Exploring Machine Tooling

Companion Lesson to X-STEM All Access Episode "Creativity, Coding & CNC Machining"

Grade/ Grade Band: Middle School	**Topic:** Engineering

Brief Lesson Description:
In this hands-on lesson, students will explore various machine tools—such as lathes, presses, 3D printers, CNC machines, and drills—and their applications in creating specialized parts. Using real-world examples and interactive activities, students will engage in the process of identifying appropriate tools for specific tasks and understanding the key functions and attributes of each machine.

Performance Expectation(s):
MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success

Specific Learning Outcomes:

Students will be able to:
- explore various types of machine tooling
- evaluate the effectiveness of different applications
- design solutions to determine the best tool for a specific task

Narrative / Background Information

Prior Student Knowledge:
1. Basic Understanding of Forces and Motion (Physics)
   a. How forces (e.g., cutting, bending, drilling) are applied to materials.
   b. The effects of rotational motion (e.g., spinning of a drill or lathe).
2. Measurement and Units (Mathematics)
   a. Familiarity with basic units of measurement (e.g., length in millimeters or inches, angles in degrees).
   b. Understanding the importance of precision and tolerances in measurements.
3. General Understanding of Tools and Machines
   a. Awareness of common tools and their purposes (e.g., hammers, screwdrivers, wrenches).
   b. A broad concept of how machines extend human capabilities (e.g., making tasks easier or faster).

Science & Engineering Practices:	**Disciplinary Core Ideas:**	**Crosscutting Concepts:**
Analyzing and Interpreting Data: Students compare attributes and applications of different machine tools to determine the best match for a specific task. Constructing Explanations and Designing Solutions: Students explain their choices for specific machines to fabricate a given part and justify how these meet the design criteria. Engaging in Argument from Evidence: Students discuss and defend their tool selection during group and class presentations, using evidence from their analyses.	ETS1.B: Developing Possible Solutions A solution needs to be tested and refined to improve its performance. Students identify and justify the best tool combinations to meet project criteria. ETS1.C: Optimizing the Design Solution Students analyze machine characteristics and integrate the best features of each tool into their solutions to optimize the production process. PS2.A: Forces and Motion Understanding how forces are applied in machine processes (e.g., cutting, drilling, bending) helps students connect physical principles to tooling applications.	Structure and Function: Students explore how the design and attributes of each machine tool (e.g., precision, motion, or force applied) determine its function and applications. Cause and Effect: Students observe how machine attributes (e.g., speed, precision) influence outcomes during simulations and decision-making. Systems and System Models: The machine shop is viewed as a system of interconnected tools, each playing a role in creating a finished product.

Possible Preconceptions/Misconceptions:
1. **Precision is not that important; close enough is good enough**. Students may underestimate the importance of exact measurements and tolerances. Addressing This: Share real-world examples where slight deviations (e.g., in aeronautics or medical devices) can cause failures.
2. **One machine can handle every step of manufacturing.** Students might think a single tool or machine can perform all the necessary steps in creating a product. Addressing This: Discuss how different tools work together in a system to achieve a finished product, like turning, drilling, and finishing processes.
3. **Modern machines don't need human input**. Some students may think CNCs, 3D printers, or other advanced tools are fully autonomous. Addressing This: Explain the role of programming, setup, and troubleshooting that humans perform to make these machines function effectively.

4. **More expensive machines are always better.** Students may assume that higher-cost machines are universally superior, regardless of the task. Addressing This: Introduce cost-benefit analysis and examples where simpler tools are more effective than costly, complex ones for specific tasks.
5. **Machine tooling is only for big industries**. Students might think machine tooling has no relevance to everyday life or smaller-scale projects. Addressing This: Share relatable applications, such as DIY projects, hobbyist uses (e.g., 3D printing), or crafting custom parts for repairs.

LESSON PLAN – 5-E Model

ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:

Purpose: Introduce the idea that different machines serve specific purposes and are necessary for creating specialized components. Get students thinking about how tools vary in function, efficiency, and appropriateness based on application.

Activity:

1. Show students a specialty part made in a machine shop (e.g., a precision gear, metal bracket, or custom-designed object). This can be a physical representation to be passed around or an image (like this one)
2. Ask the question: ***"How might you make a specialty part like this one?"***
3. Facilitate a brainstorming session where students propose tools or machines they might use to create such a part. Record their responses to revisit later.

Next, show the students the X-STEM Video "Creativity, Coding & CNC Machining." After watching the video, facilitate a brief class discussion using the following discussion questions.

Discussion Questions:

- ***What industries or products did the video mention that rely on CNC machining?***
- ***What factors might you consider when selecting a machine or tool for a specific task?***
- ***How do you think the material of the part being made influences the choice of machine?***

EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:

Purpose: Students explore the functional principles of various machines by simulating their operation.

Activity: Simulate Machine Applications Using Kitchen Tools

1. Provide small groups with kitchen tools that mimic machine operations. Examples:
    - Apple Peeler/Corer/Cutter: Simulates a lathe for rotating, shaping and cutting.
    - Manual dumpling press: Simulates a bending machine (like a press brake) for bending and shaping materials.
    - Cookie Press: Represents 3D printing for shaping parts from raw materials.
    - Corkscrew or Hand Drill: Represents a drill press for making holes.
2. Have students use these tools on soft materials like playdough or fruits (e.g., apples) and observe how each tool manipulates the material differently.
3. Record their observations and discuss which tools are best suited for specific tasks.

Discussion Questions:

- ***What kind of shapes or modifications does each tool allow you to create?***
- ***How might these kitchen tools compare to actual machine shop tools?***

EXPLAIN:

Objective: Students can obtain and evaluate information to understand the capabilities and real-world applications of various machine tools.

Activity:

1. Show a video or virtual tour of a machine shop (e.g., a YouTube video showcasing lathes, benders, 3D printers, CNC machines, and drill presses in action).
    a. Videos: Pick a video from the Practical Machinist shop tour playlist or Simple machine shop tour and an explanation
    b. Virtual tour of a machine shop: Laney Machine Shop Tour
2. As students watch the video, explore the digital resources, and/or read the informational text, have them complete the graphic organizer, writing down the machine's primary function, key features, and typical applications.
    a. Student copy of graphic organizer
    b. Teacher Key
3. Discuss how each machine works and what types of parts it is typically used to create.

Discussion Questions:

- ***What similarities and differences did you notice between machines that perform cutting tasks, like lathes, CNCs, and laser***

cutting machines?

- ***How does the material being worked on (e.g., metal, plastic, or wood) influence the choice of machine?***
- ***How do modern tools like CNCs and 3D printers differ from traditional machines like lathes and drills in terms of efficiency and accuracy?***

ELABORATE: Applications and Extensions:

Objective: Students apply their knowledge of primary functions and key features to match machines to specific manufacturing tasks and justify their choices.

Activity: Determine the Machines Needed for a Given Part

1. Provide each group with an illustration or example of a specific part (e.g., a metal bracket, threaded rod, engraved plate, or custom-shaped polymer piece).
2. Challenge students to analyze the part and determine which machines they would use to make it.
3. Encourage students to consider the order of operations (e.g., bending before drilling or 3D printing versus machining).

Discussion Questions:

- ***Why do certain attributes make a tooling type more suitable for specific applications?***
- ***How do the properties of each tool affect its effectiveness in various scenarios?***

EVALUATE:

Formative Monitoring (Questioning / Discussion):
Questions throughout the lesson in ***bold and italics*** can be used to check students' understanding throughout the lesson.

Summative Assessment (Quiz **/ Project /** Report**):**
Objective: Students demonstrate their understanding of machine tooling applications and communicate their reasoning effectively.
Presentation: Each group presents their chosen machines and explains:

1. What machines they would use to make their assigned part.
2. Why they selected each machine, considering factors such as precision, efficiency, and material requirements.

Evaluate the presentations based on accuracy, clarity of reasoning, and ability to connect machine tools to part features. Provide feedback on their reasoning and ensure alignment with real-world machine shop practices.

Elaborate Further / Reflect/ Enrichment:
Objective: Students will independently analyze engineering (technical) drawings to identify critical details and determine the tools and processes needed to manufacture the represented part.
Provide students with:

- Engineering drawings of simple parts (can include the provided NASA resource for reference and examples).
- Annotated examples of dimensions, tolerances, and different views (e.g., orthographic, isometric).
- Rulers
- Access to the NASA resource: Engineering Working Drawing Basics.
- Video Link: Understanding Engineering Drawings

Activity:
Step 1: Familiarize Yourself with Engineering Drawings

- Review the example engineering drawings, watch the video, and read the provided reference sheet.
- Pay special attention to the key elements, including:
  - Views: Orthographic, isometric, and section views.
  - Dimensions: Measurements and tolerances.
  - Line Types: Centerlines, hidden lines, and outlines.
- Answer the following reflection questions:
  - What information is included in each view?
  - Why are multiple views necessary?
  - What do tolerances tell you about the precision needed for the part?

Step 2: Analyze the Provided Drawings

- Select one drawing from the packet.
- Complete the following tasks:
  - Identify the part's key dimensions and tolerances.
  - Determine the function of the part based on its design (e.g., holding, connecting, rotating).
  - Write down which tools or machines (e.g., lathe, drill press, CNC, 3D printer) would be necessary to manufacture the part and explain why.
  - Repeat the process for at least one additional drawing.

Step 3: Create Your Engineering Drawing (Optional Challenge)

- Think of a simple part you could design, such as a small keychain, bracket, or toy piece.
- Sketch your part using basic engineering drawing conventions:

- Include at least two views (e.g., front and top).
- Label dimensions and tolerances.
- Reflect on what tools and processes would be needed to manufacture your part.

Reflection Questions- At the end of the activity, answer the following questions:

- What did you find challenging about interpreting engineering drawings?
- How do tolerances affect tool selection and precision?
- Why is it important for engineers and machinists to communicate effectively through technical drawings?
- How does understanding technical drawings help you think more critically about the manufacturing process?

CAREER CONNECTIONS:

CNC machining offers a diverse range of career opportunities, from drafting designs as a CAD/CAM specialist to crafting specialized tools as a Tool and Die Maker. This activity allows students to explore and learn about potential career paths within this field.

1. Explore Career Clusters:
   a. Visit USA Science Festival Career Resources and navigate to the Explore Opportunities by Industry section.
   b. Select the CNC Machining Industry or Machine Tooling Industry to browse career options.
2. Choose a Career:
   a. Students will select one career from the chosen industry cluster that interests them.
3. Research Your Career:
   a. Using the provided graphic organizer or a class notebook, students will gather the following information about their chosen career:
      - Job description: Typical responsibilities and duties.
      - Education and training required: Degrees, certifications, or technical training.
      - Skills and qualities needed: Key traits for success in the field.
      - Average salary: Typical earnings for the role.
      - Work environment and schedule: Typical working conditions and hours.
4. Students will select one of the following choice board activities to synthesize their research:

Career Profile Research the job description, required skills, and average salary for your chosen career. Summarize your findings in a blog entry.	**Career Path Match** Create a visual timeline or flowchart showing the education, training, and steps required to enter and advance in this career.	**Day in the Life** Write a diary entry or create a video/blog describing a typical day for someone in this career. Use research to make it realistic.

5. Share findings: Provide an opportunity for students to share their findings. This could be a class presentation, a gallery walk with posters, or a peer discussion group.

SOCIAL EMOTIONAL LEARNING ACTIVITY

Objective: Students will develop skills in resilience, adaptability, and stress management by reflecting on how they approach challenges and setbacks in any context, whether personal, academic, or social.

CASEL Competencies Addressed:

- **Self-Management**: Demonstrate resilience and the ability to manage emotions and stress.
- **Self-Awareness**: Reflect on one's own thoughts, emotions, and behaviors when facing challenges.
- **Responsible Decision-Making**: Evaluate different strategies to solve problems effectively.

Lesson Sequence:

1. **Engage Activity:** Encourage students to recognize initial emotional responses and think about resilience as a skill to overcome challenges.
   a. **Present a hypothetical scenario:** "You're working on a project, and the tool you planned to use for a key step is unavailable. How would you handle this situation?"
   b. **Facilitate a quick discussion** where students brainstorm their immediate reactions to this problem.
      - ***How does it feel when things don't go as planned?***

- ***What strategies do you already use to stay calm and figure out solutions?***

2. **Personal Reflection on Problem-Solving**
   a. Distribute a short reflection worksheet with these prompts:
      - Describe a time when you faced a challenge or unexpected problem.
      - How did you react? What emotions did you feel?
      - What helped you get through it? If you struggled, what could have helped?
      - What would you do differently if you faced a similar challenge in the future?
   b. Allow students time to write and reflect individually**.**
3. **Discussion:** Introduce the concepts of resilience, adaptability, and stress management.
   a. **Key Points to Highlight:**
      - **Resilience:** The ability to recover and move forward after setbacks.
      - **Adaptability:** Adjusting your plan when circumstances change.
      - **Stress Management:** Strategies to remain calm and focused under pressure.
   b. **Relate** these skills to problem-solving in real-world contexts, such as selecting the right machine for a part or finding alternatives when tools are unavailable.
      - ***Why is resilience important in both personal and professional challenges?***
      - ***How can staying adaptable help you solve problems more effectively?***
4. **Activity: Group Challenge—The Puzzle Problem**
   a. Divide students into small groups and give them a simple challenge, like solving a puzzle, building a structure with limited materials, or completing a task where the "rules" change midway. Examples:
      - Start building a tower with blocks, then limit the number of blocks they can use.
      - Begin a word puzzle and then introduce a time limit or change one of the rules.
   b. After the activity, **discuss** as a group:
      - ***How did your team handle the changes?***
      - ***What emotions did you feel during the activity, and how did you manage them?***
      - ***What strategies helped you adapt and keep going?***
5. **Assessment/Reflection**: As a class, reflect on the group challenge
   a. Questions:
      - ***What strategies worked well for staying calm and finding solutions?***
      - ***What could be improved for next time?***
   b. Ask students to identify one personal resilience or stress-management strategy they want to practice in future challenges. Have students share their reflections verbally or write them in a journal entry.

Materials Required for This Lesson/Activity	
Quantity	**Description**
2 per class	Apple Peeler/Corer/Cutter
2 per class	Manual dumpling press
2 per class	Cookie Press
2 per class	Cork screw or hand drill
1 per student pair	Fruit (apple) and/or small container of playdoh/dough for using the tools on
1 per student	Computer connected to the internet (for career research and video/virtual tour of machine shop)

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