

Design	Operations
X	X

Competencies

7.2.1. Interpret personal safety rights according to the employee Right to Know plan.

7.2.2. Describe how working under the influence of drugs and alcohol increases the risk of accident, lowers productivity, raises insurance costs and reduces profits.

7.2.3. Select, use, store, maintain and dispose of personal protective equipment (PPE) appropriate to job tasks, conditions and materials.

7.2.4. Identify workplace risk factors associated with lifting, operating and moving heavy objects and establish an ergonomics process.

7.2.5. Identify, inspect and use safety equipment appropriate for a task.

7.2.6. Use safe practices when working with electrical, mechanical, or other equipment.