Massachusetts Department of Elementary & Secondary Education

Office for College, Career and Technical Education

Vocational Technical Education Framework

Manufacturing, Engineering & Technology Services Occupational Cluster

Advanced Manufacturing Technology (VMACH)

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Office for College, Career, and Technical Education
75 Pleasant Street, Malden, MA 02148-4906
781-338-3910
www.doe.mass.edu/ccte/cvte/

This document was prepared by the
Massachusetts Department of Elementary and Secondary Education
Jeffrey C. Riley, Commissioner

Massachusetts Department of Elementary and Secondary Education
75 Pleasant Street, Malden, MA 02148-4906
Phone 781-338-3000 TTY: N.E.T. Relay 800-439-2370
www.doe.mass.edu

Table of Contents

Acknowledgements

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The Department of Elementary and Secondary Education wishes to thank all the groups that contributed to the development of these standards and all the teachers, administrators, and private sector advisory committee members who provided valuable employer validation of standards.

This updated Framework reflects current business and industry standards and includes the addition of the *Hours of Instruction*, *updates to Industry Recognized Credentials, Equipment,* and the *addition of Embedded Academic Performance Examples.*

Contributors to the 2021 Advanced Manufacturing Framework (VMACH)

Advanced Manufacturing Program State-wide Steering Committee

Robert LePage, Assistant Secretary of Education, Executive Office of Education
Jennifer James, Executive Office of Labor and Workforce Development
Marina R. Zhavoronkova, Executive Office of Labor and Workforce Development
Helena Fruscio, Executive Office of Housing and Economic Development
Aneesh Sahni, Fellow, Executive Office of Education

Massachusetts Department of Elementary and Secondary Education
Judith Klimkiewicz, Special Assistant to the Commissioner
Lisa Sandler, Statewide Initiatives Coordinator
Jolanta Conway, Administrator, Adult & Community Learning Services
Derek Kalchbrenner, College & Career Readiness Program Specialist
Dave Edmonds, Educational Specialist-Safety, Health, Accessibility and Workforce Development

Massachusetts Association of Vocational Administrators (MAVA) - Project Administrators:
Kevin Farr, Executive Director, Massachusetts Association of Vocational Administrators (MAVA)
Peter Dewar, MAVA Assistant Executive Director
David J. Ferreira, MAVA Communications Coordinator
Kathy Conole, MAVA Consultant
Russell Mangsen, MAVA Curriculum Specialist
Robert Lussier, Executive Director, MA Vocational Technical Teacher Testing Program

Superintendents Consulted
James J. Brosnan, Superintendent, Northern Berkshire Vocational Regional School District
Lou Lopes, Superintendent, Southeastern Regional Technical School District

Industry Recognized Credentials
Mary Ellen MacLeod – Tri-County Regional Vocational Technical High School
Valerie Wlodyka – Pathfinder Regional Technical High School

Embedded Academics
Heidi Driscoll, Director of Academic Curriculum, Instruction, and Assessment, Southeastern RVTHS

Contributors to the 2021 Advanced Manufacturing Framework (VMACH)
Strands 2 and 3:

Subject Matter Experts:

John Allard, Assabet Valley Regional Vocational Technical School
Tony Bazzinotti, Shawsheen Valley Technical High School
Scott Botto, McCann Technical School District
Thomas Canastra, Greater New Bedford Regional Vocational Technical School
Kurt Chouinard, Diman Regional Vocational Technical School
Keith Gilman, Pathfinder Regional Vocational Technical High School
Brian Fillion, Nashoba Valley Technical High School
Michael Leone, Essex Agricultural and Technical High School
Paul Moskevitz, Whittier Regional Vocational Technical School District
Matthew Niedzielski, Smith Vocational and Agricultural High School
Michael Oliveira, Diman Regional Vocational Technical School
Alex Peters, Minuteman Regional Technical Vocational School District
Michael Rose, Bristol-Plymouth Regional Technical School District
Thomas Tinney, McCann Technical School District
Chris Waterworth, Greater Lawrence Technical School District
Robert Wood, Southeastern Regional Vocational Technical School

Industry Representatives:

Paul Diamond, North Easton Machine
Christopher Leclerc, Mastercam CNC Software
Mark Lewis, East Coast Welding & Fabrication, LLC
Michael McCormick, AccuRounds
John Mulligan, UMass Lowell
Wayne Spritz, A.W. Chesterton Co.
Glenn Sundberg, UMass Lowell
Rico Traversa, VSS Inc.

Technology Support Specialist

Rebecca Buck – McCann Technical School District
Valerie Wlodyka – Pathfinder Regional Technical High School

Hours of Instruction

Hours of Instruction have been provided for each framework standard to ensure that adequate instructional time is provided for students to attain complete and comprehensive knowledge of the subject matter.

Schedule of Hours		
2.A	Fundamentals of Safety in Machine Tool Technology	80
2.B	Problem Solving	10
2.C	Machine Maintenance	10
2.D	Quality Control - Measuring/Inspection	50
2.E	Material Sciences	10
2.F	Blueprints/Detail Drawings	80
2.G	Process Planning	20
2.H	Machining Operations	50
2.I	Power Saw Processes	10
2.J	Finishing Processes	10
2.K	Grinding Processes	10
2.L	Lathe Processes	150
2.M	Milling Processes	150
2.N	Computer Aided Drafting and Design (CAD)	200
2.O	Additive Manufacturing Process	20
2.P	CNC Programming	90
2.Q	Computer Aided Manufacturing (CAM)	200
2.R	CNC Machine Set up and Operations	200
2.S	Advanced CNC Set up and Operations (A+)	40
2.T	Electrical Discharge Machining (EDM) (A+)	40
2.U	Robotics (A+)	40
	Total:	1350
	Total with Advanced Topics:	1470

Overview & Organization of Strands

The Massachusetts Department of Elementary and Secondary Education understands the necessity of maintaining current Vocational Technical Education Frameworks which ensure that vocational technical students across the Commonwealth are taught the most rigorous and relevant standards aligned to the needs of business and industry.

This Revised Framework models the same format of all Massachusetts' Vocational Technical Education Frameworks and is organized into six strands. Standardized VTE Frameworks Strands 1, 4, 5, and 6 ensure currency with industry standards.

Strand Two has been revised to include technical standards aligned to current business and industry standards, including new processes utilizing state-of-the-art equipment. The equipment necessary to deliver standards is also identified in this framework. To meet Chapter 74 vocational technical education standards, the equipment must meet industry standards.

Strand Three, Embedded Academic Knowledge and Skills, has been revised to clarify the direct connection of Core Academic Frameworks as they apply to Vocational Technical Education Frameworks.

Framework revision teams created Embedded Academic Performance Examples to provide specific learning scenarios which are typically utilized in VTE classrooms and labs to create real life learning experiences which provide students with knowledge attainment in Vocational Technical Education Frameworks and Academic Learning Standards. It is understood that most VTE learning experiences include Academic Knowledge attainment. The Performance Examples provided in this Framework are intended to provide awareness of these learning experience.

During Phase 3 of the 2021 Framework Revision Process, Strands One, Four, Five, and Six teams completed the revision of these strands. All Strand One, Four, Five and Six teams worked collaboratively with staff from the Department of Elementary and Secondary Education and the Advisors of the Massachusetts Career and Technical Student Organizations to crosswalk standards to national Career & Technical Student Organizations Curricula, as applicable. The Office for College, Career, and Technical Education contracted the MAVA Consultant Team to work closely with the office to complete all the work accomplished during the 2021 Framework Revision Project. A remarkable amount of work was accomplished through the efforts of numerous professionals who collaborated and diligently supported this work. The Office for College, Career, and Technical Education is grateful for all the support received from the field, particularly all the teachers (technical and academic), administrators, advisory committee members, business and industry representatives, the Division of Professional Licensure boards, the Massachusetts Association of Vocational Administrators, the MAVA Consultants, and the Massachusetts Vocational Association, whose contributions were tremendous.

The ***Strand Two Team*** maintained the structure the 2013 framework that includes topic headings, standards and objectives, and performance examples. The Strand Two Framework now includes Hours of Instruction, as well as identifying Basic, Essential, Advanced and Advanced (A+) skill standards that are coded B, E, A and A+.

The ***Strand Three Team*** provided embedded academics performance examples that were developed to reflect the Standards for Literacy in Content Areas, the Standards for Mathematical Practice, the High School Science & Engineering Practices, and the Digital Literacy & Computer Science Practices.

Skill Standard Levels

The 2021 Framework identifies vocational competencies in three skill levels; basic, essential and advanced. **See below for more information.**

B = Basic Standards: Fundamental Skills All Chapter 74 state-approved vocational programs are required to deliver basic standards.

E = Essential Standards: Knowledge and Skills required for industry licensure and credentials. All Chapter 74 state-approved vocational programs are required to deliver essential standards.

A = Advanced Standards: Higher-level knowledge and skills beyond essential entry level employment standards. All Chapter 74 state-approved vocational programs are required to deliver advanced standards.

A+ = Advanced Plus (A+): Denotes Advanced Standards - highest level of supplemental training

- **Advanced (A+) Skills Standards** are identified in Strand Two by a plus sign (A+). Although these standards are not required, they are provided as suggestions that districts may choose to use to increase the depth of a particular topic, or add additional topics, particularly for advanced students or for those seniors who do not participate in cooperative education. Advanced (A+) standards are identified with the use of a plus sign (A+).

It is not required that all students achieve "advanced (A+) level standards", however, all Chapter 74 state-approved programs must have the capacity to deliver all three skill levels; Basic, Essential, and Advanced.

Definitions - Equipment

Simulator – a computer or application designed to provide a realistic operation of an industry standard or control, not to include educational trainers.
Educational Trainer - equipment which is designed strictly for educational purposes. Trainers cannot be a substitute or replacement for industry standard equipment.
Industry Standard Equipment – current and relevant equipment used in the industry relating to the standard functioning and implementation of operations in the respective fields of production, not to be confused with educational trainers.
Industry Standard - a set of criteria within an industry relating to the standard functioning and carrying out of operations in their respective fields of production. It is the generally accepted requirements followed by the members of an industry.
Software - current and relevant software used in the industry relating to the standard functioning and implementation of operations in the respective fields of production.

Organization of Framework – Strand 2

The Vocational Technical Education Framework contains knowledge and skills covering all aspects of industry, reflected in six strands: Safety and Health, Technical, Embedded Academics, Employability, Management and Entrepreneurship, and Technological.

Standards and objectives are grouped under topic headings, which are displayed in bold. Each standard is followed by a performance example.

In the excerpt below, 2.R is the topic; 2.R.01 is the first standard and 2.R.01.01 through 2.R.01.06 are the objectives under that standard. Topic 2.S includes Advanced (A+) Skill Levels as defined on a previous page of this Framework.

Strand 2 includes Hours of Instruction, Equipment Needed, and Skill Levels.

2.R	**CNC Machine Set up and Operations**	
	Hours of Instruction	200
	Equipment Needed – (Must Meet Industry Standards) CNC Mills and CNC Lathes	
2.R.01	**Operate CNC and conversational machines**	**SKILL LEVEL**
2.R.01.01	Use Manual Data Input (MDI) and control panel operations including simple programming, tool changes and spindle speeds.	B, E, A
2.R.01.02	Demonstrate sequential start-up and shut-down operations.	B
2.R.01.03	Set up datum point, tool length offsets and tool geometry offsets.	B, E, A
2.R.01.04	Set cutter compensation.	B, E, A
2.R.01.05	Load programs, dry run, edit, and execute program.	B, E, A
	Performance Example: Students will demonstrate the operation of the control panel to set up, run, and edit a program for a shop designed project.	
2.S	**Advanced CNC Set up and Operations***	
	Hours of Instruction	40
	Equipment Needed – (Must Meet Industry Standards) 4 and 5 Axis Mills, Live Tooling Lathes, Probing Systems	
2.S.01	**Advanced Multiple Axis and Live Tooling**	**SKILL LEVEL**
2.S.01.01	Set up a workpiece on a CNC milling 4th axis rotary table.	A+
2.S.01.02	Set up a workpiece on a 5-axis CNC milling machine.	A+
2.S.01.03	Set up live tooling on a CNC mill/turn center.	A+
2.S.01.04	Set part origin on a CNC milling machine using a probing system.	A+
2.S.01.05	Set tool length and diameter offsets on a CNC milling machine using a table mounted tool setter.	A+
2.S.01.06	Set multi-axis offsets with a CNC lathe tool presetter.	A+
	Performance Example: Students will demonstrate the operation of the control panel to set up, run, and edit a program for a shop designed project using 4 axis, 5 axis milling as well as live tooling.	

Strand 2: Technical Knowledge and Skills

2.A	**Fundamentals of Safety in Machine Tool Technology**	
	Hours of Instruction	80
2.A.01	**Demonstrate machine tool safety**	**SKILL LEVEL**
2.A.01.01	Utilize personal protective equipment (PPE), following OSHA regulations and industry standards.	B, E
2.A.01.02	Explain and implement machine guarding.	B
	Demonstrate safe operation of equipment, following OSHA regulations and industry standards.	B
	Performance Example: Students will demonstrate safe operation of equipment, following the rules of the shop. Personal Protective Equipment (PPE) rules will be strictly adhered to. Students will pass safety tests for all equipment before they are allowed to operate said equipment.	
2.B	**Problem Solving**	
	Hours of Instruction	10
2.B.01	**Demonstrate skills in problem solving**	**SKILL LEVEL**
2.B.01.01	Identify the problem or source of the problem.	B, E, A
2.B.01.02	Predict solutions using a structured problem-solving process.	B, E, A
2.B.01.03	Apply designated strategies to remedy the given problem.	B, E, A
	Performance Example: Using appropriate shop project designs, students will identify problems in the manufacturing process. Students will solve these problems using strategies in a group setting or alone.	
2.C	**Machine Maintenance**	
	Hours of Instruction	10
2.C.01	**Manage equipment and machinery**	**SKILL LEVEL**
2.C.01.01	Identify appropriate person(s) for maintenance and repair of equipment.	B
2.C.01.02	Review and state equipment indicators to ensure that equipment is operating according to manufacturer's specifications.	A
2.C.01.03	Demonstrate ability to maintain equipment.	B, E, A
2.C.01.04	Report and maintain a written log for service and recommend process repair of equipment.	E
	Performance Example: Students will follow a preventative maintenance program developed by the instructors according to machine specifications.	
2.D	**Quality Control - Measuring/Inspection**	
	Hours of Instruction	50
	Equipment Needed – (Must Meet Industry Standards) Coordinate Measuring Machines, Profilometer, Optical Comparator, Height Gauge	
2.D.01	**Review inspection procedures**	**SKILL LEVEL**
2.D.01.01	Measure work piece with a scale within a tolerance of +/- 1/64".	B

2.D.01.02	Measure work piece outside diameter, inside diameter and depth with the precision instrument to a tolerance of +/- .001".	B
2.D.01.03	Measure work piece with a precision caliper within a tolerance of +/- .005".	B
2.D.01.04	Measure radius on a work piece**.**	B, E, A
2.D.01.05	Measure angle(s).	B, E, A
2.D.01.06	Measure location and size of a feature to a tolerance of at least +/- .001".	E, A
2.D.01.07	Identify a thread and measure outside and pitch diameter to design specifications.	E
2.D.01.08	Compare and/or measure surface finish quality of a part to print specification.	E, A
2.D.01.09	Describe clean room and climate-controlled environments and their purpose in the Manufacturing Industry.	B
	Performance Example: Students will demonstrate the ability to distinguish among the appropriate precision measuring tools according to allowable tolerances on a given design. Using appropriate measuring tools and a print with specifications, the student will measure and document all dimensions to determine if a product passes inspection.	
2.E	**Material Sciences**	
	Hours of Instruction	10
2.E.01	**Describe material properties**	**SKILL LEVEL**
2.E.01.01	Identify types of metals and advanced materials. (i.e. carbon fiber, plastics, composites).	E, A
2.E.01.02	Identify properties that affect machinability.	E, A
2.E.01.03	Describe heat treatment processes: harden, temper, anneal, normalize, and case harden.	A
	Performance Example: Through research and discovery, students will identify material properties that have a direct effect on its machinability.	
2.F	**Blueprints/Detail Drawings**	
	Hours of Instruction	80
2.F.01	**Read Blueprints/Detail Drawing and create sketches**	**SKILL LEVEL**
2.F.01.01	Read and interpret detail drawings to meet American National Standards Institute (ANSI) and International Organization for Standards (ISO) standards.	B, E, A
2.F.01.02	Read and interpret assembly drawings.	B, E, A
2.F.01.03	Design and sketch a basic work piece including mathematical annotation.	B, E, A
	Performance Example: Students will build and assemble products according to detailed drawings and annotated hand sketches. This will include the interpretation of prints with geometric dimensioning and tolerancing symbols, and fitment and weldment callouts that meet ANSI and ISO specifications.	
2.G	**Process Planning**	
	Hours of Instruction	20

2.G.01	**Plan production process**	**SKILL LEVEL**
2.G.01.01	Determine and select appropriate material, size and quantity needed to complete specified product(s).	B, E, A
2.G.01.02	Formulate an order of operations, proper tooling and workholding devices.	B, E, A
2.G.01.03	Describe LEAN principles	E, A
	Performance Example: Students will research all materials and tooling needed to build a product from the curriculum. Students will design a LEAN production plan that will satisfy the steps needed to create the project from start to completion.	
2.H	**Machining Operations**	
	Hours of Instruction	50
2.H.01	**Demonstrate general machining operations**	**SKILL LEVEL**
	Drill a hole to the designated size and in the predetermined location.	B
2.H.01.02	Countersink a hole to depth and diameter specified by blueprint and/or standard.	E
2.H.01.03	Machine a hole to a specified tolerance of +/- .001".	E, A
2.H.01.04	Tap a hole to specified depth and thread size.	B, E, A
2.H.01.05	Counter bore a hole to the specified diameter and depth according to the blueprint.	E
2.H.0106	Calculate speeds and feeds for given tooling and material.	B
	Performance Example: Using shop developed projects and tasks, students will perform machining operations that are relevant to a multitude of machines.	
2.I	**Power Saw Processes**	
	Hours of Instruction	10
	Equipment Needed – (Must Meet Industry Standards) Power Saw	
2.I.01	**Operate a Power Saw**	**SKILL LEVEL**
2.I.01.01	Identify the appropriate blade and speed for specified task.	B
2.I.01.02	Cut material using power saws to specified length.	B
	Performance Example: Students will demonstrate the use of power saw equipment and cut material for the creation of shop designed projects and tasks.	
2.J	**Finishing Processes**	
	Hours of Instruction	10
2.J.01	**Demonstrate finishing operations**	**SKILL LEVEL**
2.J.01.01	Explain the selection and process of finishing techniques.	B, E, A
2.J.01.02	Deburr work piece.	B
	Performance Example: Through classroom work and shop projects, students will demonstrate the operations of finishing processes for the completion of a product.	
2.K	**Grinding Processes**	
	Hours of Instruction	10
	Equipment Needed – (Must Meet Industry Standards)	

	Surface Grinder, Bench Grinder	
2.K.01	**Operate precision grinding equipment**	**SKILL LEVEL**
2.K.01.01	Demonstrate mounting of a grinding wheel according to industry standards.	A
2.K.01.02	Demonstrate precision grinding operations.	A
2.K.02	**Off-hand Grinding**	**SKILL LEVEL**
2.K.02.01	Dress wheel, set tool rest and spark guard on pedestal grinder to proper height and clearance.	B
2.K.02.02	Explain and demonstrate the grinding of tools for specific application and use.	B
	Performance Example: Using industry standard equipment and classroom theory, students will demonstrate precision grinding operations using the tools associated with the production of square and cylindrical finished products. Through classroom work and shop projects, students will demonstrate the operations of offhand grinding for the completion of a product and sharpening of tools associated with the trade.	
2.L	**Lathe Processes**	
	Hours of Instruction	150
	Equipment Needed – (Must Meet Industry Standards) Conversational and CNC Lathes	
2.L.01	**Operate precision turning equipment**	**SKILL LEVEL**
2.L.01.01	Identify and setup work-holding devices including universal and independent chucks and collets.	B, E, A
2.L.01.02	Demonstrate outside turning procedures, including facing, grooving, turning diameters to a shoulder, and tapering to a specified tolerance.	B, E, A
2.L.01.03	Demonstrate inside turning procedures, including boring, grooving and tapering to a specified tolerance.	E, A
2.L.01.04	Demonstrate single-point threading to a specified tolerance.	E, A
2.L.01.05	Demonstrate cut-off techniques.	E, A
2.L.01.06	Machine a form into the work piece.	A
2.L.01.07	Knurl a piece to design specifications from blue print.	B
2.L.01.08	File and polish a work piece.	B, E, A
	Performance Example: Students will demonstrate skills in the turning of cylindrical and square stock through the completion of shop designed projects and tasks. Through the selection of appropriate work holding devices, students will demonstrate a working knowledge set up and fixtures needed for the completion of machining processes.	
2.M	**Milling Processes**	
	Hours of Instruction	150
	Equipment Needed – (Must Meet Industry Standards) Conversational and CNC Mills	
2.M.01	**Operate precision milling equipment**	**SKILL LEVEL**
2.M.01.01	Indicate vise within a tolerance of .0005” over a 6" span.	B, E

2.M.01.02	Tram milling head within a tolerance of .001" over a 6" diameter sweep.	E, A
2.M.01.03	Locate a datum feature using an edge finder.	B, E
2.M.01.04	Locate and indicate holes and pins.	E, A
2.M.01.05	Mill a flat surface within a specified surface finish using a variety of tooling.	B, E
2.M.01.06	Mill a variety of angles within a specified tolerance.	E, A
2.M.01.07	Square a work piece within a specified tolerance.	E
2.M.01.08	Apply climb and conventional milling strategies.	B
2.M.01.09	Mill a shoulder, slots and pockets within a specified tolerance.	B
2.M.01.10	Setup and Bore a hole to size and location within a tolerance of +/- .001".	A
2.M.01.11	Describe the operation of keys and keyways.	B
2.M.01.12	Mill keyways and keyseats to specifications.	A
	Performance Example: Students will demonstrate skills in the set up and milling of shapes and surfaces using cylindrical and square material through the completion of shop designed projects and tasks. Using industry standard locating tools, students will demonstrate a working knowledge of datums to setup and machine a finish product.	
2.N	**Computer Aided Drafting and Design (CAD)**	
	Hours of Instruction	200
	Equipment Needed – (Must Meet Industry Standards) Computers, CAD Software	
2.N.01	**Demonstrate and apply basic CAD operations using current industry standard software**	**SKILL LEVEL**
2.N.01.01	Create solid three-dimensional models.	B, E, A
2.N.01.02	Create three-dimensional assembly models.	A
2.N.01.03	Create part level design or drawing specifications.	B, E, A
2.N.01.04	Create assembly level design and drawing specifications.	A
2.N.01.05	Convert files to generic formats i.e. (.pdf, .dxf, .igs, .stp, .stl, etc.).	B
	Performance Example: Modify or create model based on requirements, record CAD data and create output file.	
2.O	**Additive Manufacturing Process**	
	Hours of Instruction	20
	Equipment Needed Additive Manufacturing Equipment	
2.O.01	**Use additive manufacturing**	**SKILL LEVEL**
2.O.01.01	Demonstrate manufacturing a part using an additive manufacturing machine.	A
	Performance Example: Students will produce an additive manufacturing part based on CAD model they have created.	
2.P	**CNC Programming**	
	Hours of Instruction	90
	Equipment Needed – (Must Meet Industry Standards) Conversational and CNC Mills/Lathes, and Respective Simulators	

2.P.01	**Demonstrate basic programming strategies at the machine control**	**SKILL LEVEL**
2.P.01.01	Define G and M codes.	B, E, A
2.P.01.02	Construct a safe and effective part program using G and M codes.	B, E, A
2.P.01.03	Construct a safe and effective part program using conversational programming strategies.	B, E, A
2.P.01.04	Transfer part program to and from a machine control.	B, E, A
	Performance Example: Using industry standard CNC equipment and classroom theory, students will demonstrate a working knowledge of a written program and the different codes that are associated within it.	
2.Q	**Computer Aided Manufacturing (CAM)**	
	Hours of Instruction	200
	Equipment Needed – (Must Meet Industry Standards) CAM Software, Computers, CNC Machines	
2.Q.01	**Demonstrate and apply the Computer Aided Manufacturing (CAM) process using industry standard software**	**SKILL LEVEL**
2.Q.01.01	Use computer aided manufacturing (CAM) software to apply machining processes to design (e.g., speeds, feeds, cutter compensation, etc.).	B, E, A
2.Q.01.02	Post process program and transfer to and from CNC machine.	B, E, A
	Performance Example: Using industry standard software, students will design and apply machining processes for the completion of shop projects and tasks. Students will demonstrate the process of posting and receiving of programs to a CNC machine to properly complete a project to shop specifications.	
2.R	**CNC Machine Set up and Operations**	
	Hours of Instruction	200
	Equipment Needed – (Must Meet Industry Standards) CNC Mills and CNC Lathes	
2.R.01	**Operate CNC and conversational machines**	**SKILL LEVEL**
2.R.01.01	Use Manual Data Input (MDI) and control panel operations including simple programming, tool changes and spindle speeds.	B, E, A
2.R.01.02	Demonstrate sequential start-up and shut-down operations.	B
2.R.01.03	Set up datum point, tool length offsets and tool geometry offsets.	B, E, A
2.R.01.04	Set cutter compensation.	B, E, A
2.R.01.05	Load programs, dry run, edit, and execute program.	B, E, A
	Performance Example: Students will demonstrate the operation of the control panel to set up, run, and edit a program for a shop designed project.	
2.S	**Advanced CNC Set up and Operations***	
	Hours of Instruction	40
	Equipment Needed – (Must Meet Industry Standards) 4 and 5 Axis Mills, Live Tooling Lathes, Probing Systems	
2.S.01	**Advanced Multiple Axis and Live Tooling**	**SKILL LEVEL**
2.S.01.01	Set up a workpiece on a CNC milling 4th axis rotary table.	A+
2.S.01.02	Set up a workpiece on a 5-axis CNC milling machine.	A+
2.S.01.03	Set up live tooling on a CNC mill/turn center.	A+

2.S.01.04	Set part origin on a CNC milling machine using a probing system.	A+
2.S.01.05	Set tool length and diameter offsets on a CNC milling machine using a table mounted tool setter.	A+
2.S.01.06	Set multi-axis offsets with a CNC lathe tool presetter.	A+
	Performance Example: Students will demonstrate the operation of the control panel to set up, run, and edit a program for a shop designed project using 4 axis, 5 axis milling as well as live tooling.	
2.T	**Electrical Discharge Machining (EDM) (A+)**	
	Hours of Instruction	40
2.T.01	**Use Electrical Discharge Machining Equipment (A+)**	**SKILL LEVEL**
2.T.01.01	Demonstrate manufacturing a part using an electrical discharge machine.	A+
	Performance Example: Students will produce a part utilizing EDM technology.	
2.U	**Robotics (A+)**	
	Hours of Instruction	40
2.U.01	**Describe how robotics are used in the manufacturing process**	**SKILL LEVEL**
2.U.01.01	Describe a Computer Integrated Manufacturing (CIM) system utilizing appropriate safety precautions. (i.e cages, light curtains).	A+
2.U.01.02	Describe automated systems engineering introductory knowledge and skills.	A+
2.U.01.03	Define an automated system and a robot.	A+
2.U.01.04	Identify individual components used in CIM systems.	A+
2.U.01.05	Describe the working relationship between the CNC equipment and the robot.	A+
2.U.01.06	Describe and identify various grippers: standard, servo, non-servo, vacuum, and magnetic (end effector).	A+
2.U.01.07	Define the following robot terms: degrees of freedom, position axes, orientation axes, work envelope, tool center point.	A+
2.U.01.08	Define and give an example of the following specifications for industrial robots: payload, repeatability, memory capacity, and environmental requirements.	A+
2.U.01.09	Describe open-loop and close-loop control systems.	A+
	Performance Example: Student will describe the integration of robotics into the manufacturing process.	

Strand 3: Embedded Academics

Embedded Academics Grades 9 –14 for Chapter 74 Vocational Technical Education Programs

Due to the thoughtful planning that went into the revisions of the English Language Arts & Literacy (2017), Mathematics (2017), Science and Technology Engineering (2016), and Digital Literacy Frameworks (2016), the current Vocational Technical Education Frameworks can move forward with a new level of embedded academics that are more content focused and more meaningful to students as they attain transferrable skills. Core content area experts carefully developed the literacy standards and academic practices in the aforementioned Massachusetts Frameworks documents which are highlighted. The Standards for Literacy in Content Areas, the Standards for Mathematical Practice, the High School Science & Engineering Practices, and the Digital Literacy & Computer Science Practices complement but do not take the place of the grade-level or course-level content standards in any of the discipline-specific Vocational Technical Education Frameworks.

Mathematics, science, technology, reading, writing, speaking, and listening skills and standards focus on understanding and practicing discipline-specific literacy, math, STE, and communication skills, using resources and characteristics of specific Vocational Technical Education programs. The philosophy of the embedded academics is not to have vocational teachers become traditional content teachers of English, science, and mathematics but is intended to reinforce the concept that it is the responsibility of all teachers to embed rich academic experiences in Vocational Technical Education. This will ensure that students recognize the transferrable skills that are essential for success in 21st century careers and in college. In rigorous Vocational Technical Education, students have hands-on and real-world experiences which develop relevant connections both from academic areas to Vocational Technical areas and vice versa.

The performance examples included in Strand Three are models developed using the portrait from the English Language Arts & Literacy (2017) of Students Who Are Ready for College, Careers, and Civic Participation. The examples illustrate how individual vocational teachers may use academic practices and literacy standards from the Massachusetts Frameworks listed above to seamlessly embed and explicitly teach relevant academics through Vocational Technical Education.

Vocational Technical Education of the past and of the 21st century naturally embed the elements of the portrait of Students Who are Ready for College, Careers, and Civic Participation through the hands-on and real-world experiences that students engage in throughout their tenure as Vocational Technical students. The following guidelines and practices that are collated in this document for easy reference are directly from the English Language Arts & Literacy (2017), Mathematics (2017), Science & Technology Engineering (2016), and Digital Literacy Frameworks (2016).

Advanced Manufacturing Performance Task 1

Students acting in the role of a machinist will create an aerospace engine component using a lathe per United Technologies specifications. After consulting the machinist handbook and OSHA Handbook, the machinist will select proper tools, material, order of operations, and gauging to create the aerospace part and clearly document in a process plan to the supervisor. Once approved, the machinist will demonstrate safe operation of equipment and strictly adhere to all Personal Protective Equipment (PPE) rules. The project consists of proper removal of material to obtain proper features and characteristics as well as dimensional specifications. Upon completion of the project, the machinist will perform a first level inspection and document the results of the inspection in the process plan.

Embedded Math:

[SMP.1]	Make sense of problems and persevere in solving them.
[SMP.4]	Model with mathematics.
[SMP.5]	Use appropriate tools strategically.
[SMP.6]	Attend to precision.

Embedded Science & Engineering:

[SEP.1]	Asking questions (for science) & defining problems (for engineering).
[SEP.3]	Planning and carrying out investigations.
[SEP.4]	Analyzing and interpreting data.
[SEP.5]	Using mathematics and computational thinking.

Embedded Reading in Science & Technical Subjects:

[RCA-ST.11-12.3]	Follow precisely a complex multi-step procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
[RCA-ST.11-12.4]	Determine the meaning of general academic vocabulary as well as symbols, notation, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to advanced manufacturing texts and topics.
[RCA-ST.11-12.10]	Independently and proficiently read and comprehend science/technical texts exhibiting complexity appropriate for the grade/course.

Embedded Writing in Content Areas:

[WCA.11-12.2d]	Use precise language, domain-specific vocabulary and techniques to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers.
[WCA.11-12.3]	In technical subjects, students must be able to write precise enough descriptions of the step-by-step procedures they use in their investigations, analyses, or technical work that others can replicate them and reach the same results

Embedded Digital Literacy:

[DLCS.4]	Analyzing
[DLCS.6]	Collaborating

Embedded Speaking & Listening in Content Areas:

[SLCA.11-12.1]	Initiate and participate effectively in a range of collaborative discussions (one-on-one, ingroups, and teacher-led) with diverse partners on discipline-specific topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

[SLCA.11-12.6] Adapt speech to a variety of contexts and tasks, demonstrating a command of formal English when indicated or appropriate.

Vocational Technical Education Standards

[AMT-2.B.01.03] Apply designated strategies to remedy the given problem.

[AMT-2.C.01.02] Review and state equipment indicators to ensure that equipment is operating according to manufacturer specifications.

[AMT-2.D.01.02] Measure work piece outside diameter, inside diameter and depth with the precision instrument to a tolerance of +/- .001.

[AMT-2.E.01.01] Identify types of metals and advanced materials. (i.e.: carbon fiber, plastics, composites).

[AMT-2.E.01.02] Identify properties that affect machinability.

[AMT-2.F.01.01] Read and interpret detail drawings to meet American National Standards Institute (ANSI) and International Organization for Standards (ISO) standards.

[AMT-2.G.01.01] Determine and select appropriate material, size and quantity needed to complete specified product(s).

[AMT-2.G.01.02] Formulate an order of operations, proper tooling and work holding devices.

[AMT-2.G.01.03] Describe LEAN principles.

[AMT-2.H.01.06] Calculate speeds and feeds for given tooling and material.

[AMT-2. L.01.01] Identify and setup work holding devices including universal and independent chucks and collets.

[AMT-2.L.01.02] Demonstrate outside turning procedures, including facing, grooving, turning diameters to a shoulder, and tapering to a specified tolerance.

Advanced Manufacturing Performance Task 2

Students acting in the role of a Computer Aided Manufacturing (CAM) programmer will devise a program for a Computer Numerical Control (CNC) mill to create a medical device per a major medical/pharmaceutical company's specifications. After consulting the ANSI and ISO Standards, the programmer will select proper tools, speeds, feeds, and order of operations to create the medical device component and clearly document in a process plan to the supervisor. The programming consists of proper removal of material to obtain proper features and characteristics as well as dimensional specifications. Upon completion of the CNC program, the programmer will verify using a simulation method to validate the program for safe operations.

Embedded Math:

[SMP.1]	Make sense of problems and persevere in solving them.
[SMP.4]	Model with mathematics.
[SMP.5]	Use appropriate tools strategically.
[SMP.6]	Attend to precision.

Embedded Science & Engineering:

[SEP.1]	Asking questions (for science) & defining problems (for engineering).
[SEP.2]	Developing and using models.
[SEP.3]	Planning and carrying out investigations.
[SEP.5]	Using mathematics and computational thinking.
[SEP.8]	Obtaining, evaluating, and communicating information.

Embedded Reading in Science & Technical Subjects:

[RCA-ST.11-12.3]	Follow precisely a complex multi-step procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
[RCA-ST.11-12.4]	Determine the meaning of general academic vocabulary as well as symbols, notation, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to advanced manufacturing texts and topics.
[RCA-ST.11-12.10]	Independently and proficiently read and comprehend science/technical texts exhibiting complexity appropriate for the grade/course.

Embedded Writing in Content Areas:

[WCA.11-12.2d]	Use precise language, domain-specific vocabulary and techniques to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers.
[WCA.11-12.2e]	Establish and maintain a style appropriate to audience and purpose (e.g., formal for academic writing) while attending to the norms and conventions of the discipline in which they are writing.
[WCA.11-12.3]	In technical subjects, students must be able to write precise enough descriptions of the step-by-step procedures they use in their investigations, analyses, or technical work that others can replicate them and (possibly) reach the same results.

Embedded Digital Literacy:

[DLCS.1]	Creating
[DLCS.4]	Analyzing
[DLCS.5]	Communicating

Embedded Speaking & Listening in Content Areas:

[SLCA.11-12.1] Initiate and participate effectively in a range of collaborative discussions (one-on-one, ingroups, and teacher-led) with diverse partners on discipline-specific topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

[SLCA.11-12.6] Adapt speech to a variety of contexts and tasks, demonstrating a command of formal English when indicated or appropriate.

Vocational Technical Education Standards:

[AMT-2.B.01.01] Identify the problem or source of the problem.

[AMT-2.E.01.02] Identify properties that affect machinability.

[AMT-2.F.01.01] Read and interpret detail drawings to meet American National Standards Institute (ANSI) and International Organization for Standards (ISO) standards.

[AMT-2.G.01.01] Determine and select appropriate material, size and quantity needed to complete specified product(s).

[AMT-2.G.01.02] Formulate an order of operations, proper tooling and work holding devices.

[AMT-2.H.01.06] Calculate speeds and feeds for given tooling and material.

[AMT-2.Q.01.01] Use computer aided manufacturing (CAM) software to apply machining processes to design (e.g., speeds, feeds, cutter compensation, etc.).

[AMT-2.Q.01.02] Post process program and transfer to and from CNC machine.

Advanced Manufacturing Performance Task 3

Students acting in the role of a Quality Control Inspector will use a variety of inspection equipment to inspect a camshaft for General Motors (GM). The inspector will ensure that customer specifications are met while performing the first piece and final inspection before the parts are approved for delivery to GM. After consulting the ANSI and ISO Standards in conjunction with GM's specifications the inspector will use a coordinate measurement machine (CMM), profilometer, height gauge, and other necessary precision measuring tools to ensure GM's specifications are achieved. The inspector will maintain proper documentation that will be provided to GM as per contract.

Embedded Math:

[SMP.1]	Make sense of problems and persevere in solving them.
[SMP.4]	Model with mathematics.
[SMP.5]	Use appropriate tools strategically.
[SMP.6]	Attend to precision.

Embedded Science & Engineering:

[SEP.1]	Asking questions (for science) & defining problems (for engineering).
[SEP.3]	Planning and carrying out investigations.
[SEP.4]	Analyzing and interpreting data.
[SEP.5]	Using mathematics and computational thinking.
[SEP.8]	Obtaining, evaluating, and communicating information.

Embedded Reading in Science & Technical Subjects:

[RCA-ST.11-12.1]	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
[RCA-ST.11-12.2]	Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
[RCA-ST.11-12.3]	Follow precisely a complex multi-step procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
[RCA-ST.11-12.4]	Determine the meaning of general academic vocabulary as well as symbols, notation, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to advanced manufacturing texts and topics.
[RCA-ST.11-12.10]	Independently and proficiently read and comprehend science/technical texts exhibiting complexity appropriate for the grade/course.

Embedded Writing in Content Areas:

[WCA.11-12.2d]	Use precise language, domain-specific vocabulary and techniques to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers.
[WCA.11-12.2e]	Establish and maintain a style appropriate to audience and purpose (e.g., formal for academic writing) while attending to the norms and conventions of the discipline in which they are writing.
[WCA.11-12.3]	In technical subjects, students must be able to write precise enough descriptions of the step-by-step procedures they use in their investigations, analyses, or technical work that others can replicate them and (possibly) reach the same results.

Embedded Digital Literacy:

[DLCS.4]	Analyzing
[DLCS.5]	Communicating
[DLCS.6]	Collaborating

Embedded Speaking & Listening in Content Areas:

[SLCA.11-12.1]	Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on discipline-specific topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
[SLCA.11-12.6]	Adapt speech to a variety of contexts and tasks, demonstrating a command of formal English when indicated or appropriate.

Vocational Technical Education Standards:

[AMT-2.D.01.02]	Measure work piece outside diameter, inside diameter and depth with the precision instrument to a tolerance of +/- .001.
[AMT-2.D.01.03]	Measure work piece with a precision caliper within a tolerance of +/- .005.
[AMT-2.D.01.04]	Measure radius on a work piece.
[AMT-2.D.01.05]	Measure angle(s).
[AMT-2.D.01.06]	Measure location and size of a feature to a tolerance of at least +/- .001.
[AMT-2.D.01.08]	Compare and/or measure surface finish quality of a part to print specification.
[AMT-2.D.01.09]	Describe clean room and climate controlled environments and their purpose in the manufacturing industry.
[AMT-2.E.01.03]	Describe heat treatment processes: harden, temper, anneal, normalize, and case harden.
[AMT-2.F.01.01]	Read and interpret detail drawings to meet American National Standards Institute (ANSI) and International Organization for Standards (ISO) standards.

Appendices

Disclaimer: Reference in the Appendices Section to any specific commercial products, processes, or services, or the use of any trade, firm or corporation name is for the information and convenience of the public and does not constitute endorsement or recommendation by the Massachusetts Department of Elementary and Secondary Education or the Massachusetts Association of Vocational Administrators.

Appendix A

Industry Recognized Credentials (IRCs)

An **Industry** R**ecognized Credential** is verification of an individual's qualification or competence. An authoritative third party issues the credential. **IRCs** are valued in the labor market and are a validation of an individual's knowledge and skill.
Industry-recognized credentials are accepted by multiple employers across an industry. They are often endorsed by recognized trade associations or organizations representing a significant part of an industry or sector.
IRCs are identified as either **"Essential"** or **"Optional"**.

Essential IRCs indicate credentials that are in high demand by employers.
School districts that offer VTE programs with **"Essential"** IRCs must ensure that adequate time and resources are available for students to be instructed in the standards necessary to be prepared for the certification examination, as well as, provide opportunities for students to obtain these certifications.

Optional IRCs provide credentials that enhance employment opportunities.

Certification Title	Essential	Optional	Hours of Instruction need to attain this Credential
OSHA General Industry – 10 Hour (OSHA G10)	X		10
MACWIC (Manufacturing Advancement Center Workforce Innovation Collaborative) Level 1 Certification		X	40
MACWIC (Manufacturing Advancement Center Workforce Innovation Collaborative) Level 2 Certification		X	40
Autodesk Inventor Certified Associate		X	50
HAAS Certification Lathe		X	
HAAS Certification Mill		X	
MASTERCAM Associate Certification		X	
Manufacturing Product specific certifications (i.e. VEX, FANUC Operator, NOTCH)		X	
National Occupational Competency Testing Institute NOCTI		X	
National Institute for Metalworking Skills (NIMS)		X	
Certified SolidWorks Associate (CSWA)		X	

DESE Statewide Articulation Agreement

ARTICULATION AGREEMENT

Between

Massachusetts Community Colleges

And

Massachusetts Chapter 74 State-Approved

for more information, click

http://www.masscc.org/partnerships-initiatives/voc-schools-articulation-agreements

Student Organizations

- SkillsUSA www.maskillsusa.org