This document is a Program of Study for Machine Tool Technology/Machinist programs at the secondary level. This program of study is considered a framework, not a curriculum. From this framework educators may use this as a tool to provide structure for developing learning modules, unit plans, or daily lesson plans that meet the tasks or standards within the program of study. This program of study is based on research, experience, and many resources. The goal is to train a workforce that is skilled, knowledgeable, and able to meet the needs of the industry today and well into the future.

Machinists use machine tools, such as lathes, milling machines, and machining centers, to produce precision metal parts. Although they may produce large quantities of one part, precision machinists often produce small batches or one-of-a-kind items. They use their knowledge of the working properties of metals and their skill with machine tools to plan and carry out the operations needed to make machined products that meet precise specifications.

Machinists first review electronic or written blueprints or specifications for a job before they machine a part. Next, they calculate where to cut or bore into the workpiece – the piece of steel, aluminum, titanium, plastic, silicon or any other material that is being shaped. They determine how fast to feed the workpiece into the machine and how much material to remove. They then select tools and materials for the job, plan the sequence of cutting and finishing operations, and mark the workpiece to show where cuts should be made.

After this layout work is completed, machinists perform the necessary machining operations. They position the workpiece on the machine tool – drill press, lathe, milling machine, or other type of machine – set the controls, and make the cuts. During the machining process, they must constantly monitor the feed rate and speed of the machine. Machinists also ensure that the workpiece is properly lubricated and cooled because the machining of metal products generates a significant amount of heat. The temperature of the workpiece is a key concern because most metals expand when heated; machinists must adjust the size of their cuts relative to the temperature.

During the cutting process, machinists detect problems by listening for specific sounds – for example, that of a dull cutting tool or excessive vibration. Dull cutting tools are removed and replaced. Cutting speeds are adjusted to compensate for harmonic vibrations, which can decrease the accuracy of cuts, particularly on newer high-speed spindles and lathes. After the work is completed, machinists use both simple and highly sophisticated measuring tools to check the accuracy of their work against blueprints.

Some machinists, often called production machinists, may produce large quantities of one part, especially parts requiring the use of complex operations and great precision. Many modern machine tools are computer numerically controlled (CNC). CNC machines, following a computer program, control the cutting tool speed, change dull tools, and perform all of the necessary cuts to create a part. Frequently, machinists work with computer control programmers to determine how the automated equipment will cut a part. The machinist determines the cutting path, speed of the cut and the feed rate, and the programmer converts path, speed, and feed information into a set of instructions for the CNC machine tool.
Because most machinists train in CNC programming, they may write basic programs themselves and often modify programs in response to problems encountered during test runs. Modifications, called offsets, not only fix problems, but they also improve efficiency by reducing manufacturing time and tool wear. After the production process is designed, computer control operators implement it by performing relatively simple and repetitive operations.

Some manufacturing techniques employ automated parts loaders, automatic tool changers, and computer controls, allowing machines to operate without anyone present. One production machinist, working 8 hours a day, might monitor equipment, replace worn cutting tools, check the accuracy of parts being produced, adjust offsets, and perform other tasks on several CNC machines that operate 24 hours a day. In the off-hours, during what is known as “lights-out manufacturing,” a factory may need only a few machinists to monitor the entire factory.

Maintenance machinists repair or make new parts for existing machinery. After an industrial machinery mechanic or maintenance worker discovers the broken part of a machine, they give the broken part to the machinist. To replace broken parts, maintenance machinists refer to blueprints and perform the same machining operations that were needed to create the original part. While production machinists are concentrated in a few industries, maintenance machinists work in many manufacturing industries.

Because the technology of machining is changing rapidly, machinists must learn to operate a wide range of machines. Some newer machines use lasers, water jets, or electrified wires to cut the workpiece. While some of the computer controls are similar to other machine tools, machinists must understand the unique cutting properties of these different machines. As engineers create new types of machine tools and new materials to machine, machinists must constantly learn new machining properties and techniques.

Today, most machine shops are relatively clean, well lit, and ventilated. Many computer-controlled machines are partially or totally enclosed, minimizing the exposure of workers to noise, debris, and the lubricants used to cool workpieces during machining. Nevertheless, working around machine tools presents certain dangers, and workers must follow safety precautions. Machinists wear protective equipment, such as safety glasses to shield against bits of flying metal and earplugs to dampen machinery noise. They also must exercise caution when handling hazardous coolants and lubricants, although many common water-based lubricants present little hazard. The job requires stamina because machinists stand most of the day and, at times, may need to lift moderately heavy workpieces. Modern factories use autoloaders and overhead cranes to reduce heavy lifting.

Many machinists work a 40-hour week. Evening and weekend shifts are becoming more common as companies extend hours of operation to make better use of expensive machines. However, this trend is somewhat offset by lights-out manufacturing that uses fewer machinists and the use of machine operators for less desirable shifts. Overtime is common during peak production periods.

Machinists train in apprenticeship programs, career and technical schools, or community or technical colleges, or informally on the job. Many entrants previously have worked as machine setters, operators, or tenders.
There are many different ways to become a skilled machinist. Many entrants previously have worked as machine setters, operators, or tenders. In high school, students should take math courses, especially trigonometry, and, if available, courses in blueprint reading, metalworking, and drafting. After high school, some machinists learn entirely on the job, but most acquire their skills in a mix of classroom and on-the-job training. Formal apprenticeship programs, typically sponsored by a union or manufacturer, are an excellent way to learn the job of machinist, but are often hard to get into. Apprentices usually must have a high school diploma, GED, or the equivalent, and most have taken algebra and trigonometry classes.

Apprenticeship programs consist of paid shop training and related classroom instruction lasting up to 4 years. In shop training, apprentices work almost full time and are supervised by an experienced machinist while learning to operate various machine tools. Classroom instruction includes math, physics, materials science, blueprint reading, mechanical drawing, and quality and safety practices. In addition, as machine shops have increased their use of computer-controlled equipment, training in the operation and programming of CNC machine tools has become essential. Apprenticeship classes are often taught in cooperation with local community colleges or vocational-technical schools. A growing number of machinists are learning the trade through 2-year associate degree programs at community or technical colleges. Graduates of these programs still need significant on-the-job experience before they are fully qualified.

People interested in becoming machinists should be mechanically inclined, have good problem-solving abilities, be able to work independently, and be able to do highly accurate work (tolerances may reach 50/1,000,000ths of an inch) that requires concentration and physical effort. Experience working with machine tools is helpful. In fact, many entrants have worked as machine setters, operators, or tenders.

To boost the skill level of machinists and to create a more uniform standard of competency, a number of training facilities, State apprenticeship boards, and colleges are implementing curriculums that incorporate national skills standards developed by the National Institute of Metalworking Skills (NIMS). After completing such a curriculum and passing practical and written exams, trainees are granted a NIMS credential. Completing a recognized certification program provides a machinist with better career opportunities and helps employers better judge the abilities of new hires. Journeyworker certification can be obtained from State apprenticeship boards after completing an apprenticeship.

As new automation is introduced, machinists normally receive additional training to update their skills. This training usually is provided by a representative of the equipment manufacturer or a local technical school. Some employers offer tuition reimbursement for job-related courses.

Assumptions of This Program of Study

High-quality programs should meet the following standards:

- Promote positive working relationships
- Implement a curriculum that fosters all areas of skill development – cognitive, emotional, language, physical, and social
- Use developmentally, culturally, and linguistically appropriate and effective teaching approaches
- Provide ongoing assessments of student progress
• Employ and support qualified teaching staff
• Establish and maintain collaborative relationships with families
• Establish and maintain relationships and use resources of the community
• Provide a safe and healthy learning environment
• Implement strong program organization and supervision policies that result in high-quality teaching and learning
• Integrate academic skills and aptitudes necessary for gainful employment and promoting a foundation of lifelong learning

Academic Rigor

Research shows that career success requires the same level of college-prep courses as postsecondary success requires. The Department of Education’s focus is to ensure that every student graduates prepared for college and a career. In order to be successful in this program of study, students should follow the academic sequence as determined by Pennsylvania’s high school reform efforts.

Resources Used for This Program of Study

• MAVCC (Multistate Academic Vocational Curriculum Consortium) http://www.mavcc.org/
• NOCTI (National Occupational Competency Testing Institute http://www.nocti.org/
• O*NET http://online.onetcenter.org/
• Pennsylvania Department of Labor & Industry High Priority Occupations http://www.portal.state.pa.us/portal/server.pt/community/high_priority_occupations/12910
• VTECS (A Consortium of Innovative Career and Workforce Development Resources) http://www.vtecs.org/

CIP Code

48.0501 MACHINE TOOL TECHNOLOGY/MACHINIST

Pennsylvania CIP
An instructional program that prepares individuals to apply technical knowledge and skills in all aspects of shaping metal parts. Instruction involves making computations relating to work dimensions, tooling and feeds and speeds of machining. Emphasis is placed upon bench work and the operation of lathes, power saws, shapers, milling machines, grinders, drills and computer operated equipment (CNC and CIM). Instruction also includes the use of precision measuring instruments such as layout tools, micrometers and gauges; methods of machining and heat treatment of various metals; blueprint reading; and the layout of machine parts. Instruction prepares students to operate all types of hand and computer controlled machines.
Integrate Academic Career Education and Work Standards for Student Success

As students participate in career exploration activities and rigorous studies from elementary grades through graduation, they learn to appreciate the relationship between their classroom learning and the skills needed within the workplace. The academic and workplace skills within the Academic Standards for Career Education and Work are expected to be addressed within classrooms and achieved by all students throughout Pennsylvania. No student should leave secondary education without a solid foundation in these Standards.

http://www.portal.state.pa.us/portal/server.pt/community/state_board_of_education/8830/state_academic_standards/529102

CEW Standards Tool Kit for teachers to implement CEW Standards
www.pacareerstandards.com

Pennsylvania Approved Certifications

http://www.portal.state.pa.us/portal/server.pt/community/instructional_resources/7392/industry-recognized_certifications_for_career_and_technical_education_programs/507887

The Programs of Study Documents

- Crosswalk Template for Task Alignment (excel) – Machine Tool Technology/Machinist – Instructions: Indicate the number code(s) of your school’s program competency or competencies aligned to each program of study competency.
- Crosswalk Template for Task Alignment (pdf) – Machine Tool Technology/Machinist – Instructions: Indicate the number code(s) of your school’s program competency or competencies aligned to each program of study competency.
- Scope and Sequence Template (word) – Enter secondary technical Program of Study courses. Postsecondary courses will be determined when the Statewide Articulation Agreement for this Program of Study is complete.
- Scope and Sequence Template (pdf) – Enter secondary technical Program of Study courses. Postsecondary courses will be determined when the Statewide Articulation Agreement for this Program of Study is complete.
- PA Academic Standards/Eligible Content Alignment Task List (excel) – Machine Tool Technology/Machinist – Crosswalk of PA Academic Standards/Eligible Content for Reading, Writing, Speaking and Listening (RWSL), Math, and Science aligned to Program of Study Secondary Competency List.
- PA Academic Standards/Eligible Content Alignment Task List (pdf) – Machine Tool Technology/Machinist – Crosswalk of PA Academic Standards/Eligible Content for Reading, Writing, Speaking and Listening (RWSL), Math, and Science aligned to Program of Study Secondary Competency List.
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