Ohio

Engineering and Science Technologies and Manufacturing Technologies

CAREER FIELD TECHNICAL CONTENT STANDARDS

2018

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Ohio | Department of Education

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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 middle and 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 Department of Higher Education Secondary Career-Technical Alignment Initiative.

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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 career 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 http://education.ohio.gov/Topics/Career-Tech). 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 to address the needs of an entire industry and business sector. Ohio's 16 career fields align with national efforts to broaden and integrate career-technical education 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 occupation. 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**
  Academic skills provide the foundation for career success. The integration of academic content standards with career field technical content standards help to contextualize learning for students that make 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**
  Students need knowledge and skills for success in a variety of postsecondary options, which include apprenticeships, industry credentials 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 clear articulated sequence of rigorous academic and career-technical coursework. Beginning as early as middle school, students are exposed to career planning with options such as postsecondary degrees, industry-recognized certificate, and/or licensure. The career pathway is developed, implemented and maintained in partnership among secondary and postsecondary education and business. Career pathways are available to all students and adult learners that lead to rewarding careers.

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

1. Coursework in a chosen career field based on 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 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 and postsecondary placement requirements;
9. Various areas 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
    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 contains 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 6 strands of content per career field.
  For example, 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. This provides the facilitation to 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 their lifetime.

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

These essential outcomes and competencies specify industry-based knowledge or hands-on skills that are required by the end of 12th grade to be successful in a 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 began in March 2017 and culminated in August 2018. 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 engagement 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;
    - Motoman FS100/DX100 Basic Programming with Material Handling (IACET Approved);
    - Manufacturing Skill Standards Council (MSSC)-Certified Production Technician (4 modules);
    - Fanuc - Handling Tool Operation & Programming J2P0310 IACT Approved;
    - Allen Bradley PLC;
    - 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/Advisory Panel

The Engineering and Science Technologies and Manufacturing Technologies Career Field Technical Content Standards were posted for public comment from March-April 2017. In June 2017 a futuring/advisory panel of key business and industry representatives from across the state were identified and invited to review the Engineering and Science Technologies and Manufacturing Technologies Content Standards and advise the Ohio Department of Education. 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. The panel reviewed all public comments and proposed changes to a teacher workgroup, Ohio Department of Higher Education, and Ohio Department of Education staff that completed revisions and edits to the standards. The standards were vetted through the futuring/advisory panel and were asked to provide feedback via electronic survey for finalization of the standards document.

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. The partnership between the Ohio Department of Higher Education's CTAG development process and the Ohio Department of Education's Career Field Technical Content Standards resulted in tighter alignment between secondary career-technical and postsecondary content. This led to the development of pathways, which encouraged college enrollment and increased statewide postsecondary options for career-technical students. For more information on CTAGs and opportunities for statewide postsecondary articulated transfer credit, visit https://transfercredit.ohio.gov.

Acknowledgements

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Those listed above provided vision and implementation support for the Information Technology Career Field Technical Content Standards and Ohio's Information Technology educational programs.

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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 Communication	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 13		
Outcome 2.1: Electrical and 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 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 19		
Outcome 3.1: Robotic Fundamentals	X	X
Outcome 3.2: Robotic Operation	X	X
Outcome 3.3: Industrial Robotic Programming	X	X
Outcome 3.4: Power Technologies	X	X
Outcome 3.5: Pumping Systems	X	X
Outcome 3.6: Mechanical Drives Systems	X	X
Outcome 3.7: Programmable Logic Controllers (PLCs)	X	X
Strand 4: Materials Joining page 24		
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 Material Joining Processes		X
Outcome 4.5: Testing and Inspection		X
Outcome 4.6: Cutting Processes		X
Outcome 4.7: Fabrication		X
Strand 5: Pre-Engineering: Design and Development page 28		
Outcome 5.1: The Design Process	X	X
Outcome 5.2: Sketching, Drawing, and Visualization	X	X
Outcome 5.3: Computer-Aided Drafting and Modeling	X	X
Outcome 5.4: Materials	X	X
Outcome 5.5: Production and Process Design	X	X
Outcome 5.6: Materials Handling	X	X
Strand 6: Precision and Advanced Machining page 32		
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
Outcome 6.9: Computer Numerical Control (CNC)	X	X
Outcome 6.10: Additive Manufacturing	X	X
Outcome 6.11: Quality	X	X
Strand 7: Industrial Maintenance and Safety page 37		
Outcome 7.1: Site Safety	X	X
Outcome 7.2: Personal Safety	X	X
Outcome 7.3: Industrial Maintenance Safety	X	X
Outcome 7.4: Industrial Maintenance Installation and Repair	X	X
Total Outcomes by Pathway:	48	46
Total Outcomes:	55	

ENGINEERING AND SCIENCE TECHNOLOGIES AND MANUFACTURING TECHNOLOGIES

CAREER FIELD
TECHNICAL CONTENT STANDARDS

STRANDS 1-7

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, resume 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 resumes.
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 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 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. Electrical and Electronic Theory

Explain electrical and electronic principles and theory.

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 electrical properties 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 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 values.

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 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.
2.2.11. Use circuit theorems in circuit analysis (e.g., Maximum power transfer, Thevenin, Source Transformation).
2.2.12. Use analysis techniques in circuit analysis (e.g., mesh, loop, superposition, single & double subscript notation).

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. Identify information in the National Electrical Code (NEC) and other applicable codes.
2.3.3. Apply applicable codes to installation of electrical equipment.
2.3.4. Use National Fire Protection Association (NFPA) NFPA 70E procedures to create a safety working environment.

Outcome 2.4. Electronic Components

Describe the functions and purposes of electronic components.

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 resistor compositions and their uses.
2.4.3. Identify symbols for electronic components.
2.4.4. Compare negative positive negative (NPN) and positive negative positive (PNP) bipolar junction transistors (BJT).
2.4.5. Identify types of transistors and diodes and explain their uses (e.g., 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 the purpose and function of thyristors (e.g., diacs, triacs, and varisters).
2.4.7. Describe the purpose and operation of zener diodes.
2.4.8. Describe the purpose and operation of optical interface 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 Connections

Connect individual components into an electrical circuit.

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. Describe methods of electrical connections and the purpose for each method.
2.5.3. Select type of electrical connection for electrical components.
2.5.4. Protect circuit boards from electrostatic discharge (ESD).
2.5.5. Use electrical connections to connect individual electronic units.
2.5.6. Combine components per wiring prints, schematics and block diagrams
2.5.7. Select and install terminal strip according to wiring diagram and/or schematics.

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

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 (e.g., contactors, starters, variable-frequency drive (VFD) 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 to control single speed motors and variable speed motor applications.

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. Robotic Fundamentals

Apply robotics fundamentals.

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

Design	Operations
X	X

Competencies

3.1.1. Identify the components of a robot system and explain their roles in the robot's operation cycle.
3.1.2. Maintain robot components and controllers.
3.1.3. Select type of industrial robot to meet specific applications.
3.1.4. Use job specifications to create programs for robot operations, sensors and feeder systems.
3.1.5. Plan, program and test a robot using teach pendant and simulation software.
3.1.6. Identify the robot's payload and identify the concepts of payload weight and moment of inertia to select an appropriate robot.
3.1.7. Use robot speed specifications to calculate estimated cycle times for sample tasks.
3.1.8. Direct robot to home position using absolute and incremental coordinates.
3.1.9. Compare robotic applications and processes (e.g., palletizing, vision, pick and place, welding).
3.1.10. Identify the robot's work envelope and apply the concepts of reach and articulation to evaluate whether a robot is suited to an application.
3.1.11. Analyze the performance and troubleshoot the operation of a robot.

Outcome 3.2. Robotic Operation

Plan and operate robotic production processes.

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

Design	Operations
X	X

Competencies

3.2.1. Perform controller startup and shutdown.
3.2.2. Operate a teach pendant and pendant menu.
3.2.3. Use coordinates and motion functions to execute robotic processes.
3.2.4. Identify and explain alarms, errors and recovery.
3.2.5. Select, display and run a robotic program (job).
3.2.6. Execute robotic programming including tool path commands.
3.2.7. Modify command positions (i.e., touching-up points).
3.2.8. Explain non-motion instructions (i.e., control instructions, arithmetic instructions and input/output instructions).
3.2.9. Compare robotic applications and processes (e.g., pick and place, welding).
3.2.10. Describe common end of arm tooling.
3.2.11. Select appropriate robot based on payload weight, moment and inertia.
3.2.12. Describe Cartesian space, the Right-Hand rule and how locations are represented in three-dimensional space.
3.2.13. Determine home position using absolute and incremental coordinates (e.g., fixed and floating zero).
3.2.14. Analyze the information contained in positional data.
3.2.15. Perform robot I/O analysis and manipulation.
3.2.16. Determine application suitability using work envelop, reach and articulation.

Outcome 3.3. Industrial Robotic Programming

Write, edit and test robotic programming.

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

Design	Operations
X	X

Competencies

3.3.1. Program pendant hardware.
3.3.2. Program Control Group.
3.3.3. Create, modify, and test robotic programs (e.g., second home, toolpath, non-motion commands).
3.3.4. Program macro and micro instructions, conditional statements, and arithmetic variables and instructions.
3.3.5. Program, monitor and operate universal inputs and outputs.
3.3.6. Create user frames.
3.3.7. Calibrate and modify tool control point (TCP).
3.3.8. Describe the use of subroutines.
3.3.9. Perform data manipulation (e.g., counters, data tables).
3.3.10. Describe the various file types used for import/export of 3D data.
3.3.11. Upload and download data between robotic simulation and a real robot.
3.3.12. Compare the differences between programming in robotic simulation and programming a physical robot.
3.3.13. Perform a robotic simulation to verify reach, cycle time, interference and workcell layout.

Outcome 3.4. Power Technologies

Install, maintain and troubleshoot power systems.

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

Design	Operations
X	X

Competencies

3.4.1. Calculate fluid pressure and flow and describe how it relates to the functioning of 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 electromechanical, pneumatic and hydraulic actuation.
3.4.13. Perform general maintenance on pneumatic, hydraulic and vacuum systems.
3.4.14. De-energize pneumatic, hydraulic and vacuum systems.
3.4.15. Compare types and functions of compressors.

Outcome 3.5. Pumping Systems

Install, maintain, and troubleshoot pumps and pumping systems.

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

Design	Operations
X	X

Competencies

3.5.1. Compare 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. Mechanical Drives Systems

Install, maintain, and monitor mechanical drives systems.

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

Design	Operations
X	X

Competencies

3.6.1. Compare types of gears, couplings, belts and chains and describe their uses.
3.6.2. Perform shaft alignment on rotating equipment.
3.6.3. Select bearings for specific applications.
3.6.4. Calculate or obtain speed and torque ratios for belt and chain drives per design specifications.
3.6.5. Install and align power transmissions systems.
3.6.6. Perform power transmissions systems maintenance.
3.6.7. Monitor power transmissions systems.
3.6.8. Troubleshoots for power transmission systems problems and inefficiencies.

Outcome 3.7. Programmable Logic Controllers (PLCs)

Program, install, and monitor 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

3.7.1. Describe the use of Programmable Logic Circuits (PLC) in manufacturing automation.
3.7.2. Identify programmable logic controller (PLC) hardware components.
3.7.3. Design programmable logic controller (PLC) program.
3.7.4. Develop, apply and execute a ladder logic program.
3.7.5. Perform a data transfer transaction (e.g., PLC to HMI, PLC to PLC).
3.7.6. Design a motor control program using manual and automatic modes.
3.7.7. Monitor and troubleshoot a network and hardwired system with a programmable logic controller (PLC).
3.7.8. Monitor and troubleshoot programmable logic controller (PLC) operation.
3.7.9. Install and maintain programmable logic controllers (PLCs).

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, current and voltage.
4.1.9. Describe types of transfer modes.
4.1.10. Describe the effects of wire size and type on deposition rate and current ranges.
4.1.11. Identify the characteristics of a stable arc, arc voltage and arc length.
4.1.12 Describe the relationship of current and voltage as it applies to constant voltage power sources.
4.1.13. Explain conditions when arc blow occurs and how to reduce arc blow.
4.1.14. Describe how polarity affects the arc welding process.
4.1.15. Explain the effects of high frequency when welding aluminum with the gas tungsten arc welding (GTAW) process.
4.1.16. Compare transformers, rectifiers and inverters in relation to the arc welding process.

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 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 types of welds in the six positions 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 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 Material Joining Processes

Perform types of non-arc material joining processes in the six 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 and plastics to be joined.
4.4.2. Select the types of material joining 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.
4.5.8. Describe emerging non-destructive examination process related to quality testing.

Outcome 4.6. Cutting Processes

Cut materials using cutting processes.

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

Design	Operations
	X

Competencies

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

Outcome 4.7. Fabrication

Fabricate parts and weldment using fabrication equipment and tools.

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

Design	Operations
	X

Competencies

4.7.1. Evaluate material structures and equipment and plan the method of repair.
4.7.2. Evaluate project design and identify welding type to meet the specifications to plan the method of fabrication.
4.7.3. Lay out and cut materials.
4.7.4. Shape stock through bending, cutting, drilling and filing.
4.7.5. Form and assemble material through cutting and bending.
4.7.6. Edge material through rolling turning, beading and crimping.
4.7.7. Identify various methods of fastening materials.
4.7.8. Fasten material using a range of hardware.
4.7.9. Join material using a range of adhesives.
4.7.10. Process cold metals through tapping, threading, torqueing and smoothing.
4.7.11 Compare surface coatings and apply them under appropriate environmental conditions.
4.7.12. Explain and demonstrate the process of squaring and fixturing.

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. Use process planning and improvement tools to manage the life cycle of a product.
5.1.7. Identify the potential concept and design flaws (e.g., concept model corrections, audit documentation using Design Failure Mode Effect Analysis [DFMEA]).
5.1.8. Compare design considerations for product recycling or disposal for the end of a product's life cycle.
5.1.9. Document progress and capture ideas during the development phase.

Outcome 5.2. Sketching, Drawing, and Visualization

Conceptualize, sketch, and draw design projects and components.

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

Design	Operations
X	X

Competencies

5.2.1. Compare technical sketching and drawing.
5.2.2. Sketch possible solutions to an existing design problem.
5.2.3. Apply 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 (e.g., geometric dimension and tolerancing [GD&T], run out, location, and form).
5.2.9. Select a view to graphically communicate a design solution.
5.2.10. Use reverse engineering to determine the strengths and weaknesses of a design.

Outcome 5.3. Computer-Aided Drafting and Modeling

Computer-aided Drafting and Modeling 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 to computer-aided modeling (e.g., casting, molding, forming, separating, conditioning, assembling, finishing, rapid prototyping, 3-D printing).
5.3.2. Evaluate a sketch and generate a model utilizing three-dimensional modeling.
5.3.3. Compare conceptual, physical and mathematical design models used to check design.
5.3.4. Perform part manipulation during the creation of an assembly model.
5.3.5. Analyze assembly constraints and successfully construct an assembly drawing.
5.3.6. Use 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, drawings, 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.
5.3.13. Create and interpret auxiliary views, orthographic projections, isometric drawings, oblique drawings, and perspective drawings.
5.3.14. Create a sectional view drawing.
5.3.15. Illustrate the types of breaks and symbols used in drawing sectional views.
5.3.16. Produce a reverse-engineered drawing from a solid object.
5.3.17. Add technical elements (e.g., parts lists, titles, finishes, tolerances, specifications, hidden surfaces) to drawings.
5.3.18. Apply tolerancing techniques and dimensioning to the computer aided design process.

Outcome 5.4. Materials

Select materials for design projects and components.

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

Design	Operations
X	X

Competencies

5.4.1. Compare advantages of materials used in manufacturing based on physical properties.
5.4.2. Identify the production processes used to create materials.
5.4.3. Determine the production processes used to create products from categories of materials (e.g., organic materials, metals, polymers, ceramics and composites).
5.4.4. Evaluate the types and magnitude of stresses and forces.
5.4.5. Analyze material properties by destructive and nondestructive tests.
5.4.6. Select materials for a given application based on specified criteria (e.g., cost, availability, manufacturability).
5.4.7. Analyze the strength of a design using simulation modeling software (e.g., finite element analysis).
5.4.8. Use a material and develop a product.

Outcome 5.5. Production and Process Design

Identify and evaluate production and process design.

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

Design	Operations
X	X

Competencies

5.5.1. Plan and apply manufacturing processes (e.g., casting, molding, forming, separating, conditioning, assembling, finishing, rapid prototyping, 3-D printing).
5.5.2. Use process planning and improvement tools (e.g., flowcharts, diagrams, design for manufacturability [DFM]).
5.5.3. Identify the planning and process procedures for production (e.g., corrective preventive actions, audit documentation, Process Failure Mode Effect Analysis [PFMEA]).
5.5.4. Determine critical characteristics and establish quality controls.
5.5.5. Employ project scheduling techniques (e.g., critical path methodology [CPM], project evaluation and review technique [PERT]).
5.5.6. Identify criteria and constraints and determine how those will affect the design of the production process.
5.5.7. Estimate time, tooling, product packaging and material costs.
5.5.8. Monitor performance and compare to time, tool and material cost estimates.
5.5.9. Set capacity to account for fluctuation in demand.
5.5.10. Adjust the plan as necessary to respond to variations (e.g., process, demand, material).
5.5.11. Evaluate final solutions and communicate observations, processes and results.
5.5.12. Develop a packaging design that prepares a product for shipping.

Outcome 5.6. Materials Handling

Perform tasks as they pertain to materials handling.

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

Design	Operations
X	X

Competencies

5.6.1. Perform material handling techniques.
5.6.2. Document and track materials (e.g., substandard and scrapped parts, materials and assemblies).
5.6.3. Document inspection results.
5.6.4. Read and interpret bills of materials and routing sheets.
5.6.5. Determine method of shipping.

Strand 6. Precision and Advanced 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. Identify information and symbols provided in drawings and specifications.
6.1.5. Measure and inspect work pieces according to product 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.
6.3.7. Identify production dies.

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, tooling, 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 and deburr 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.

Outcome 6.9. 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

6.9.1. Maintain CNC milling/turning machine components and controllers.
6.9.2. Plan a CNC production process for jobs in a machining cell.
6.9.3. 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.
6.9.4. Create a tool setup sheet.
6.9.5. Work from a process sheet and part print.
6.9.6. Set up and operate CNC milling/turning machines.
6.9.7. Monitor the operations of a machining cell and troubleshoot problems that arise.
6.9.8. Verify part quality against job specifications.

Outcome 6.10. Additive Manufacturing

Apply standard practices of additive manufacturing.

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

Design	Operations
X	X

Competencies

6.10.1. Identify and explain additive manufacturing processes, technologies, and applications.
6.10.2. Describe the steps of the additive manufacturing (e.g., pre-processing processing and post-processing).
6.10.3. Explain the costs involved in additive manufacturing.
6.10.4. Describe the advantages and disadvantages of additive manufacturing processes.
6.10.5. Identify the tooling and equipment needs for additive manufacturing.
6.10.6. Setup additive manufacturing equipment.
6.10.7. Convert CAD files to stereolithography (STL) files.
6.10.8. Describe thermal distortion in additive manufacturing.
6.10.9. Perform rapid prototyping.
6.10.10. Use additive manufacturing as a secondary process.
6.10.11. Describe additive manufacturing processes (e.g., extrusion, directed energy deposition, material jetting, binger jetting, powderbed fusion).

Outcome 6.11. Quality

Apply quality processes.

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

Design	Operations
X	X

Competencies

6.11.1. Identify quality control systems (e.g., Statistical Process Control (SPC), Six Sigma, Total Quality Management (TQM), Lean Management, "Plan-Do-Check-Act" and International Organization of Standardization standards, especially ISO 9001 for manufacturers).
6.11.2. Troubleshoot manufacturing defects.
6.11.3. Tag and segregate non-conforming material.
6.11.4. Use statistical methods to ensure quality.
6.11.5. Maintain customer interaction to ensure quality.

Strand 7. Industrial Maintenance and Safety

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 accidents, 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.
7.2.7. Create and distribute training materials.
7.2.8. Safely operate manual, electrical-powered and pneumatic tools.

Outcome 7.3. Industrial Maintenance Safety

Plan, develop and ensure industrial maintenance safety.

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

Design	Operations
X	X

Competencies

7.3.1. Safely operate machinery and equipment.
7.3.2. Follow equipment shutdown procedures.
7.3.3. Perform leak checks on equipment.
7.3.4. Report and document unsafe machinery conditions.
7.3.5. Safely operate platforms, man lifts and ladders.
7.3.6. Identify tools and equipment requiring safety certification.
7.3.7. Use environmental data systems.
7.3.8. Monitor equipment for unsafe conditions.
7.3.9. Identify the benefits of cross-training.
7.3.10. Deliver set-up and operational procedures.

Outcome 7.4. Industrial Maintenance Installation and Repair

Inspect, maintain and repair industrial equipment.

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

Design	Operations
X	X

Competencies

7.4.1. Identify installation techniques using manuals, checklists, and regulations.
7.4.2. Identify equipment alarms.
7.4.3. Maintain inspection processes and records.
7.4.4. Calibrate and adjust manufacturing equipment.
7.4.5. Inspect and correct machine malfunctions.