Manufacturing Cluster Technical Knowledge and Skills
High School/College PRECISION MACHINING *Student Checklist*

2	1	N		STUDENT:	DATE:
2	**1**	**N**	**CODE**	**N = Not Exposed to Performance Element, 1 = Progressing with Performance Element, 2 = Mastery of Performance Element**	
2	**1**	**N**	**CODE**	**MACHINE SAFETY (PM.MS)**	
			PM.MS.1	*Demonstrates personal safety*	
			PM.MS.2	*Demonstrates general shop safety*	
			PM.MS.3	*Understands and practice safe operation of the machines now being used*	
			PM.MS.4	*Demonstrates knowledge of proper actions to be taken in an emergency*	
			PM.MS.5	*Knows and demonstrate an understanding of safety codes and rules used to safeguard self, other workers and the equipment and tooling*	
			PM.MS.6	*Applies good hygiene in the use of cutting fluids and/or other chemicals typically used for machining*	
			PM.MS.7	*Is able to read, understand and follow a Material Safety Data Sheet (MSDS)*	
			PM.MS.8	*Demonstrates safe work habits when performing any of the machining, bench work, material handling or measurement competencies*	
			PM.MS.9	*Uses a MSDS sheet, determine and explain the steps to be taken related to the cleanup and reporting of a chemical spill in a typical machine shop situation*	
			PM.MS.11	*Recognizes and corrects unsafe work practices*	
2	**1**	**N**	**CODE**	**MATH AND MEASUREMENTS (PM.MM)**	
			PM.MM.1	*Identifies basic metal-working tools used in measuring*	
			PM.MM.2	*Uses visual measuring tools to accuracy of 1/32 of an inch*	
			PM.MM.3	*Selects the most suitable measuring tool for the tolerance specified*	
			PM.MM.4	*Uses layout and marking tools as required*	
			PM.MM.5	*Applies basic arithmetic skills to solve problems*	
			PM.MM.6	*Applies functional algebra, geometry, trigonometry to solve problems*	
			PM.MM.7	*Uses formulas, handbook tables, charts and technical reports to solve problems or make decisions*	

			PM.MM.8	Is able to chart, interpret and explain statistical process control and inspection data
			PM.MM.9	Is able to calculate the correct amount of grind stock to be left on a part when doing roughing operations
			PM.MM.10	Calculates center offsets for taper turning and compound slide settings for angle turning
			PM.MM.11	Measures test parts to the nearest 0.001"
			PM.MM.12	Calculates CNC speeds and feeds
			PM.MM.13	Calculates programming coordinates from the drawing
			PM.MM.14	Calculates radius tangent points
			PM.MM.15	Calculates stock utilization and setup
			PM.MM.16	Calculates tolerances
			PM.MM.17	Can calculate mass properties (volume, density, etc.)
			PM.MM.18	Verifies part measurements to standards
2	1	N	CODE	**INTERPRETING DATA (PM.ID.)**
			PM.ID.1	Reads, interpret, conceptualize and be able to report (orally, handwritten note or paper document) common manufacturing processes related to precision machining and relate them to features of a part or engineering drawing of a part
			PM.ID.2	Interprets single or multiple page engineering drawings or sketches (inch or metric) to determine features to be machined
			PM.ID.3	Translates geometric tolerance symbols and other part specifications contained within feature control symbols used in machining and measurement. (ASME Y14.5-1982)
			PM.ID.4	Demonstrates knowledge and understanding of projection theory and other engineering drawing principles
			PM.ID.5	Is able to produce an appropriate freehand orthographic, oblique, isometric or perspective Sketch of a part to be machined
			PM.ID.6	Writes or letters legibly
			PM.ID.7	Enters, retrieve, update, change or analyze computer- stored data related to machining or inspection
			PM.ID.8	Is able to orally explain machining procedures and/or practices
			PM.ID.9	Scale usage is known
			PM.ID.10	Knows how to sketch
			PM.ID.11	Reads Orthographic views
			PM.ID.12	Reads Auxiliary views
			PM.ID.13	Reads Sectional views
			PM.ID.14	Can Dimension and use tolerance including geometric dimensioning and tolerances
			PM.ID.15	Reads Detail and assembly drawings
			PM.ID.16	Presentation/pictorial drawings
			PM.ID.17	Locates Materials and specifications on a print
			PM.ID.18	Uses of reference materials
			PM.ID.19	Can create or interpret Computer-generated 3-D models

			PM.ID.20	*Transfers information from drawing to CAD drawing*
			PM.ID.21	*Creates a CAD file for manufacturing*
			PM.ID.22	*Can document a manufacturing process*
			PM.ID.23	*Exports a CAD file*
			PM.ID.24	*Reads and interpret technical blue prints*
			PM.ID.25	*Understand all symbols on technical blue prints, such as geometric tolerances, surface-finish symbols, corner-break symbols, etc*
			PM.ID.26	*Documents inspection and calibration frequencies*
2	**1**	**N**	**CODE**	**PROCESS CONTROL (PM.PC.)**
			PM.PC.1	*Uses current industrial engineering drawings and work pieces, make precision measurements for specific features*
			PM.PC.2	*Demonstrate ability to select and use the proper measuring device (inch or metric) for the feature to be measured*
			PM.PC.3	*Understand and be able to explain the reason for using calibrated measuring tools*
			PM.PC.4	*Is able to make the appropriate calculations to set up the measuring device or to mathematically determine location of part features*
			PM.PC.5	*Demonstrate knowledge of and be able to select, assemble and disassemble gage black sets using the least block method*
			PM.PC.6	*Demonstrate knowledge of and ability to measure surface finishes*
			PM.PC.7	*Is able to effectively use common precision machining measuring tools (inch or metric) such as: steel rules; combination square sets, depth gages, spring calipers, outside/inside/ depth micrometers, vernier/dial/digital calipers, vernier/digital height gage, protractor, mechanical/electronic indicators, go/no-go gages; comparators; surface plates, angle plates, parallel blocks, inspection centers, sine bars/ plates, and profilometer/surface finish comparison devices*
			PM.PC.8	*Is able to physically measure for: parallelism; squareness; roundness; concentricity; axial run out; flatness; hole location/size; angles; tapers; threads; linear*
			PM.PC.9	*Knows which manufacturing processes are capable of producing specific surface finishes economically.*
			PM.PC.10	*Demonstrates knowledge of the general classes of fits*
			PM.PC.11	***Demonstrates a knowledge of statistical process control (SPC) terminology and ability to use quality***
2	**1**	**N**	**CODE**	**PHYSICAL SCIENCE (PM.PS.)**
			PM.PS.1	*Demonstrate fundamental knowledge of principles of mechanics, machines, heat, light, sound and other forms of energy in relation to cutting and work holding tooling used in both manual and CNC machining.* *Is able to read and use machinability tables to determine the effect the work piece material has on such things as cutting speed, feed rate, depth of cut, cutter selection, tool wear, surface finish, etc.*
			PM.PS.2	*Is able to describe the physical and/or metallurgical characteristics of cast irons, steels, nonferrous metals, composites, plastics and other materials that could be machined*
			PM.PS.3	*Understands and be able to discuss the effects of heat-treating and coating processes on materials used for work*

				pieces and/or cutting tools
			PM.PS.4	*Is able to explain the process by which carbide and/or ceramic cutting tool inserts are made*
2	**1**	**N**	**CODE**	**HAND TOOLS (PM.HT)**
			PM.HT.1	*Demonstrates ability to use layout hand tools (in conjunction with the measuring tool competencies listed in the next section) including coating materials, surface plates, v-blocks, scribers, dividers, trammels, keyseat rules, hermaphrodite calipers, angle plates, surface gage, and prick and center punches*
			PM.HT.2	*Is able to find the center of a square, cylindrical, rectangular work piece; layout bolt circles and hole locations; layout features to be produced*
			PM.HT.3	*Demonstrates ability to properly use hammer, screwdrivers, files, chisels, wrenches, hand taps and tap wrenches, threading dies, hand reamers, hand hack saws and blade applications, and a bench vise*
			PM.HT.4	*Knows how to deburr work pieces after machining or hand operations*
			PM.HT.5	*Is able to hand letter or number stamp parts*
2	**1**	**N**	**CODE**	**SAWS AND GRINDERS (PM.SG.)**
			PM.SG.1	*Demonstrates knowledge of power and hack sawing and band sawing processes including: machine types and applications; work holding accessories; basic setup considerations, blade/ band selection; special safety precautions*
			PM.SG.2	*Demonstrates knowledge of surface, cylindrical, centerless and internal grinding machines and their applications*
			PM.SG.3	*Has the Ability to set up and operate a manual horizontal reciprocating surface grinder*
			PM.SG.4	*Performs surface grinding operations to produce flat, parallel, stepped and angle surfaces*
			PM.SG.5	*Has the Ability to use a permanent magnet chuck (table) on a surface grinder*
			PM.SG.6	*Has Ability to determine proper infeed, work speed and crossfeed speed*
			PM.SG.7	*Has Ability to dress the wheel*
			PM.SG.8	*Demonstrates knowledge of grinding wheel characteristics, construction, standards and selection including: wheel markings, wheel shapes, proper storage for wheels and how to inspect a grinding wheel*
			PM.SG.9	*Demonstrates knowledge of cutting fluids used in grinding operations*
			PM.SG.10	*Demonstrates knowledge of superabrasive technology and applications*
			PM.SG.11	*Has the Ability to obtain and hold surface finish tolerances*
			PM.SG.12	*Has the Ability to obtain and hold close inch or metric dimensional tolerances*
			PM.SG.13	*Selects the correct machine or blade for the job to be done*
			PM.SG.14	*Mounts a blade and prepare the machine for use*
			PM.SG.15	*Identifies various types of offhand grinders*
			PM.SG.16	*Dresses and true a grinding wheel*
			PM.SG.17	*Prepares a grinder for safe operation*
			PM.SG.18	*List safety rules for using abrasives and saws*

2	1	N	CODE	MANUAL DRILLS (PM.MD.)
			PM.MD.1	*Prepares the drill including selecting proper RPM for the cutting tool being used*
			PM.MD.2	*Selects and safely mounts work-holding device*
			PM.MD.3	*Properly mounts work piece in work-holding device*
			PM.MD.4	*Selects the proper cutting tool for the job*
			PM.MD.5	*Performs drilling, countersinking, counterboring, spot-facing, reaming and tapping operations*
			PM.MD.6	*Demonstrates knowledge of drill press classifications and their applications*
			PM.MD.7	*Demonstrates knowledge of common drill press cutting tool types and applications*
			PM.MD.8	*Demonstrates knowledge of common drill press work-holding devices and their applications*
2	1	N	CODE	MANUAL LATHE (PM.ML.)
			PM.ML.1	*Is able to set up machine for single or multiple part production, which includes setting machine stops, proper speeds, feeds and depth of cuts for the material to be machined and the type of cutting tools available*
			PM.ML.2	*From the cutting tools available (could be HSS, cast alloys or carbide), select the best tool for the operation and mount properly*
			PM.ML.3	*Performs basic turning operations: work between centers, three or four-jaw chuck work, collet work, center drilling, straight turning, shoulder and end facing, chamfering, radius turning, grooving, cutting off, drilling, boring, reaming, taper and angle turning, roughing (leaving grind stock) and finishing, knurling, filing and polishing and internal and external thread chasing.*
			PM.ML.4	*Demonstrates the ability to hold inch and/or metric dimensional, geometric and surface finish tolerance requirements*
			PM.ML.5	*Is able to identify and discuss the application of other types of lathes and the advantages of each*
2	1	N	CODE	VIRTICAL MILL (PM.VM.)
			PM.VM.1	*Is able to set up machine for single or multiple part production, which includes setting machine stops, calculating proper cubic feet per minute, chip load, depth of cut, speeds and feeds for the material being machined and the type of cutters available*
			PM.VM.2	*Is able to select the proper work-holding device and set it up properly to withstand the cutting forces present*
			PM.VM.3	*Is able to make table setups, using straps and clamps, vise setups, V-block setups and indexing devices*
			PM.VM.4	*Is able to select the proper cutting tool holding device; mount it properly; determine correct direction of rotation; determine when a cutter is dull; be able to change inserts and chip breakers*
			PM.VM.5	*Performs basic milling operations that include plain, face, end, side, form, angle, grooving, keyway/keyseat and cut-off*
			PM.VM.6	*Demonstrates ability to setup and use a dividing head and/or rotary table*
			PM.VM.7	*Demonstrates the ability to tram in the machine head, milling vise or other work holding devices*
			PM.VM.8	*Demonstrates knowledge of cutter types, styles and materials*

2	1	N	CODE	CNC MILL AND LATHE (PM.CNC)
			PM.CNC 1	*Use of a PC and keyboarding skills, using offline CNC programming software, ability to program, setup and operate basic CNC machines*
			PM.CNC 2	*Writes and verifies CNC program without the use of CAM software (competitor has the opportunity to correct any program errors on the machine)b. Display complete knowledge of DIN/ISO programming (G and M codes)c. Apply the correct use of cutter compensation (G41/G42)d. Adjust speeds and feeds as needed*
			PM.CNC.3	*Setup machine and establish a zero reference point for machining the part*
			PM.CNC.4	*Selects and mount necessary tools from the provided set*
			PM.CNC.5	*Establishes tool offsets and enter them into the CNC machine control*
			PM.CNC.6	*Enters any necessary tool corrections into the CNC machine control*
			PM.CNC.7	*Creates process plan (Job Plan)*
			PM.CNC.8	*Reads-in CAD export file*
			PM.CNC.9	*Creates tool path*
			PM.CNC.10	*Creates CNC code*
			PM.CNC.11	*Sends CNC code to machine tool*
			PM.CNC.12	*Process ECO*
			PM.CNC.13	*Verifies CNC file existence*
			PM.CNC.14	*Verifies toolpath*
			PM.CNC.15	*Setup part on a mill or lathe*
			PM.CNC.16	*Demonstrates the knowledge of In-process quality assurance*
			PM.CNC.17	*Performs tool changes*
			PM.CNC.18	*Performs multiple machining operations in one setup*
			PM.CNC.19	*Verifies (TQM) process and part*
			PM.CNC.20	*Understands machine capabilities to determine proper speeds, feeds and depth of cuts for the cutting tools available and the material being machined*
			PM.CNC.21	*Knows the operational sequence required for machining linear and circular interpolation profiles*
			PM.CNC.22	*Writes a CNC program to machine a simple part using offline programming software on a personal computer*
			PM.CNC.23	*Demonstrates knowledge of types of CNC machines including machining centers; axes designations; advantages of CNC; CAD/CAM; work-holding systems; and cutting tools used with CNC machining*
			PM.CNC.24	*Knows the operational sequence required for machining cylindrical parts*
			PM.CNC.25	*Knows the use of G02 and G03 codes for arcs and contours; macro code for the incremental feed command on a fixed cycle*
			PM.CNC.26	*Verifies the CNC program using graphic verification with offline programming software on a personal computer*

2	1	N	CODE	MACHINE KNOWLEDGE (PM.MK.)
			PM.MK.1	*Be able to demonstrate an understanding of the components that boost machine performance and cut costs* *2. Selection of the best cutting tool for the material being machined* *3. Selection of proper cutting tool geometry related to horsepower of machine and the material being machined* *4. Capability of the machine to produce the tolerance required* *6. Testing for and maintaining machine geometries to manufacturer specifications* *7. Awareness of new or emerging precision machining technologies*
			PM.MK.2	*Be able to discuss the variables that could cause machining problems such as tool/work overhang, tool grade/geometry, machine condition/ power, cutting fluid, shape of work, chip breakers, material hardness, etc.*
			PM.MK.3	*Be able to discuss what chip shape and color can tell you about optimum cutting*
			PM.MK.4	*Be able to discuss the relative machinability of steels*
			PM.MK.5	*Explain a technical issue related to precision machining technology such as sequence of operations, one piece vs. production set-ups; related non-machining operations such as heat treating, deburring, material handling, etc. or*
			PM.MK.6	*Analyze a specific machining related problem and then make an oral report*
			PM.MK.7	*From photographs, identify and explain the proper use or application of precision machining technology related machinery or tooling*
			PM.MK.8	*From a list of modern precision machining technology related terms, explain the meaning of each term and discuss the current application of each term*
			PM.MK.9	*Be able to set up machine for single or multiple part production, which includes setting machine stops, calculating proper cubic feet per minute, chip load, depth of cut, speeds and feeds for the material being machined and the type of cutters available*
			PM.MK.10	*Be able to select the proper work-holding device and set it up properly to withstand the cutting forces present*
			PM.MK.11	*Be able to make table setups, using straps and clamps, vise setups, V-block setups and indexing devices*
			PM.MK.12	*Be able to select the proper cutting tool holding device; mount it properly; determine correct direction of rotation; determine when a cutter is dull; be able to change inserts and chip breakers*
			PM.MK.13	*Perform basic milling operations that include plain, face, end, side, form, angle, grooving, keyway/keyseat and cut-off*
			PM.MK.14	*Demonstrate ability to setup and use a dividing head and/or rotary table*
			PM.MK.15	*Demonstrate the ability to tram in the machine head, milling vise or other workholding devices*
			PM.MK.16	*Demonstrate knowledge of cutter types, styles and materials*

NIMS Skill Standards

Contact the National Institute For Metalworking Skills (NIMS), Duties and Standards for Machining Skills, Levels I and II. Information on how to obtain these skill standards may be obtained directly from NIMS by calling (703) 352-4971, or on the Web at *www.nimsskills. org*.