High School
Computer Integrated Manufacturing
Curriculum Essentials
Document

Boulder Valley School District
Department of CTEC
May 2012
Introduction – Computer Integrated Manufacturing ™ Course

This document is intended to be a complete teaching curriculum, not just a guide or an outline. The curriculum is composed of units, which contain lessons and activities. The teacher guidelines and resource materials are integrated, via links, into the curriculum to make it easier for teachers to have access to the teaching tools needed to implement the course.

Each Unit begins with a Purpose, a listing of Concepts, Essential Questions, and Lessons for the Unit with a recommendation for Unit Evaluations. The Concepts are the broad learning objectives for the unit. The intent of the Essential Questions, in combination with the Purpose of each lesson that is an anticipatory set, is to create a framework for teachers and students to focus student learning. Course specific projects can be developed by the students to solve problems posed by the questions. The Concepts and Essential Questions along with the anticipatory set should be communicated to the students at the beginning of every Unit to establish the focus of the unit’s learning objectives.

Each Unit is composed of lessons. Included in the Lessons are the Concepts specific to each Lesson; a listing of technology, science, mathematics, and English language arts national standards; Performance Objectives aligned with the national standards; Assessment suggestions; Essential questions aligned with the Concepts; Key Terms; a Day-by-Day Lesson plan; and a listing of instructional resources to aid instruction. Each of these components is clearly discussed and described in the Lesson Template and Activities, Projects, Problems Template found in the Course Implementation Suggestions section. Each Lesson is to begin with the instructor presenting the Lesson’s Purpose and Essential Questions to the students for them to think about and to develop solutions to, by the end of the Lesson. These questions are repeated for students at the end of an activity that is designed to help students focus their thoughts, learn skills, and apply those skills to solve problems, a key tenet of project-based learning.

This curriculum is designed to be taught to high school students within a typical high school schedule. This means that a class which meets each day for 40 minutes, 175 days a year should be able to cover the content of this course. Some minor adjustments will need to be made by those schools that teach under a double block system. For the most part, this will simply entail combining two days worth of activities into one.
# Computer Integrated Manufacturing Overview

## Course Description
Manufacturing enjoys a rich history of innovation and continual improvement. The manufacturing process began with innovators making products to improve the quality of our lives. While improvement once focused on refining individual manufacturing processes, recent manufacturing has been seen as a system. Manufacturing as an enterprise focuses on improving overall safety; improving material, financial, and time efficiency; and improving customer satisfaction. The integration of hardware and software solutions is transforming worldwide manufacturing into predominantly computer integrated manufacturing. These solutions and most electronic devices in our lives are controlled by a system containing a processor, sensors, and outputs.

## Topics at a Glance
- Design for Manufacturing
- Control Systems
- History of Manufacturing
- Costs of Manufacturing
- Design for Manufacturing
- How we make things
- Product Development
- Integration of Manufacturing Elements
- Introduction to Robotic Automation
- Elements of Automation Power
- Robotic Programming and Usage

## Explanation
1. Students will explain what manufacturing is and how it has changed through history.
2. Students will explain the enterprise wheel: Why does it look as it does and how do the parts fit together?
3. Students will explain topics in manufacturing based upon the research of other students.

## Interpretation
4. Students will interpret kaizen, explain how it applies to the manufacturing process, and discuss its advantages and disadvantages.

## Application
5. Students will use the enterprise wheel to summarize activities of an organization.

## Empathy
6. Students will describe how the typical plant worker's life improved with the industrial revolution and beyond.
Prepared Graduates

The preschool through twelfth-grade concepts and skills that all students who complete the Colorado education system must master to ensure their success in a postsecondary and workforce setting.

1. CTE Essential Skills: Academic Foundations

ESSK.01: Achieve additional academic knowledge and skills required to pursue the full range of career and postsecondary education opportunities within a career cluster.

Prepared Graduate Competencies in the CTE Essential Skills standard:

- Complete required training, education, and certification to prepare for employment in a particular career field
- Demonstrate language arts, mathematics, and scientific knowledge and skills required to pursue the full range of post-secondary and career opportunities

2. CTE Essential Skills: Communications Standards

ESSK.02: Use oral and written communication skills in creating, expressing, and interrupting information and ideas, including technical terminology and information

Prepared Graduate Competencies in the CTE Essential Skills standard:

- Select and employ appropriate reading and communication strategies to learn and use technical concepts and vocabulary in practice
- Demonstrate use of concepts, strategies, and systems for obtaining and conveying ideas and information to enhance communication in the workplace

3. CTE Essential Skills: Problem Solving and Critical Thinking

ESSK.03: Solve problems using critical thinking skills (analyze, synthesize, and evaluate) independently and in teams using creativity and innovation.
Prepared Graduate Competencies in the CTE Essential Skills standard:

- Employ critical thinking skills independently and in teams to solve problems and make decisions
- Employ critical thinking and interpersonal skills to resolve conflicts with staff and/or customers
- Conduct technical research to gather information necessary for decision-making

4. CTE Essential Skills: Safety, Health, and Environmental

ESSK.06: Understand the importance of health, safety, and environmental management systems in organizations and their importance to organizational performance and regulatory compliance

Prepared Graduate Competencies in the CTE Essential Skills standard:

- Implement personal and jobsite safety rules and regulations to maintain safe and helpful working conditions and environment
- Complete work tasks in accordance with employee rights and responsibilities and employers obligations to maintain workplace safety and health

5. CTE Essential Skills: Leadership and Teamwork

ESSK.07: Use leadership and teamwork skills in collaborating with others to accomplish organizational goals and objectives

Prepared Graduate Competencies in the CTE Essential Skills standard:

- Employ leadership skills to accomplish organizational skills and objectives
6. CTE Essential Skills: Employability and Career Development

ESSK.09: Know and understand the importance of employability skills; explore, plan, and effectively manage careers; know and understand the importance of entrepreneurship skills

Prepared Graduate Competencies in the CTE Essential Skills standard:

- Identify and demonstrate positive work behaviors and personal qualities needed to be employable
- Develop skills related to seeking and applying for employment to find and obtain a desired job
COLORADO COMMUNITY COLLEGE SYSTEM CAREER & TECHNICAL EDUCATION TECHNICAL STANDARDS
REVISION & ACADEMIC ALIGNMENT PROCESS

Colorado’s 21st Century Career & Technical Education Programs have evolved beyond the historic
perception of vocational education. They are Colorado’s best kept secret for:

• Relevant & rigorous learning
• Raising achievement among all students
• Strengthening Colorado’s workforce & economy

Colorado Career & Technical Education serves more than 116,000 Colorado secondary students annually
through 1,200 programs in 160 school districts, 270 High Schools, 8 Technical Centers, 16 Community
Colleges & 3 Technical Colleges. One of every three Colorado high school students gains valuable
experiences by their enrollment in these programs.

ALIGNMENT REQUIRED BY SB 08-212

22-7-1005. Preschool through elementary and secondary education - aligned standards - adoption -
revisions.

2(b): In developing the preschool through elementary and secondary education standards, the State
Board shall also take into account any Career & Technical Education standards adopted by the State Board
for Community Colleges and Occupational Education, created in Section 23-60-104, C.R.S., and, to the
extent practicable, shall align the appropriate portions of the preschool through elementary and secondary
education standards with the Career and Technical standards.

STANDARDS REVIEW AND ALIGNMENT PROCESS

Beginning in the fall of 2008, the Colorado Community College System conducted an intensive standards
review and alignment process that involved:

NATIONAL BENCHMARK REVIEW

Colorado Career & Technical Education recently adopted the Career Cluster and Pathway Model endorsed
by the United State Department of Education, Division of Adult and Technical Education. This model
provided access to a national set of business and industry validated knowledge and skill statements for 16
of the 17 cluster areas. California and Ohio provided the comparative standards for the Energy cluster

• Based on this review Colorado CTE has moved from program-specific to Cluster & Pathway based
standards and outcomes
• In addition, we arrived at fewer, higher, clearer and more transferrable standards, expectations and
outcomes.

COLORADO CONTENT TEAMS REVIEW

The review, benchmarking and adjusting of the Colorado Cluster and Pathway standards, expectations and
outcomes was through the dedicated work of Content Teams comprised of secondary and postsecondary
faculty from across the state. Participation by instructors from each level ensured competency alignment
between secondary and postsecondary programs. These individuals also proposed the draft academic
alignments for math, science reading, writing and communication, social studies (including Personal
Financial Literacy) and post secondary and workforce readiness (PWR.)
ACADEMIC ALIGNMENT REVIEW

In order to validate the alignment of the academic standards to the Career & Technical Education standards, subject matter experts in math, science, reading, writing and communication, and social studies were partnered with career & technical educators to determine if and when a true alignment existed.

CURRENT STATUS

• One set of aligned Essential skills to drive Postsecondary and Workforce Readiness inclusion in all Career & Technical Education programs.

• 52 pathways with validated academic alignments

• 12 pathways with revised standards ready for alignment (currently there are no approved programs in these pathways)

• 21 pathways where no secondary programming currently exists. Standards and alignments will be developed as programs emerge.

• Available for review at: www.coloradostateplan.com/content_standards.htm
Unit 1 Principles of Manufacturing

Preface

Manufacturing enjoys a rich history of innovation and continual improvement. The manufacturing process began with innovators making products to improve the quality of our lives. While improvement once focused on refining individual manufacturing processes, recent manufacturing has been seen as a system. Manufacturing as an enterprise focuses on improving overall safety; improving material, financial, and time efficiency; and improving customer satisfaction. The integration of hardware and software solutions is transforming worldwide manufacturing into predominantly computer integrated manufacturing. These solutions and most electronic devices in our lives are controlled by a system containing a processor, sensors, and outputs.

In this unit students will explore the history of manufacturing and understand how the enterprise wheel graphically demonstrates the interconnectivity of manufacturing systems. Students will use control systems to simulate a factory cell while considering factors such as cost and time.

Lessons

| Lesson 1.1 History of Manufacturing | htm | doc |
| Lesson 1.2 Control Systems | htm | doc |
| Lesson 1.3 The Cost of Manufacturing | htm | doc |

Concepts

1. Manufacturing is a series of interrelated activities and operations that involve product design, planning, producing, materials control, quality assurance, management, and marketing of that product.
2. Manufacturing is essential to a healthy economy, including jobs and attainment of personal goals.
3. National manufacturing avoids health risks that are accepted in other countries.
4. Many careers are associated with the area of manufacturing.
5. Different procedures are used in the creation of products.
6. Flowcharting is a powerful graphical organizer used by technicians, computer programmers, engineers, and professionals in a variety of roles and responsibilities.
7. During the design and development process, flowcharting is used to plan and depict the process flow for an entire system and all of its subsystems.
8. Computer programmers use flowcharting symbols to graphically organize the flow of program control, including all inputs, outputs, and conditions that may occur.
9. Everyday products including cars, microwaves, ovens, hair dryers, coffee pots, and washing machines all use control systems to manage their operation.
10. When designing a control system, cost and safety are two key factors that must be considered.
11. Many factors come into play when calculating the cost of manufacturing a product.
12. Tradeoffs may be made between hiring highly skilled or experienced workers and keeping costs down.
13. The less time a part takes to make, the more potential profit is available.
14. Long term planning and investments may cost more up front but may provide additional savings in the future.

Essential Questions

Lesson 1.1 History of Manufacturing
1. What is manufacturing and why is it important to our economy?
2. What are the manufacturing procedures known as JIT, CIM, CAD, and lean manufacturing?
3. What is kaizen and how is this technique used in manufacturing?
4. What is the enterprise wheel and how does it illustrate a cohesive manufacturing procedure?

Lesson 1.2 Control Systems
1. What are the benefits of using flowcharting in manufacturing?
2. During which stage(s) of the design process is flowcharting used?
3. Outside of design, in what other areas can flowcharting methods be applied?
4. How can a control system be designed to make a transfer system function?
5. What is the difference between open and closed loop systems?
6. How is it possible to instruct a machine to interact with its surroundings and call attention if something goes wrong?

Lesson 1.3 The Cost of Manufacturing
1. How can a system’s cost be minimized without compromising quality?
2. What safety factors should be considered when developing a control system?

Unit Evaluation
The Essential Questions and Conclusion questions at the end of each activity may be used along with the Assessment suggestions provided in each lesson to develop summative assessment tools, such as tests or end of unit projects.

Lesson 1.1 History of Manufacturing
Preface

As manufacturing became increasingly important, the race to find newer and faster ways to produce products began. The computer revolutionized manufacturing, and manufacturers quickly grasped the advantages that computer-integrated manufacturing offers.

Today the computer monitors the complete enterprise. Automation has become a complete operational form. From the time the first piece of raw material enters the system to the time the finished product departs the system, it is tracked. A time versus profit tracking system has been implemented for inventory. Sometimes the stock is even tracked until it reaches the wholesaler and the retailer.

What does it take to keep such a manufacturing machine going? Most of what goes on in today’s manufacturing companies is driven by a system of computers networked to provide seamless movement from raw materials to finished product. That system is called Computer-Integrated Manufacturing (CIM). An understanding of how the CIM system works is important to the enterprise system. Without the use of computers, today’s manufacturing enterprise could not keep up with supply and demand.

As a CIM student, the ability to function in the manufacturing enterprise is dependent on a solid understanding of CIM principles. In this lesson students will study the components of a CIM enterprise system and how they work together. Students will perform research, present oral and written reports, and create a factory simulation.

Concepts

1. Manufacturing is a series of interrelated activities and operations that involve product design, planning, producing, materials control, quality assurance, management, and marketing of that product.
2. Manufacturing is essential to a healthy economy, including jobs and attainment of personal goals.
3. National manufacturing avoids health risks that are accepted in other countries.
4. Many careers are associated with the area of manufacturing.
5. Different procedures are used in the creation of products.

Standards and Benchmarks Addressed

Standards for Technological Literacy

**Standard 1:** Students will develop an understanding of the characteristics and scope of technology.

- **BM J:** The nature and development of technological knowledge and processes are functions of the setting.
- **BM K:** The rate of technological development and diffusion is increasing rapidly.
- **BM M:** Most development of technologies these days is driven by the profit motive and the market.
- **BM EE:** Management is the process of planning, organizing, and controlling work.

**Standard 4:** Students will develop an understanding of the cultural, social, economic, and political effects of technology.

- **BM H:** Changes caused by the use of technology can range from gradual to rapid and from subtle to obvious.
- **BM I:** Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.
Standard 5: Students will develop an understanding of the effects of technology on the environment.

BM G: Humans can devise technologies to conserve water, soil, and energy through such techniques as reusing, reducing, and recycling.

Standard 6: Students will develop an understanding of the role of society in the development and use of technology.

BM J: A number of different factors, such as advertising, the strength of the economy, the goals of a company, and the latest fads contribute to shaping the design of and demand for various technologies.

Standard 7: Students will develop an understanding of the influence of technology on history.

BM G: Most technological development has been evolutionary, the result of a series of refinements to a basic invention.

BM H: The evolution of civilization has been directly affected by, and has in turn affected, the development and use of tools and materials.

BM J: Early in the history of technology, the development of many tools and machines was based not on scientific knowledge but on technological know-how.

BM N: The Industrial Revolution saw the development of continuous manufacturing, sophisticated transportation and communication systems, advanced construction practices, and improved education and leisure time.

Standard 19: Students will develop an understanding of and be able to select and use manufacturing technologies.

BM O: Manufacturing systems may be classified into types, such as customized production, batch production, and continuous production. Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

BM P: The interchangeability of parts increases the effectiveness of manufacturing processes.

National Science Education Standards

Science and Technology Standard E: As a result of activities in grades 9-12, all students should develop

Understandings about science and technology

Science in Personal and Social Perspectives Standard F: As a result of activities in grades 9-12, all students should develop understanding of

Natural resources

Natural and human-induced hazards

Science and technology in local, national, and global challenges

History and Nature of Science Standard G: As a result of activities in grades 9-12, all students should develop understanding of

Science as a human endeavor

Nature of scientific knowledge

Historical perspectives

Standards for English Language Arts
**Standard 1:** Students read a wide range of print and nonprint texts to build an understanding of texts of themselves, and of the cultures of the United States and the world; to acquire new information; to respond to the needs and demands of society and the workplace; and for personal fulfillment. Among these texts are fiction and nonfiction, classical and contemporary works.

**Standard 4:** Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

**Standard 5:** Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences and for a variety of purposes.

**Standard 12:** Students use spoken, written and visual language to accomplish their own purposes (e.g. for learning, enjoyment, persuasion, and the exchange of information).

**Performance Objectives**

*It is expected that students will:*

- Explore manufacturing through research and projects.
- Understand what the enterprise wheel represents and how it represents the overall manufacturing scheme.
- Research a topic in manufacturing, develop a presentation, and present findings to a group.
- Explain the different procedures used in manufacturing.

**Assessment**

*Explanation*

1. Students will explain what manufacturing is and how it has changed through history.

2. Students will explain the enterprise wheel: Why does it look as it does and how do the parts fit together?

3. Students will explain topics in manufacturing based upon the research of other students.

*Interpretation*

4. Students will interpret kaizen, explain how it applies to the manufacturing process, and discuss its advantages and disadvantages.

*Application*

5. Students will use the enterprise wheel to summarize activities of an organization.

*Empathy*
6. Students will describe how the typical plant worker’s life improved with the industrial revolution and beyond.

**Essential Questions**

1. What is manufacturing and why is it important to our economy?
2. What are the manufacturing procedures known as JIT, CIM, CAD, and lean manufacturing?
3. What is kaizen and how is this technique used in manufacturing?
4. What is the enterprise wheel and how does it illustrate a cohesive manufacturing procedure?

**Key Terms**

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td><strong>Automated Guidance Vehicle (AGV)</strong></td>
<td>A computer-controlled system that uses pallets and other interface equipment to transport work pieces to NC machine tools and other equipment in a flexible manufacturing system.</td>
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<tr>
<td><strong>Automated Storage/Retrieval System (ASRS)</strong></td>
<td>A system that moves material either vertically or horizontally between a storage compartment and a transfer station or within a process.</td>
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<tr>
<td><strong>Automation</strong></td>
<td>The use of technology to ease human labor or extend the mental or physical capabilities of humans.</td>
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<tr>
<td><strong>Computer Aided Design (CAD)</strong></td>
<td>The use of computers in converting the initial idea for a product into a detailed engineering design.</td>
</tr>
<tr>
<td><strong>Computer Aided Manufacturing (CAM)</strong></td>
<td>The use of computers in converting engineering designs into finished products.</td>
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<tr>
<td><strong>Computer Integrated Manufacturing (CIM)</strong></td>
<td>A company-wide management philosophy for planning, integration, and implementation of automation.</td>
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<tr>
<td><strong>Dependent Variable</strong></td>
<td>A variable whose value depends on the value of another variable.</td>
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<tr>
<td><strong>Independent Variable</strong></td>
<td>The controlling factor between variables, on which the value of the other variable depends.</td>
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<tr>
<td><strong>Just in Time (JIT)</strong></td>
<td>A system that eliminates work-in-process (WIP) inventory by scheduling arrival of parts and assemblies for an operation at the time they are needed and not before.</td>
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<tr>
<td><strong>Kaizen</strong></td>
<td>Continuous improvement that involves all participants.</td>
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<tr>
<td><strong>Lean Manufacturing</strong></td>
<td>The systematic elimination of waste.</td>
</tr>
<tr>
<td><strong>Manufacturing</strong></td>
<td>A series of interrelated activities and operations that involve product design and the planning, producing, materials control, quality assurance, management, and marketing of that product.</td>
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<tr>
<td><strong>Robotics</strong></td>
<td>The science and technology of robots, their design, manufacture, and application.</td>
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<tr>
<td><strong>Six SIGMA</strong></td>
<td>Six Sigma at many organizations is a measure of quality that strives for near perfection. To achieve Six Sigma, a process must not produce more than 3.4 defects per million opportunities.</td>
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</table>
Variable

A quantity that can assume any of a set of values.

Day-by-Day Plans

Time: 8 days

NOTE: In preparation for teaching this lesson, it is strongly recommended that the teacher read the Lesson 1.1 Teacher Notes.

Day 1 – 2:

The teacher will present Concepts, Key Terms, and Essential Questions in order to provide a lesson overview.

The teacher will discuss the importance of journals and engineering notebooks and their differences.

The teacher will distribute an engineer’s notebook to each student.

Note: The teacher will determine whether students will record their notes in a daily journal, portfolio, or their engineer’s notebook. For purposes of written directions in the day-by-day for each lesson in this course, it will be assumed that students will record their notes in a journal. The journal may be a three-ring binder, spiral bound notebook, or electronic.

The teacher will distribute Sample Engineer’s Notebook Entries to each student.

The teacher will present Engineer's Notebook.ppt and discuss what constitutes acceptable and unacceptable entries.

Note: The teacher may want to present the extended version of this presentation. The extended version is located in the Instructional Resources at the end of this lesson.

The teacher will distribute Engineering Abbreviations and Symbols and Engineering Formulas then explain that these reference sheets will be used throughout the course.

The teacher will distribute Activity 1.1.1 History of Manufacturing.

The teacher will present History of Manufacturing.ppt.

Students will complete Activity 1.1.1. If necessary, the Conclusion questions may be assigned as homework.

The teacher will assess students using the Activity 1.1.1 History of Manufacturing Answer Key.

Optional: The teacher may wish to assign Key Terms 1.1 Crossword Puzzle after all key terms have been introduced.

Day 3:

The teacher will distribute Activity 1.1.2 Enterprise Wheel.

The teacher will present Enterprise Wheel.ppt.

Students will complete Activity 1.1.2 Enterprise Wheel.

The teacher may choose to distribute a copy of the Enterprise Wheel Image to students for reference throughout the course.

The teacher will assess students using the Activity 1.1.2 Enterprise Wheel Answer Key.

The teacher will distribute Project 1.1.3 Manufacturing Research and Project 1.1.3 Manufacturing Research Rubric.

Students will preview the rubric to understand how their project will be evaluated.

Students will begin Project 1.1.3 Manufacturing Research.
Day 4 – 8:

Students will complete Project 1.1.3 Manufacturing Research and present to class. The teacher will assess the students using the Project 1.1.3 Manufacturing Research Rubric.

Students will complete Lesson 1.1 Assessment. The teacher will assess students using the Lesson 1.1 Assessment Answer Key.

Instructional Resources

Presentations
- History of Manufacturing
- Enterprise Wheel
- Engineer’s Notebook

Documents
- Engineering Abbreviations and Symbols
- Engineering Formulas
- Sample Engineer’s Notebook Entries
- Activity 1.1.1 History of Manufacturing
- Activity 1.1.2 Enterprise Wheel
- Enterprise Wheel Image
- Project 1.1.3 Manufacturing Research
- Lesson 1.1 Assessment
- Key Terms 1.1 Crossword Puzzle

Answer Keys and Rubrics
- Activity 1.1.1 History of Manufacturing Answer Key
- Activity 1.1.2 Enterprise Wheel Answer Key
- Project 1.1.3 Manufacturing Research Rubric
- Lesson 1.1 Assessment Answer Key
- Key Terms 1.1 Crossword Puzzle Answer Key

Teacher Guidelines
- Lesson 1.1 Teacher Notes
- Engineer’s Notebook (extended version)
- Lesson 1.1 Assessment

Reference Sources


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for the English language arts*. Newark, DE: IRA; Urbana, IL: NCTE.


Lesson 1.2 Control Systems

Preface
In this lesson students will learn how to create a control system. Students will first look at flowcharts; they will learn the symbols and applications that can be associated with them. Students will apply this knowledge to create simple automated devices which will lead to the design of a product transfer system.

Concepts
1. Flowcharting is a powerful graphical organizer used by technicians, computer programmers, engineers, and professionals in a variety of roles and responsibilities.
2. During the design and development process, flowcharting is used to plan and depict the process flow for an entire system and all of its subsystems.
3. Computer programmers use flowcharting symbols to graphically organize the flow of program control, including all inputs, outputs, and conditions that may occur.
4. Everyday products including cars, microwaves, ovens, hair dryers, coffee pots, and washing machines all use control systems to manage their operation.

Standards and Benchmarks Addressed

Standards for Technological Literacy

**Standard 1:** Students will develop an understanding of the characteristics and scope of technology.

**BM J:** The nature and development of technological knowledge and processes are functions of the setting.

**Standard 2:** Students will develop an understanding of the core concepts of technology.

**BM W:** Systems’ thinking applies logic and creativity with appropriate compromises in complex real-life problems.

**BM Y:** The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop.
BM AA: Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

BM FF: Complex systems have many layers of controls and feedback loops to provide information.

Standard 8: Students will develop an understanding of the attributes of design.
BM J: The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

Standard 9: Students will develop an understanding of engineering design.
BM J: Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.
BM K: A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.
BM L: The process of engineering design takes into account a number of factors.

Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.
BM L: Many technological problems require a multidisciplinary approach.

Standard 11: Students will develop abilities to apply the design process.
BM R: Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

Standard 12: Students will develop the abilities to use and maintain technological products and systems.
BM L: Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.
BM M: Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.
BM N: Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.
BM O: Operate systems so that they function in the way they were designed.

Standard 13: Students will develop the abilities to assess the impact of products and systems.
BM J: Collect information and evaluate its quality.

Standard 16: Students will develop an understanding of and be able to select and use energy and power technologies.
BM N: Power systems must have a source of energy, a process, and loads.

Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.
BM M: Information and communication systems allow information to be transferred from human to human, human to machine, machine to human, and machine to machine.
BM O: Communication systems are made up of source, encoder, transmitter, receiver, decoder, storage retrieval and destination.
BM Q: Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

Standard 19: Students will develop an understanding of and be able to select and use manufacturing technologies.
BM P: The interchangeability of parts increases the effectiveness of manufacturing processes.
National Science Education Standards

Unifying Concepts and Processes: As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes.

- Systems, order, and organization
- Evidence, models, and explanation

Science and Technology Standard E: As a result of activities in grades 9-12, all students should develop

- Abilities of technological design
- Understandings about science and technology

Standards for English Language Arts

Standard 4: Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 5: Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences and for a variety of purposes.

Standard 12: Students use spoken, written and visual language to accomplish their own purposes (e.g. for learning, enjoyment, persuasion, and the exchange of information).

Performance Objectives

It is expected that students will:

- Identify basic flowcharting symbols and discuss their functions.
- Create a flowchart that portrays a manufacturing process.
- Apply flowcharting to areas other than manufacturing.
- Identify a control system and explain its application to manufacturing.
- Model and create a program to control an automated system.

Assessment

Explanation

1. Students will explain the function of a flowchart.
2. Students will discuss other areas in which flowcharting methods can be applied (e.g., business, health, education, etc.).

Application

3. Using five or more steps, students will develop a flowchart to describe a manufacturing process.
4. Using five or more steps, students will develop a flowchart to describe a computer program process.
5. Students will apply flowcharting skills to create control systems.
Self-knowledge

6. Students will create a physical model and a program to demonstrate their mastery of the concepts in activity 1.2.2a-j.

Essential Questions

1. What are the benefits of using flowcharting in manufacturing?
2. During which stage(s) of the design process is flowcharting used?
3. Outside of design, in what other areas can flowcharting methods be applied?
4. How can a control system be designed to make a transfer system function?
5. What is the difference between open and closed loop systems?
6. How is it possible to instruct a machine to interact with its surroundings and call attention if something goes wrong?

Key Terms

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<tr>
<td>Automation</td>
<td>The use of technology to ease human labor or extend the mental or physical capabilities of humans.</td>
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<tr>
<td>Closed Loop</td>
<td>A system that uses feedback from the output to control the input.</td>
</tr>
<tr>
<td>Control System</td>
<td>A system in which one or more outputs are forced to change in a desired manner as time progresses.</td>
</tr>
<tr>
<td>Decision Block</td>
<td>The diamond-shaped block used for YES/NO questions. These blocks have two outputs, 1 (for yes) and 2 (for no).</td>
</tr>
<tr>
<td>Flow Chart</td>
<td>A graphical representation of the progress of a system for the definition, analysis, or solution of a data-processing or manufacturing problem.</td>
</tr>
<tr>
<td>Flow Lines</td>
<td>The connecting line or arrow between symbols on a flow chart.</td>
</tr>
<tr>
<td>Input/Output Block</td>
<td>A function that makes information available for processing or that records processed information.</td>
</tr>
<tr>
<td>Interface</td>
<td>The connection between the computer and the control system.</td>
</tr>
<tr>
<td>Iterative</td>
<td>Process flow that may repeat or skip steps until some condition is satisfied.</td>
</tr>
<tr>
<td>Open Loop</td>
<td>A control system that has no means for comparing the output with input for control purposes. An open-loop system often requires human intervention.</td>
</tr>
<tr>
<td>Potentiometer</td>
<td>A variable resistor.</td>
</tr>
<tr>
<td>Process Block</td>
<td>Part of a flowchart that tells the program what action to take.</td>
</tr>
<tr>
<td>Schematic</td>
<td>A diagram that uses special symbols in place of actual pictures. In a wiring schematic, for example, a squiggly line is used to represent a resistor.</td>
</tr>
<tr>
<td>Sequential</td>
<td>Occurring in regular succession without gaps.</td>
</tr>
<tr>
<td>Simulation</td>
<td>A representation of a situation or problem with a similar but simpler model or a more easily manipulated model in order to determine experimental results.</td>
</tr>
</tbody>
</table>
Day-by-Day Plans

Time: 10 days

NOTE: There are two sets of resources available based on whether you are using the VEX® robotics platform or the fischertechnik® platform. Choose the appropriate resource as indicated by (VEX) or (FT) at the end of each resource.

VEX platform

Day 1-2:

NOTE: In preparation for teaching this lesson, it is strongly recommended that the teacher read the Lesson 1.2 Teacher Notes (VEX).

The teacher will present Concepts, Key Terms, and Essential Questions in order to provide a lesson overview.

The teacher will present Control Systems.ppt.

Students will take notes in their journals.

Optional: The teacher may wish to assign Key Terms 1.2 Crossword Puzzle after all key terms have been introduced.

The teacher will present Introduction to VEX Robotics Platform and ROBOTC Software (VEX) while students take notes.

The teacher will introduce the Robotics Reference Guide (VEX) to students as a general resource. It is available for download in the VEX / ROBOTC Resources page of the Virtual Academy.

The teacher will explain VEX Cortex Configuration over USB found in the Robotics Reference (VEX) document to help students connect the Cortex and communicate with the computer.

The teacher will distribute Activity 1.2.2 Inputs and Outputs (VEX) and POE Testbed Build Instructions.

In teams of two or three, students will complete Activity 1.2.2 Inputs and Outputs (VEX) while the teacher keeps students on task and answers any questions during the process.

Students will answer the Activity 1.2.2 Inputs and Outputs (VEX) conclusion questions individually for homework.

Optional: The teacher may want to distribute Lesson 1.2 Key Terms Crossword for homework once the key terms have been introduced.

Day 3:

The teacher will review and collect 1.2.2 Inputs and Outputs (VEX) from students. The teacher will evaluate student submissions with Activity 1.2.2 Inputs and Outputs Answer Key (VEX).

The teacher will present Program Design (VEX) while students take notes.

The teacher will distribute and explain Program Design resource found in the Robotics Reference document and Activity 1.2.3 Basic Outputs Programming (VEX).

Students will complete Activity 1.2.3 Basic Outputs Programming (VEX).

The teacher will keep students on task, answer any questions during the process, and provide feedback for the programs that students are asked to demonstrate.
Students will answer Activity 1.2.3 Basic Outputs Programming (VEX) conclusion questions for homework.

Day 4:

The teacher will review and collect Activity 1.2.3 Basic Outputs Programming (VEX) from students. The teacher will evaluate student submissions with Activity 1.2.3 Basic Outputs Programming Answer Key (VEX) and Activity 1.2.3 Basic Outputs Programming ROBOTC Program Answer Key (VEX).

The teacher will distribute and explain Activity 1.2.4 Basic Inputs Programming (VEX).

Students will complete Activity 1.2.4 Basic Inputs Programming (VEX).

The teacher will keep students on task, answer any questions during the process, and provide feedback for the programs that students are asked to demonstrate.

Students will answer Activity 1.2.4 Basic Inputs Programming (VEX) conclusion questions for homework.

Day 5:

The teacher will review and collect Activity 1.2.4 Basic Inputs Programming (VEX) from students. The teacher will evaluate student submissions with Activity 1.2.4 Basic Inputs Programming Answer Key (VEX) and Activity 1.2.4 Basic Inputs Programming ROBOTC Program Answer Key (VEX).

The teacher will present While and If-Else Loops (VEX) while students take notes.

The teacher will distribute and explain Activity 1.2.5 While and If-Else Loops (VEX).

Students will complete Activity 1.2.5 If Else and While Loops (VEX).

The teacher will keep students on task, answer any questions during the process, and provide feedback for the programs that students are asked to demonstrate.

Students will answer Activity 1.2.5 If Else and While Loops (VEX) conclusion questions for homework.

Day 6:

The teacher will review and collect Activity 1.2.5 If Else and While Loops (VEX). The teacher will evaluate student submissions with Activity 1.2.5 While and If-Else Loops Answer Key (VEX) and Activity 1.2.5 While and If-Else Loops ROBOTC Program Answer Key (VEX).

The teacher will present Variable and Functions (VEX) while students take notes.

The teacher will distribute and explain Activity 1.2.6 Variables and Functions (VEX).

Students will complete Activity 1.2.6 Variables and Functions (VEX).

The teacher will keep students on task, answer any questions during the process, and provide feedback for the programs that students are asked to demonstrate.

Students will answer Activity 1.2.6 Variables and Functions (VEX) conclusion questions for homework.

Day 7:

The teacher will review and collect Activity 1.2.6 Variables and Functions (VEX) from students. The teacher will evaluate student submissions with Activity 1.2.6 Variable and Functions Answer Key (VEX) and Activity 1.2.6 Variable and Functions Answer Key (VEX) ROBOTC Program.

The teacher will distribute and explain Activity 1.2.7 Open and Closed Loop Systems (VEX).
Students will complete Activity 1.2.7 Open and Closed Loop Systems (VEX) while the teacher keeps students on task, answers any questions during the process, and provides feedback for the programs that students are asked to demonstrate.

Students will answer Activity 1.2.7 Open and Closed Loop Systems (VEX) conclusion questions for homework.

**Day 8-10**

The teacher will review and collect Activity 1.2.7 Open and Closed Loop Systems (VEX) from students. The teacher will evaluate student submissions with Activity 1.2.7 Open and Closed Loop Systems Answer Key (VEX) and Activity 1.2.7 Open and Closed Loop Systems ROBOTC Program Answer Key (VEX).

Students will work on completing all unfinished activities.

**Fischertechnik® platform**

**Day 1 - 2:**

The teacher will present Concepts, Key Terms, and Essential Questions in order to provide a lesson overview.

The teacher will present Control Systems.ppt.

Students will take notes in their journals.

**Optional:** The teacher may wish to assign Key Terms 1.2 Crossword Puzzle after all key terms have been introduced.

The teacher will assess students’ knowledge level of fischertechnik usage. Utilize curriculum option A (fischertechnik proficient) when students are proficient with fischertechnik usage or option B (fischertechnik novice) activities when students have a limited understanding of fischertechnik usage. Read Lesson 1.2 Teacher Notes (FT) for details.

**Option A (fischertechnik proficient)**

- The teacher will deliver Creating Flowcharts Review (FT).
- The teacher will introduce and explain expectations for Project 1.2.1 Freight Elevator (FT), Project Report Rubric and the Written Report Template.
- Students will work in teams of two to three to document progress in their engineering notebooks.
- Students will begin work on Project 1.2.1 Freight Elevator (FT) and submit their engineering notebooks and a report using the Written Report Template.

**Option B (fischertechnik novice)**

- The teacher will distribute and explain the Activity 1.2.2a Interface Setup (FT) document to help students connect the fischertechnik interfaces and communicate with the computer.
- The teacher will distribute Activity 1.2.2 Inputs and Outputs (FT).
- In teams of two or three, students will complete Activity 1.2.2 Inputs and Outputs while the teacher keeps students on task and answers any questions during the process.
- Students will answer the Activity 1.2.2 Inputs and Outputs conclusion questions individually for homework.
Day 2:

**Option A (fischertechnik proficient):**
- Students will continue work on Project 1.2.1 Freight Elevator (FT) and submit their engineering notebooks and a report using the Written Report Template.

**Option B (fischertechnik novice):**
- The teacher will review and collect Activity 1.2.2 Inputs and Outputs from students.
- The teacher will deliver *Creating Flowcharts (FT).*
- Students will take notes during the presentation in their journals.
- The teacher will distribute and explain *Activity 1.2.3 Flowcharting (FT)* and *Activity 1.2.3a Flowcharting Guide (FT).*

Day 3:

**Option A (fischertechnik proficient):**
- Students will continue work on Project 1.2.1 Freight Elevator (FT) and submit their engineering notebooks and a report using the Written Report Template.

**Option B (fischertechnik novice):**
- Students will complete Activity 1.2.3 Flowcharting.
- The teacher will review and collect Activity 1.2.3 Flowcharting from students.
- The teacher will present *RoboPro Introduction (FT).*
- The teacher will distribute and explain *Activity 1.2.4 Basic Programming (FT).*
- Students will complete Activity 1.2.4 Basic Programming Design.
- The teacher will keep students on task, answer any questions during the process, and provide feedback for the programs that students are asked to demonstrate.
- Students will answer Activity 1.2.4 Basic Programming conclusion questions for homework.

Day 4:

**Option A (fischertechnik proficient):**
- Students will continue work on Project 1.2.1 Freight Elevator (FT) and submit their engineering notebooks and a report using the Written Report Template.

**Option B (fischertechnik novice):**
- The teacher will review and collect Activity 1.2.4 Basic Programming from students.
- The teacher will distribute and explain *Activity 1.2.5 Branch Functions (FT).*
- Students will complete Activity 1.2.5 Branch Functions.
- The teacher will keep students on task, answer any questions during the process, and provide feedback for the programs that students are asked to demonstrate.
- Students will answer Activity 1.2.5 Branch Functions conclusion questions for homework.
Day 5:

**Option A (fischertechnik proficient):**
- Students will continue work on Project 1.2.1 Freight Elevator (FT) and submit their engineering notebooks and a report using the Written Report Template.

**Option B (fischertechnik novice):**
- The teacher will review and collect Activity 1.2.5 Branch Functions
- The teacher will distribute and explain *Activity 1.2.6 Variable Functions (FT).*
- Students will complete Activity 1.2.6 Variable Functions.
- The teacher will keep students on task, answer any questions during the process, and provide feedback for the programs that students are asked to demonstrate.
- Students will answer Activity 1.2.6 Variable Functions conclusion questions for homework.

Day 6:

**Option A (fischertechnik proficient):**
- Students will continue work on Project 1.2.1 Freight Elevator (FT) and submit their engineering notebooks and a report using the Written Report Template.

**Option B (fischertechnik novice):**
- The teacher will review and collect Activity 1.2.6 Variable Functions from students.
- The teacher will distribute and explain *Activity 1.2.7 Open and Closed Loop Systems (FT).*
- Students will complete Activity 1.2.7 Open and Closed Loop Systems while the teacher keeps students on task, answers any questions during the process, and provides feedback for the programs that students are asked to demonstrate.
- Students will answer Activity 1.2.7 Open and Closed Loop Systems conclusion questions for homework.

Day 7:

**Option A (fischertechnik proficient):**
- Students will continue work on Project 1.2.1 Freight Elevator (FT) and submit their engineering notebooks and a report using the Written Report Template.

**Option B (fischertechnik novice):**
- The teacher will review and collect Activity 1.2.7 Open and Closed Loop Systems from students.
- The teacher will distribute and explain *Activity 1.2.8 Subprogram (FT).*
- Students will complete Activity 1.2.8 Subprogram while the teacher keeps students on task, answers any questions during the process, and provides feedback for the programs that students are asked to demonstrate.
- Students will answer Activity 1.2.8 Subprogram conclusion questions for homework.
Day 8 - 9:

Option A (fischertechnik proficient):
- Students will continue work on Project 1.2.1 Freight Elevator (FT) and submit their engineering notebooks and a report using the Written Report Template.

Option B (fischertechnik novice):
- The teacher will review and collect Activity 1.2.8 Subprogram from students.
- Students will work on completing all unfinished activities.

Day 10:

Option A (fischertechnik proficient)
- Students will complete work on Project 1.2.3 Freight Elevator and submit their engineering notebooks and a report using the Written Report Template.
- Students will be evaluated using Project Report Rubric and the Project 1.2.3 Freight Elevator Answer Key.

Option B (fischertechnik novice):
- Students will work on completing all unfinished activities.

Options A and B:

The teacher will distribute Lesson 1.2 Fischertechnik Programming Assessment.

Students will complete Lesson 1.2 Fischertechnik Programming Assessment.

The teacher will evaluate students using Lesson 1.2 Fischertechnik Programming Assessment Answer Key.

NOTE: There are two sets of resources available based on whether you are using the VEX robotics platform or the fischertechnik platform. Choose the appropriate resource as indicated by (VEX) or (FT) at the end of each resource.

Instructional Resources

VEX® Platform

Presentations
- Introduction to VEX Robotics Platform and ROBOTC Software (VEX)
- Program Design (VEX)
- While and If-Else Loops (VEX)
- Variable and Functions (VEX)

Documents
- Program Design (VEX)
- POE Testbed Build Instructions
- Activity 1.2.2 Inputs and Outputs (VEX)
- Activity 1.2.3 Basic Outputs Programming (VEX)
- Activity 1.2.4 Basic Inputs Programming (VEX)
- Activity 1.2.5 While and If-Else Loops (VEX)
Activity 1.2.6 Variable and Subroutines (VEX)
Activity 1.2.7 Open and Closed Loop Systems (VEX)
Lesson 1.2 Key Terms Crossword

Answer Keys and Assessment Rubrics
Activity 1.2.2 Inputs and Outputs Answer Key (VEX)
Activity 1.2.3 Basic Outputs Programming Answer Key (VEX)
Activity 1.2.3 Basic Outputs Programming ROBOTC Program Answer Key (VEX)
Activity 1.2.4 Basic Inputs Programming Answer Key (VEX)
Activity 1.2.4 Basic Inputs Programming ROBOTC Program Answer Key (VEX)
Activity 1.2.5 While and If-Else Loops Answer Key (VEX)
Activity 1.2.5 While and If-Else Loops ROBOTC Program Answer Key (VEX)
Activity 1.2.6 Variable and Functions Answer Key (VEX)
Activity 1.2.6 Variable and Functions ROBOTC Program Answer Key (VEX)
Activity 1.2.7 Open and Closed Loop Systems Answer Key (VEX)
Activity 1.2.7 Open and Closed Loop Systems ROBOTC Program Answer Key (VEX)
Lesson 1.2 Key Terms Crossword Answer Key

Teacher Guidelines
Lesson 1.2 Teacher Notes (VEX)
Troubleshooting Guide (Virtual Academy à VEX / ROBOTC Resources)
VEX Inventor’s Guide (Virtual Academy à VEX / ROBOTC Resources)
Robotics Reference (Virtual Academy à VEX / ROBOTC Resources)
POE Testbed Build Instructions (Virtual Academy ( VEX / ROBOTC Resources)
CORTEX Diagram (VEX)

fischertechnik Platform

Presentations
Control Systems
Creating Flowcharts Review (FT)
Creating Flowcharts (FT)
RoboPro Introduction (FT)

Documents
Project 1.2.1 Freight Elevator (FT)
Activity 1.2.2 Inputs and Outputs (FT)
Activity 1.2.2a Interface Setup (FT)
Activity 1.2.3 Flowcharting (FT)
Activity 1.2.3a Flowcharting Guide (FT)
Activity 1.2.4 Basic Programming (FT)
Activity 1.2.5 Branch Functions (FT)
Activity 1.2.6 Variable Functions (FT)
Activity 1.2.7 Open and Closed Loop Systems (FT)
Activity 1.2.8 Subprogram (FT)
Lesson 1.2 Key Terms Crossword
Written Report Template
Answer Keys and Rubrics
    Project 1.2.1 Freight Elevator Answer Key (FT)
    Activity 1.2.2 Inputs and Outputs Answer Key (FT)
    Activity 1.2.3 Flowcharting Answer Key (FT)
    Activity 1.2.4 Basic Programming Answer Key (FT)
    Activity 1.2.5 Branch Functions Answer Key (FT)
    Activity 1.2.6 Variable Functions Answer Key (FT)
    Activity 1.2.7 Open and Closed Loop Systems Answer Key (FT)
    Activity 1.2.8 Subprogram Answer Key (FT)
    Project Report Rubric
    Lesson 1.2 Fischertechnik Programming Assessment Answer Key
    Key Terms 1.2 Crossword Puzzle Answer Key
Teacher Guidelines
    Lesson 1.2 Teacher Notes (FT)
    Lesson 1.2 Fischertechnik Programming Assessment

Reference Sources

Lesson 1.3 The Cost of Manufacturing

Preface

Why do we choose one material over another? Why do some companies choose plastic, while other companies choose metal for the same product? Some companies do not allow their employees to work more than 40 hours a week. Why would they limit their workers in this way?

In this activity students will develop a production plan to reduce the cost of a manufacturing system. Students will combine systems and analyze the cost of the entire system compared to the individual systems.

Concepts

1. When designing a control system, cost and safety are two key factors that must be considered.
2. Many factors come into play when calculating the cost of manufacturing a product.
3. Tradeoffs may be made between hiring highly skilled or experienced workers and keeping costs down.
4. The less time a part takes to make, the more potential profit is available.
5. Long term planning and investments may cost more up front but may provide additional savings in the future.

Standards and Benchmarks Addressed

Standards for Technological Literacy

Standard 1: Students will develop an understanding of the characteristics and scope of technology.

BM M: Most development of technologies these days is driven by the profit motive and the market.

Standard 2: Students will develop an understanding of the core concepts of technology.

BM Z: Selecting resources involves tradeoffs between competing values, such as availability, cost, desirability, and waste.

BM DD: Quality control is a planned process to ensure that a product, service, or system meets established criteria.

Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.

BM I: Making decisions about the use of technology involves weighing the tradeoffs between the positive and negative effects.

Standard 5: Students will develop an understanding of the effects of technology on the environment.

BM G: Humans can devise technologies to conserve water, soil, and energy through such techniques as reusing, reducing, and recycling.

Standard 8: Students will develop an understanding of the attributes of design.

BM J: The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

BM K: The requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.
Standard 9: Students will develop an understanding of engineering design.
   BM J: Engineering design is influenced by personal characteristics, such as
   creativity, resourcefulness, and the ability to visualize and think abstractly.
   BM L: The process of engineering design takes into account a number of factors.
   Standard 11: Students will develop abilities to apply the design process.
   BM O: Refine a design by using prototypes and modeling to ensure quality,
   efficiency, and productivity of the final product.
   BM R: Evaluate final solutions and communicate observation, processes, and
   results of the entire design process, using verbal, graphic, quantitative,
   virtual, and written means, in addition to three-dimensional models.
   Standard 12: Students will develop the abilities to use and maintain technological
   products and systems.
   BM L: Document processes and procedures and communicate them to different
   audiences using appropriate oral and written techniques.
   BM M: Diagnose a system that is malfunctioning and use tools, materials,
   machines, and knowledge to repair it.
   BM N: Troubleshoot, analyze, and maintain systems to ensure safe and proper
   function and precision.
   BM O: Operate systems so that they function in the way they were designed.
   Standard 13: Students will develop the abilities to assess the impact of products and
   systems.
   BM J: Collect information and evaluate its quality.
   Standard 16: Students will develop an understanding of and be able to select and use
   energy and power technologies.
   BM N: Power systems must have a source of energy, a process, and loads.
   Standard 17: Students will develop an understanding of and be able to select and use
   information and communication technologies.
   BM M: Information and communication systems allow information to be
   transferred from human to human, human to machine, machine to human,
   and machine to machine.
   BM O: Communication systems are made up of source, encoder, transmitter,
   receiver, decoder, storage retrieval and destination.
   BM Q: Technological knowledge and processes are communicated using symbols,
   measurement, conventions, icons, graphic images, and languages that
   incorporate a variety of visual, auditory, and tactile stimuli.
   Standard 19: Students will develop an understanding of and be able to select and use
   manufacturing technologies.
   BM P: The interchangeability of parts increases the effectiveness of manufacturing
   processes.

National Science Education Standards

Science and Technology Standard E: As a result of activities in grades 9-12, all students should
   develop
   Abilities of technological design
   Understandings about science and technology

Science in Personal and Social Perspectives Standard F: As a result of activities in grades 9-
   12, all students should develop understanding of
   Natural resources
   Natural and human-induced hazards
Principles and Standards for School Mathematics

Number and Operations: Instructional programs from pre-kindergarten through grade 12 should enable all students to understand numbers, ways of representing numbers, relationships among numbers, and number systems; understand meanings of operations and how they relate to one another; compute fluently and make reasonable estimates.

Algebra: Instructional programs from pre-kindergarten through grade 12 should enable all students to use mathematical models to represent and understand quantitative relationships.

Measurement: Instructional programs from pre-kindergarten through grade 12 should enable all students to apply appropriate techniques, tools, and formulas to determine measurements.

Problem Solving: Instructional programs from pre-kindergarten through grade 12 should enable all students to build new mathematical knowledge through problem solving; solve problems that arise in mathematics and in other contexts; apply and adapt a variety of appropriate strategies to solve problems; monitor and reflect on the process of mathematical problem solving.

Communication: Instructional programs from pre-kindergarten through grade 12 should enable all students to organize and consolidate their mathematical thinking through communication; communicate their mathematical thinking coherently and clearly to peers, teachers, and others.

Connections: Instructional programs from pre-kindergarten through grade 12 should enable all students to recognize and apply mathematics in contexts outside of mathematics.

Representation: Instructional programs from pre-kindergarten through grade 12 should enable all students to create and use representations to organize, record, and communicate mathematical ideas; select, apply, and translate among mathematical representations to solve problems; use representations to model and interpret physical, social, and mathematical phenomena.

Standards for English Language Arts

Standard 4: Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 12: Students use spoken, written and visual language to accomplish their own purposes (e.g. for learning, enjoyment, persuasion, and the exchange of information).

Performance Objectives
It is expected that students will:
- Create a control system that replicates a factory cell.
- Maximize the efficiency of the manufacturing system with respect to time and cost.
- Compare the efficiency of running multiple systems against that of one large system.

Assessment

Explanation
1. Students will list three factors that affect the cost of manufacturing.
2. Students will explain how material types affect the cost of manufacturing.
Application

3. Students will maximize the efficiency of a control system as it applies to cost.
4. Students will combine many systems into a large system.

Perspective

5. Students will understand how typical automated systems in their daily lives sense the environment and react through outputs.

Essential Questions

1. How can a system’s cost be minimized without compromising quality?
2. What safety factors should be considered when developing a control system?

Key Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Costs</td>
<td>A periodic cost that remains (more or less) unchanged irrespective of the output level or sales revenue of a firm.</td>
</tr>
<tr>
<td>Non-Value Added (NVA)</td>
<td>Typically generates a zero or negative return on the investment of resources and usually can be eliminated without impairing a process.</td>
</tr>
<tr>
<td>Overhead</td>
<td>The general, fixed cost of running a business, such as rent, lighting, and heating expenses, which cannot be charged or attributed to a specific product or part of the work operation.</td>
</tr>
<tr>
<td>Profit</td>
<td>The monetary surplus left to a producer or employer after deducting wages, rent, cost of raw materials, etc.</td>
</tr>
<tr>
<td>Raw Materials</td>
<td>Basic substance in its natural, modified, or semi-processed state, used as an input to a production process for subsequent modification or transformation into a finished good.</td>
</tr>
<tr>
<td>Value-Added</td>
<td>The difference between the price at which goods are sold and the cost of the materials used to make them.</td>
</tr>
<tr>
<td>Variable Cost</td>
<td>Periodic cost that varies, more or less, in step with the output or the sales revenue of a firm. Such costs include raw material, energy usage, labor (wages), distribution costs, etc.</td>
</tr>
</tbody>
</table>

Day-by-Day Plans

Time: 14 days

NOTE: Two sets of resources are available based on whether you are using the VEX® robotics platform or the fischertechnik® platform. Choose the appropriate resource as indicated by (VEX) or (FT) at the end of each resource.

NOTE: In preparation for teaching this lesson, it is strongly recommended that the teacher read the Lesson 1.3 Teacher Notes.

Day 1 – 2:

The teacher will present Concepts, Key Terms, and Essential Questions in order to provide a lesson overview.

The teacher will distribute Activity 1.3.1 Cost Overview.
The teacher will present *Manufacturing Costs.ppt*. Students will complete Activity 1.3.1.

**Optional:** The teacher may wish to assign *Key Terms 1.3 Crossword Puzzle* after all key terms have been introduced.

**Day 3:**

**VEX® platform:**

The teacher will introduce and explain expectations for *Project 1.3.2 Transfer System (VEX)*, *Project 1.3.2 Transfer System Performance Rubric (VEX)*, *Project Report Rubric (VEX)*.

The teacher will introduce and distribute the documents to support Project 1.3.2 Transfer System, including *Project Report Template (VEX)*, *Project Sheet (VEX)*, *Project 1.3.2a Price List for Transfer System (VEX)* and *Project 1.3.2b Using the Price List (VEX)*.

**Fischertechnik® platform:**

The teacher will introduce and explain expectations for *Project 1.3.2 Transfer System (FT)*, *Project Report Rubric (FT)*, and *Project 1.3.2 Transfer System Performance Rubric (FT)*.

The teacher will introduce and distribute the documents to support Project 1.3.2 Transfer System (FT) including *Project Report Template (FT)*, *Planning Sheet (FT)*, *Project 1.3.2a Price List for Transfer System (FT)* and *Project 1.3.2b Using the Price List (FT)*.

Students will work in teams of two to three to document progress in their engineering notebooks.

**Days 4 – 13:**

Students will complete work on Project 1.3.2 Transfer System, submit their engineering notebooks, and create a report using the Project Report Template.

**Day 14:**

Students will present their Project 1.3.2 Transfer System, submit their engineering notebooks, and create a report using the Project Report Template.

The teacher will assess teams system performance using the Project 1.3.2 Transfer System Performance Rubric.

The teacher will assess team project reports using the Project Report Rubric.

**Instructional Resources**

**NOTE:** Two sets of resources are available based on whether you are using the VEX robotics platform or the fischertechnik platform. Choose the appropriate resource as indicated by (VEX) or (FT) at the end of each resource.

**Presentations**

*Manufacturing Costs*
Documents

Activity 1.3.1 Cost Overview
Project 1.3.2 Transfer System (VEX)
Project Report Template (VEX)
Project Sheet (VEX)
Project 1.3.2a Price List for Transfer System (VEX)
Project 1.3.2b Using the Price List (VEX)
Project 1.3.2 Transfer System (FT)
Project Report Template (FT)
Planning Sheet (FT)
Project 1.3.2a Price List for Transfer System (FT)
Project 1.3.2b Using the Price List (FT)
Key Terms 1.3 Crossword Puzzle

Answer Keys and Rubrics

Project Report Rubric (VEX)
Project 1.3.2 Transfer System Performance Rubric (VEX)
Project Report Rubric (FT)
Project 1.3.2 Transfer System Performance Rubric (FT)
Key Terms 1.3 Crossword Puzzle Answer Key

Teacher Guidelines

Teacher Notes

Reference Sources


Unit 2 Manufacturing Processes

Preface

A good product design considers the manufacturability of the product. Designers use modeling software to aid prototype production and to test early designs. This improves the product function and ease with which a product can be manufactured. As a product nears the end of the design process, the required manufacturing processes must be determined. Many process techniques are available, so a good designer will select the most efficient and practical method for production. One such process is Computer Numerical Control (CNC) milling. The mill uses special instructions to guide the machine through each step to produce the desired product. Computer Aided Manufacturing (CAM) software is a powerful tool that engineers use to generate the complex instructions necessary for the milling machine.

In this unit students will consider some of the factors that are important when designing products and considering manufacturability. Students will learn how to set up a milling machine and develop programs to accurately mill products.

Lessons

| Lesson 2.1 Designing for Manufacturability | htm | doc |
| Lesson 2.2 How We Make Things | htm | doc |
| Lesson 2.3 Product Development | htm | doc |

Concepts

1. Design is a process that is used to systematically solve problems.
2. Many considerations must be made when manufacturing a quality part.
3. Material properties must be considered as part of the design process.
4. Manufacturers have an ethical responsibility to create safe products and to provide a safe work environment.
5. Manufacturers have a legal responsibility to provide safety information about their products.
6. Many engineering disciplines have a code of conduct or code of ethics that their members are expected to follow.
7. Analyzing case studies of engineering failures is a good way for engineers to avoid future failures.
8. Prototyping is part of a design process where a physical model can be evaluated to refine the design.
9. Before raw material can be used in manufacturing, it must undergo primary processing.
10. The separating process is one of the oldest manufacturing processes.
11. Milling and shearing utilize the subtractive process to create products.
12. ECM, EDM, water-, and laser-cutting are using newer technologies to enhance the accuracy and efficiency of material removal.
13. Metals, plastics, and ceramics are types of materials that are well suited to the manufacturing process.

14. The way in which a product is made is dependent upon the properties of the material that will be used.

15. Many machines exist to perform manufacturing processes.

16. Machine code is an essential tool used to communicate with some machines.

17. Jigs and fixtures are essential in maintaining consistency and quality control.

18. Computer Aided Manufacturing (CAM) programming tools make it possible to manufacture physical models using Computer Aided Design (CAD) programs.

19. Products manufactured today have been greatly influenced by the advancement of machines and technology.

20. Several variables in machining operations affect the final product in manufacturing.

21. Profit margins are essential to a company’s survival in a competitive market.

22. Prototyping is a major step in the design cycle of manufactured goods and has been greatly advanced with the advent and use of rapid prototyping processes.

Essential Questions

Lesson 2.1 Designing for Manufacturability

1. What are some major causes of defects in products?
2. How do safety and ethics affect product design?
3. When performing a redesign or improving a product, why is it important to follow a design process?
4. What properties are important when creating a new product?
5. What restrictions must you consider when modeling a product?

Lesson 2.2 How We Make Things

1. What are raw materials and how do we obtain them?
2. How do we produce industrial materials?
3. What are common secondary manufacturing processes and how are they applied in manufacturing?
4. What is the difference between conditioning, assembling, and finishing processes?
5. What is the difference between forming and molding?
6. What are some common forms of rapid prototyping, and how has this technique changed the manufacturing process?

Lesson 2.3 Product Development

1. What types of machines exist to perform manufacturing processes?
2. Why is it important for a design engineer to learn about programming codes?
3. What are jigs and fixtures? How are they the same? How are they different?
4. How has the advancement of technology and machines affected the global market?
5. What are some ways that manufacturers can verify how a part will be created without producing it physically?

6. How do machines receive data from a computer?

7. How are manufacturing companies affected by the way a product is created?

Unit Evaluation

The Essential Questions and Conclusion questions at the end of each activity may be used along with the Assessment suggestions provided in each lesson to develop summative assessment tools, such as tests or end of unit projects.
Lesson 2.1 Designing for Manufacturability

Preface

Most soft drink cans have the same basic shape. Why? Is there only one way to create a container that will hold 12 ounces of liquid? Many factors affect design, including cost, safety, functionality, and others. Can we design products that meet the needs of our clients while realizing a comfortable profit margin? Why is it so important to follow a detailed process when designing new products for the consumer?

In this lesson students will analyze bad designs and discuss ways in which they might be improved. They will use solid modeling software to improve some of the bad designs they encounter. Safety and ethics will be discussed, and students will be asked to analyze manufacturing scenarios with those in mind. Finally, students will design a product of choice using the solid modeling software.

Concepts

1. Design is a process that is used to systematically solve problems.
2. Many considerations must be made when manufacturing a quality part.
3. Material properties must be considered as part of the design process.
4. Manufacturers have an ethical responsibility to create safe products and to provide a safe work environment.
5. Manufacturers have a legal responsibility to provide safety information about their products.
6. Many engineering disciplines have a code of conduct or code of ethics that their members are expected to follow.
7. Analyzing case studies of engineering failures is a good way for engineers to avoid future failures.

Standards and Benchmarks Addressed

Standards for Technological Literacy

Standard 1: Students will develop an understanding of the characteristics and scope of technology.

BM L: Inventions and innovations are the results of specific, goal-directed research

BM M: Most development of technologies these days is driven by the profit motive and the market.

Standard 2: Students will develop an understanding of the core concepts of technology.

BM W: Systems thinking applies logic and creativity with appropriate compromises in complex real-life problems.

BM X: Systems, which are the building blocks of technology, are embedded within larger technological, social, and environmental systems.

BM Y: The stability of a technological system is influenced by all of the components in the system especially those in the feedback loop.

BM Z: Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
BM I: Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.

BM J: Ethical considerations are important in the development, selection, and use of technologies.

BM K: The transfer of a technology from one society to another can cause cultural, social, economic, and political changes affecting both societies to varying degrees.

Standard 5: Students will develop an understanding of the effects of technology on the environment.

BM G: Humans can devise technologies to conserve water, soil, and energy through such techniques as reusing, reducing and recycling.

BM K: Humans devise technologies to reduce the negative consequences of other technologies.

Standard 6: Students will develop an understanding of the role of society in the development and use of technology.

BM I: The decision whether to develop a technology is influenced by societal opinions and demands, in addition to corporate cultures.

BM J: A number of different factors, such as advertising, the strength of the economy, the goals of a company and the latest fads contribute to shaping the design of and demand for various technologies.

Standard 7: Students will develop an understanding of the influence of technology on history.

BM G: Most technological development has been evolutionary, the result of a series of refinements to a basic invention.

Standard 8: Students will develop an understanding of the attributes of design.

BM J: The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

BM K: Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

Standard 9: Students will develop an understanding of engineering design.

BM J: Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

BM L: The process of engineering design takes into account a number of factors.

Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving

BM K: Not all problems are technological, and not every problem can be solved using technology.

National Science Education Standards

Science in Personal and Social Perspectives Standard F: As a result of activities in grades 9-12, all students should develop understanding of

Natural resources

Environmental quality

Natural and human-induced hazards

Science and technology in local, national, and global challenges
**Principles and Standards for School Mathematics**

**Number Operations:** Instructional programs from pre-kindergarten through grade 12 should enable all students to understand numbers, ways of representing numbers, relationships among numbers, and number systems; understand meanings of operations and how they relate to one another; compute fluently and make reasonable estimates.

**Algebra:** Instructional programs from pre-kindergarten through grade 12 should enable all students to represent and analyze mathematical situations and structures using algebraic symbols; use mathematical models to represent and understand quantitative relationships; analyze change in various contexts.

**Geometry:** Instructional programs from pre-kindergarten through grade 12 should enable all students to analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships; specify locations and describe spatial relationships using coordinate geometry and other representational systems; apply transformations and use symmetry to analyze mathematical situations; use visualization, spatial reasoning, and geometric modeling to solve problems.

**Data Analysis and Probability Standard:** Instructional programs from pre-kindergarten through grade 12 should enable all students to formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them; select and use appropriate statistical methods to analyze data; develop and evaluate inferences and predictions that are based on data.

**Problem Solving:** Instructional programs from pre-kindergarten through grade 12 should enable all students to build new mathematical knowledge through problem solving; solve problems that arise in mathematics and in other contexts; apply and adapt a variety of appropriate strategies to solve problems; monitor and reflect on the process of mathematical problem solving.

**Communication:** Instructional programs from pre-kindergarten through grade 12 should enable all students to organize and consolidate their mathematical thinking through communication; communicate their mathematical thinking coherently and clearly to peers, teachers, and others.

**Connections:** Instructional programs from pre-kindergarten through grade 12 should enable all students to recognize and use connections among mathematical ideas; understand how mathematical ideas interconnect and build on one another to produce a coherent whole; recognize and apply mathematics in contexts outside of mathematics.

**Representation:** Instructional programs from pre-kindergarten through grade 12 should enable all students to create and use representations to organize, record, and communicate mathematical ideas; select, apply, and translate among mathematical representations to solve problems; model and interpret physical, social, and mathematical phenomena.
Standards for English Language Arts

**Standard 4:** Students adjust their use of spoken, written, and visual language (e.g. conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

**Standard 8:** Students use a variety of technological and informational resources (e.g. libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Performance Objectives

*It is expected that students will:*

- Use the design process.
- Use knowledge of design to analyze products with flaws.
- Use calculated volume, mass, surface area of parts to determine material cost, waste, and packaging requirements.
- Use solid modeling software to improve a flawed design.
- Determine whether a product is safe for a given audience (e.g., children under the age of three).
- Make ethical decisions about manufacturing.
- Create a product using solid modeling software.

Assessment

*Explanation*

1. Students will identify flaws in a design and explain why they are considered flaws.
2. Students will explain how to redesign a product to remove flaws.
3. Students will explain how the Engineering Code of Ethics is related to manufacturing.

*Application*

4. Students will apply their knowledge of design in the modeling of a product.
5. Students will analyze a manufacturing scenario and apply their knowledge of inherent design flaws and ethics.
6. Students will apply their understanding of ethics to a past real-life engineering disaster to explain how it was caused and how it might have been avoided.
7. Students will apply their knowledge of manufacturing processes to determine why a modeled design is not plausible.

*Empathy*

8. Students will analyze a scenario to determine the ethical dilemma and recommend an appropriate action(s).

Essential Questions

1. What are some major causes of defects in products?
2. How do safety and ethics affect product design?
3. When performing a redesign or improving a product, why is it important to follow a design process?
4. What properties are important when creating a new product?
5. What restrictions must you consider when modeling a product?

Key Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competent</td>
<td>Properly or sufficiently qualified; capable or efficient.</td>
</tr>
<tr>
<td>Defective</td>
<td>Imperfect in form or function.</td>
</tr>
<tr>
<td>Design Flaws</td>
<td>An imperfection in an object or machine.</td>
</tr>
<tr>
<td>Durability</td>
<td>The quality of equipment or goods of continuing to be useful after an extended period of time and usage.</td>
</tr>
<tr>
<td>Economics</td>
<td>Dealing with production, distribution, and consumption of products or wealth.</td>
</tr>
<tr>
<td>Ethics</td>
<td>The standards for ethical or moral behavior of a particular group. In our case it will be the Engineering Code of Ethics.</td>
</tr>
<tr>
<td>Functionality</td>
<td>The ability of a product to do the job for which it was intended.</td>
</tr>
<tr>
<td>Morality</td>
<td>Rules relating to principles of right and wrong in behavior.</td>
</tr>
<tr>
<td>Purpose</td>
<td>What one intends to do or bring about.</td>
</tr>
<tr>
<td>Quality Control</td>
<td>The process of making sure that products or services meet consistently high standards.</td>
</tr>
</tbody>
</table>

Day-by-Day Plans

Time: 10 Days

NOTE: In preparation for teaching this lesson, it is strongly recommended that the teacher read the Lesson 2.1 Teacher Notes.

Day 1 – 3:

The teacher will present Concepts, Key Terms, and Essential Questions in order to provide a lesson overview.

The teacher will present Design Process.ppt.

Students will take notes on the design process in their journals.

The teacher will present Bad Designs.ppt.

Students will take notes on the processes using Activity 2.1.1 Design Flaws.

Students will work on Activity 2.1.1 Design Flaws, documenting their progress in their engineer’s notebooks.

The teacher will assess students on completion.

Optional: The teacher may wish to assign Key Terms 2.1 Crossword Puzzle after all key terms have been introduced.

Day 4 – 7:

The teacher will present Design Considerations for Manufacturability.ppt.

The teacher will distribute Activity 2.1.2 Mass Properties Analysis.

Students will complete Activity 2.1.2 Mass Properties Analysis, documenting progress in their engineer’s notebooks.
The teacher will assess student work using **Activity 2.1.2 Mass Properties Analysis Answer Key**.

Optional: The teacher will present **Dial Calipers.ppt**.

**Day 8 - 10:**

The teacher will distribute **Activity 2.1.3 Ethics & Safety**.

Students will work on Activity 2.1.3 Ethics & Safety.

The teacher will assess Activity 2.1.3 Ethics & Safety using the **Activity 2.1.3 Ethics & Safety Answer Key**.

### Instructional Resources

**Presentations**

- **Design Process**
- **Bad Designs**
- **Design Considerations for Manufacturability**
- **Dial Calipers**

**Documents**

- **Activity 2.1.1 Design Flaws**
- **Activity 2.1.2 Mass Properties Analysis**
- **Activity 2.1.3 Ethics & Safety**
- **Key Terms 2.1 Crossword Puzzle**

**Answer Keys and Rubrics**

- **Activity 2.1.2 Mass Properties Analysis Answer Key**
- **Activity 2.1.3 Ethics & Safety Answer Key**
- **Key Terms 2.1 Crossword Puzzle Answer Key**

**Teacher Guidelines**

- **Teacher Notes**

### Reference Sources


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for the English language arts*. Newark, DE: IRA; Urbana, IL: NCTE.


Lesson 2.2 How We Make

Preface
The end of a violin appears to be a scrolled piece of wood. How is that created? For some products, the method of construction may be obvious. A cereal box, for example, is simply a pattern cut from cardboard and folded. But what about more complex products, such as a violin? How about the lamp in your bedroom? How was it manufactured? Were the violin and the lamp created in the same manner? Products that are used by consumers on a daily basis are all created using different manufacturing processes. As emerging technologies develop, the speed, quality, and durability of the products also improve.

In this lesson students will investigate a process for a common product and apply that knowledge by creating the product using solid modeling software.

Concepts
1. Prototyping is part of a design process where a physical model can be evaluated to refine the design.
2. Before raw material can be used in manufacturing, it must undergo primary processing.
3. The separating process is one of the oldest manufacturing processes.
4. Milling and shearing utilize the subtractive process to create products.
5. ECM, EDM, water-, and laser-cutting are using newer technologies to enhance the accuracy and efficiency of material removal.
6. Metals, plastics, and ceramics are types of materials that are well suited to the manufacturing process.
7. The way in which a product is made is dependent upon the properties of the material that will be used.

Standards and Benchmarks Addressed

Standards for Technological Literacy

Standard 2: Students will develop an understanding of the core concepts of technology.

BM AA: Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

BM BB: Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

BM CC: New technologies create new processes.

BM DD: Quality control is a planned process to ensure that a product, service, or system meets established criteria.

BM EE: Management is the process of planning, organizing, and controlling work.

BM FF: Complex systems have many layers of controls and feedback loops to provide information.

Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.

BM I: Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.

Standard 5: Students will develop an understanding of the effects of technology on the
When new technologies are developed to reduce the use of resources, considerations of trade-offs are important.

Humans devise technologies to reduce the negative consequences of other technologies.

Decisions regarding the implementation of technologies involve the weighing of tradeoffs between predicted positive and negative effects on the environment.

Students will develop an understanding of the attributes of design.

The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

Students will develop an understanding of engineering design.

Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

The process of engineering design takes into account a number of factors.

Students will develop the abilities to use and maintain technological products and systems.

Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

Operate systems so that they function in the way they were designed.

Students will develop an understanding of and be able to select and use energy and power technologies.

Energy resources can be renewable or nonrenewable.

Power systems must have a source of energy, a process, and loads.

Students will develop an understanding of and be able to select and use information and communication technologies.

Information and communication systems allow information to be transferred from human to human, human to machine, machine to human, and machine to machine.

There are many ways to communicate information, such as graphic and electronic means.

Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

Students will develop an understanding of and be able to select and use manufacturing technologies.

Servicing keeps products in good operating condition.

Materials have different qualities and may be classified as natural, synthetic, or mixed.

Chemical technologies provide a means for humans to alter or modify materials and to produce chemical products.
**National Science Education Standards**

**Science as Inquiry Standard A:** As a result of activities in grades 9-12, all students should develop
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

**Science in Personal and Social Perspectives Standard F:** As a result of activities in grades 9-12, all students should develop understanding of
- Natural resources

**Standards for English Language Arts**

**Standard 1:** Students read a wide range of print and nonprint texts to build an understanding of texts of themselves, and of the cultures of the United States and the world; to acquire new information; to respond to the needs and demands of society and the workplace; and for personal fulfillment. Among these texts are fiction and nonfiction, classical and contemporary works.

**Standard 4:** Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

**Standard 5:** Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences and for a variety of purposes.

**Standard 8:** Students use a variety of technological and informational resources (e.g. libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

**Standard 12** Students use spoken, written and visual language to accomplish their own purposes (e.g. for learning, enjoyment, persuasion, and the exchange of information).

**Performance Objectives**

*It is expected that students will:*

- Explain the difference between primary and secondary manufacturing processes.
- Analyze a product to propose the manufacturing processes used to create it.
- Explore manufacturing processes via research.
- Explore prototyping processes.

**Assessment**

*Explanation*

1. Students will explain the difference between primary and secondary manufacturing processes.
2. Students will explain the secondary manufacturing processes studied.
3. Students will explain different methods of prototyping and why they are important.
4. Students will identify products created by each of the processes studied.
Application

5. Students will determine the manufacturing processes required to produce a product.

Perspective

6. Students will compare and contrast how objects recently created could have been produced during a specific era in the past.

Essential Questions

1. What are raw materials and how do we obtain them?
2. How do we produce industrial materials?
3. What are common secondary manufacturing processes and how are they applied in manufacturing?
4. What is the difference between conditioning, assembling, and finishing processes?
5. What is the difference between forming and molding?
6. What are some common forms of rapid prototyping, and how has this technique changed the manufacturing process?

Key Terms

<p>| 3D Printing | 1) Rapid prototyping processes use systems that are low cost, small in size, fast, easy to use, and often suitable for an office environment. 2) Collective term for all rapid prototyping activities. |
| Additive Process | Fabrication of a part by adding material. |
| Assembling | The process of putting a product together out of separate parts. |
| Build Time | Length of time for the physical construction of a rapid prototype, excluding preparation and post-processing time. Also known as run time. |
| Casting | The process in which a solid material is made into a liquid, poured into a mold, and allowed to harden in the shape of the mold. |
| Ceramics | Any of various hard, brittle, heat-resistant, and corrosion-resistant materials made by shaping and then firing a nonmetallic mineral, such as clay, at a high temperature. |
| Concept Model | Physical model intended primarily for design review and not meant to be sufficiently accurate or durable for full functional or physical testing. |
| Conditioning Process | Process in which the properties of a material are changed using mechanical, thermal, or chemical means. |
| Die Casting | Similar to permanent mold casting except that the metal is injected into the mold under high pressure. |
| Electrical Discharge Machining (EDM) | A process by which an electrode spark is used to erode small amounts of material from a work piece. |
| Electrochemical Machining (ECM) | A process in which a stream of electrolyte (typically salt water) is pumped at high pressure through a gap between the positively charged work and the negatively charged tool (electrode). |
| Exhaustible Resources | Resources of which there are a limited supply. |</p>
<table>
<thead>
<tr>
<th><strong>Finishing Process</strong></th>
<th>Machining a surface to size with a fine feed produced in a lathe, milling machine, or grinder.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Forging</strong></td>
<td>A process by which metal is heated and shaped by plastic deformation by suitably applying compressive force.</td>
</tr>
<tr>
<td><strong>Forming Process</strong></td>
<td>A process that changes the size and shape of a material by a combination of force and a shaped form.</td>
</tr>
<tr>
<td><strong>Grinding</strong></td>
<td>An operation that removes material by rotating an abrasive wheel or belt against the work.</td>
</tr>
<tr>
<td><strong>Industrial Material</strong></td>
<td>Material that has been changed from raw material so that it is ready to be used in manufacturing. Also referred to as standard stock.</td>
</tr>
<tr>
<td><strong>Injection Molding</strong></td>
<td>A process during which plastic is heated in a machine and forced into a cavity by a screw or ram. The material solidifies and is then ejected.</td>
</tr>
<tr>
<td><strong>Metals</strong></td>
<td>Any of a category of electropositive elements that usually have a shiny surface, are generally good conductors of heat and electricity, and can be melted or fused, hammered into thin sheets, or drawn into wires.</td>
</tr>
<tr>
<td><strong>Molding</strong></td>
<td>A manufacturing process in which the industrial material is made into a liquid. The liquid is then introduced (poured or forced) into a prepared mold of proper design.</td>
</tr>
<tr>
<td><strong>Plastics</strong></td>
<td>Materials that undergo a permanent change in shape or size when subjected to a particular amount of stress.</td>
</tr>
<tr>
<td><strong>Photopolymer</strong></td>
<td>Liquid resin material that utilizes light (visible or ultra-violet) as a catalyst to initiate polymerization, in which the material cross-links and solidifies. This technique is used by various rapid prototyping technologies.</td>
</tr>
<tr>
<td><strong>Post Processing</strong></td>
<td>A common practice that includes clean up and finishing procedures on models after they are removed from the rapid prototyping machine. It may also include mechanical or chemical removal of support structures, powder removal, and surface finishing.</td>
</tr>
<tr>
<td><strong>Primary Processing</strong></td>
<td>The first step in manufacturing where raw materials are processed into a usable form for further manufacture.</td>
</tr>
<tr>
<td><strong>Prototype</strong></td>
<td>A full-scale working model used to test a design concept by making actual observations and necessary adjustments.</td>
</tr>
<tr>
<td><strong>Rapid Prototyping</strong></td>
<td>Computer-controlled additive fabrication. Commonly used synonyms for RP are three-dimensional printing, additive fabrication, freeform fabrication, solid freeform fabrication, and stereolithography. Note that most of these synonyms are imprecise.</td>
</tr>
<tr>
<td><strong>Raw Materials</strong></td>
<td>Basic substance in its natural, modified, or semi-processed state, used as an input to a production process for subsequent modification or transformation into a finished good.</td>
</tr>
<tr>
<td><strong>Renewable Resources</strong></td>
<td>Biological materials that can be replaced.</td>
</tr>
<tr>
<td><strong>Sand Casting</strong></td>
<td>A process of pressing moist sand around a pattern to make a mold. The pattern is removed, leaving a cavity in the sand. The cavity is the mold that will be filled with liquid metal. The result will be a casting that is identical in shape to the original pattern.</td>
</tr>
<tr>
<td><strong>Separating</strong></td>
<td>A process that removes excess material to change the size, shape, or surface.</td>
</tr>
<tr>
<td><strong>Stereolithography</strong></td>
<td>A rapid prototyping process that fabricates a part layer-wise by hardening a photopolymer with a guided laser beam.</td>
</tr>
<tr>
<td><strong>Subtractive Process</strong></td>
<td>Processes that remove material to change the size, shape, or surface of a part. There are two groups of separating processes: machining and shearing.</td>
</tr>
</tbody>
</table>
Vacuum Forming

Process to heat a thermoplastic sheet until it softens and then force the hot and pliable material against the contours of a mold using vacuum pressure.

Water Jet Cutting

A process that uses a high speed jet of water emitted from a nozzle under high pressure (10,000-60,000 psi or greater). The advantage of water jet cutting is that it does not create a burr and it is a low temperature process.

Day-by-Day Plans

Time: 6 Days

**NOTE:** In preparation for teaching this lesson, it is strongly recommended that the teacher read the [Lesson 2.2 Teacher Notes](#).

Day 1 – 3:

The teacher will present [Concepts, Key Terms, and Essential Questions](#) in order to provide a lesson overview.

The teacher will present [Creating a Prototype.ppt](#).

Students will take notes on the processes using [Activity 2.2.1 Creating a Prototype](#).

Students will complete [Activity 2.2.1 Creating a Prototype](#).

The teacher will assess the student writing assignment using [Activity 2.2.1a Creating a Prototype Presentation Rubric](#) or [Activity 2.2.1b Creating a Prototype Brochure Rubric](#).

Optional: The teacher may wish to assign [Key Terms 2.2 Crossword Puzzle](#) after all key terms have been introduced.

Day 4 – 6:

The teacher will present [Manufacturing Processes.ppt](#).

Students will take notes on the processes using [Activity 2.2.2 Manufacturing Processes](#).

The teacher will distribute [Project 2.2.3 Manufacturing Processes Research](#).

Students will work and complete [Project 2.2.3 Manufacturing Processes Research](#).

The teacher will assess the [Project 2.2.3 Manufacturing Processes Research](#) using [Project 2.2.3 Manufacturing Processes Research Rubric](#).

The teacher will review placement of sticky notes on posters.

Students will complete [Project 2.2.3 Manufacturing Processes Research](#) by posting projects on poster boards.

### Instructional Resources

**Presentations**

- [Creating a Prototype](#)
- [Manufacturing Processes](#)

**Documents**

- [Activity 2.2.1 Creating a Prototype](#)
- [Activity 2.2.2 Manufacturing Processes](#)
- [Project 2.2.3 Manufacturing Processes Research](#)
Key Terms 2.2 Crossword Puzzle

Answer Keys and Rubric

Activity 2.2.1a Creating a Prototype Presentation Rubric
Activity 2.2.1b Creating a Prototype Brochure Rubric
Key Terms 2.2 Crossword Puzzle Answer Key

Teacher Guidelines
Teacher Notes

Reference Sources


Lesson 2.3 Product Development

Preface

Machines have changed the face of manufacturing. From the first conveyor system used by Henry Ford over a hundred years ago to the laser engraver and 3-D printers of today, machines have simplified the manufacturing process and have given us unlimited potential for creativity. Technology has allowed the evolution of manufacturing to explode in the last century. The quality, speed, and durability of products have reached new heights. The profit margin for companies has also benefited from the advancement of machines and technology. Imagine where we would be if the technology were the same now as it was when mass production first began.

In this lesson students will learn about the various machines used in the real world and in the classroom. They will learn how to read and write code and apply their knowledge to the creation of a simple assembled product. Students will also learn how jigs and fixtures factor into manufacturing and will simulate their creation. Students will ultimately follow the engineering process to create an assembled product of their choice, utilizing their knowledge as applicable.

Concepts

1. Many machines exist to perform manufacturing processes.
2. Machine code is an essential tool used to communicate with some machines.
3. Jigs and fixtures are essential in maintaining consistency and quality control.
4. Computer Aided Manufacturing (CAM) programming tools make it possible to manufacture physical models using Computer Aided Design (CAD) programs.
5. Products manufactured today have been greatly influenced by the advancement of machines and technology.
6. Several variables in machining operations affect the final product in manufacturing.
7. Profit margins are essential to a company’s survival in a competitive market.
8. Prototyping is a major step in the design cycle of manufactured goods and has been greatly advanced with the advent and use of rapid prototyping processes.

Standards and Benchmarks Addressed

Standards for Technological Literacy

Standard 2: Students will develop an understanding of the core concepts of technology.

BM AA: Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

BM CC: New technologies create new processes.

BM DD: Quality control is a planned process to ensure that a product, service, or system meets established criteria.

Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.

BM I: Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.
Standard 8: Students will develop an understanding of the attributes of design.
BM J: The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.
BM K: Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

Standard 9: Students will develop an understanding of engineering design.
BM K: A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.
BM L: The process of engineering design takes into account a number of factors.

Standard 11: Students will develop abilities to apply the design process.
BM P: Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.
BM R: Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.
BM M: Information and communication systems allow information to be transferred from human to human, human to machine, machine to human, and machine to machine.
BM O: Communication systems are made up of source, encoder, transmitter, receiver, decoder, storage retrieval and destination.

Standard 19: Students will develop an understanding of and be able to select and use manufacturing technologies.
BM N: Durable goods are designed to operate for a long period of time, while non-durable goods are designed to operate for a short period of time.
BM P: The interchangeability of parts increases the effectiveness of manufacturing processes.

National Science Education Standards

Unifying Concepts and Processes Standard K-12: As a result of activities in grades K-12, all students should develop
- Systems, order, and organization
- Evidence, models, and explanation
- Change, constancy, and measurement
- Form and function

Science as Inquiry Standard A: As a result of activities in grades 9-12, all students should develop
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Science and Technology Standard E: As a result of activities in grades 9-12, all students should develop
- Abilities of technological design
- Understandings about science and technology

Science in Personal and Social Perspectives Standard F: As a result of activities in grades 9-12, all students should develop understanding of
- Natural resources
Environmental quality
Natural and human-induced hazards
Science and technology in local, national, and global challenges

Principles and Standards for School Mathematics

Number Operations: Instructional programs from pre-kindergarten through grade 12 should enable all students to understand numbers, ways of representing numbers, relationships among numbers, and number systems; understand meanings of operations and how they relate to one another; compute fluently and make reasonable estimates.

Algebra: Instructional programs from pre-kindergarten through grade 12 should enable all students to represent and analyze mathematical situations and structures using algebraic symbols; use mathematical models to represent and understand quantitative relationships; analyze change in various contexts.

Geometry: Instructional programs from pre-kindergarten through grade 12 should enable all students to analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships; specify locations and describe spatial relationships using coordinate geometry and other representational systems; apply transformations and use symmetry to analyze mathematical situations; use visualization, spatial reasoning, and geometric modeling to solve problems.

Measurement: Instructional programs from pre-kindergarten through grade 12 should enable all students to understand measurable attributes of objects and the units, systems, and processes of measurement; apply appropriate techniques, tools, and formulas to determine measurements.

Data Analysis and Probability: Instructional programs from pre-kindergarten through grade 12 should enable all students to formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them; select and use appropriate statistical methods to analyze data; develop and evaluate inferences and predictions that are based on data; understand and apply basic concepts of probability.

Problem Solving: Instructional programs from pre-kindergarten through grade 12 should enable all students to build new mathematical knowledge through problem solving; solve problems that arise in mathematics and in other contexts; apply and adapt a variety of appropriate strategies to solve problems; monitor and reflect on the process of mathematical problem solving.

Communication: Instructional programs from pre-kindergarten through grade 12 should enable all students to organize and consolidate their mathematical thinking through communication; communicate their mathematical thinking coherently and clearly to peers, teachers, and others.

Connections: Instructional programs from pre-kindergarten through grade 12 should enable all students to recognize and use connections among mathematical ideas; understand how mathematical ideas interconnect and build on one another to produce a coherent whole; recognize and apply mathematics in contexts outside of mathematics.

Representation: Instructional programs from pre-kindergarten through grade 12 should enable all students to create and use representations to organize, record, and communicate mathematical ideas; select, apply, and translate among mathematical representations to solve problems; model and interpret
physical, social, and mathematical phenomena.

**Standards for English Language Arts**

**Standard 4:** Students adjust their use of spoken, written, and visual language (e.g. conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

**Performance Objectives**

*It is expected that students will:*

- Identify machines when given a process and identify the process that a given machine performs.
- Determine the appropriate speed rate for a given material using a tool with a given diameter.
- Determine the feed rate for a given material using a tool with a given diameter.
- Read and interpret G & M codes.
- Transfer the drawings made in CAD to a CAM program.
- Create numerical code using a CAM program.
- Verify the creation of a part using a simulation software.
- Create parts using the machines demonstrated by the instructor.
- Create a product on the computer using knowledge of manufacturing processes.

**Assessment**

*Explanation*

1. List machines used to perform manufacturing processes.
2. Explain the difference between jigs and fixtures.

*Interpretation*

3. Interpret G & M codes.

*Application*

4. Calculate cutter speeds and tool rates.
5. Create an assembly using the manufacturing processes.
6. Write G & M codes to perform given functions.
7. Create jigs and fixtures to aid in the construction of an assembly.
8. Students will apply one or more of the manufacturing processes to a product they will create on the computer.

*Self-knowledge*

9. Students will analyze a part and plan the most efficient milling method among the several methods they know.
Essential Questions

1. What types of machines exist to perform manufacturing processes?
2. Why is it important for a design engineer to learn about programming codes?
3. What are jigs and fixtures? How are they the same? How are they different?
4. How has the advancement of technology and machines affected the global market?
5. What are some ways that manufacturers can verify how a part will be created without producing it physically?
6. How do machines receive data from a computer?
7. How are manufacturing companies affected by the way a product is created?

Key Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute System</td>
<td>System in which positions are given with respect to a fixed point, usually the origin.</td>
</tr>
<tr>
<td>Address Character</td>
<td>A letter used in G &amp; M code programming to designate a class of functions.</td>
</tr>
<tr>
<td>Block</td>
<td>A single line of code in an NC part program.</td>
</tr>
<tr>
<td>Bench Grinder</td>
<td>A grinding machine that has been mounted to a bench or table. The grinding wheels mount directly onto the motor shaft. Normally one wheel is coarse, for roughing, and the other is fine, for finishing.</td>
</tr>
<tr>
<td>Computer Aided Manufacturing (CAM)</td>
<td>The use of computers in converting engineering designs into finished products.</td>
</tr>
<tr>
<td>Computer Numerical Control (CNC)</td>
<td>A numerical control method in which one computer is linked with one machine tool to perform NC functions.</td>
</tr>
<tr>
<td>Feed</td>
<td>The distance advanced by the cutting tool along the length of the work for every revolution of the spindle.</td>
</tr>
<tr>
<td>Fixture</td>
<td>A device designed and built for holding a particular piece of work for machining operations.</td>
</tr>
<tr>
<td>G &amp; M Codes</td>
<td>Programming code used to control CNC machines.</td>
</tr>
<tr>
<td>Incremental</td>
<td>A system in which each position is taken from the one prior. Also called relative.</td>
</tr>
<tr>
<td>Jig</td>
<td>A device that holds and locates a piece of work and guides the tools that operate upon it.</td>
</tr>
<tr>
<td>Laser</td>
<td>An acronym for Light Amplification by Stimulated Emission of Radiation. Some common uses for lasers are cutting, measuring, and guidance systems.</td>
</tr>
<tr>
<td>Lathe</td>
<td>A machine tool used for turning cylindrical forms on work pieces. Modern lathes are often equipped with digital readouts and numerical controls.</td>
</tr>
<tr>
<td>Machinability</td>
<td>The ease or difficulty of machining as it relates to the hardness of a material to be cut.</td>
</tr>
<tr>
<td>Milling Machine</td>
<td>A machine that removes material from work by means of a rotary cutter.</td>
</tr>
<tr>
<td>Modal</td>
<td>Information that is retained by the system until new information is obtained.</td>
</tr>
<tr>
<td>Numerical Control (NC)</td>
<td>Any controlled equipment that allows an operator to program its movements through a series of coded instructions consisting of numbers, letters, symbols, etc.</td>
</tr>
<tr>
<td>Parameter</td>
<td>Attribute of a feature, such as a dimension, that can be modified.</td>
</tr>
<tr>
<td>Part Program</td>
<td>The instructions written by the programmer to produce a workpiece.</td>
</tr>
<tr>
<td>Preparatory Code</td>
<td>Codes that carry out machining operations or establish machine settings;</td>
</tr>
<tr>
<td><strong>Spindle Speed</strong></td>
<td>The number of revolutions per minute (RPM) that is made by the cutting tool of a machine.</td>
</tr>
<tr>
<td><strong>Tolerance</strong></td>
<td>The amount of interference required for two or more parts that are in contact. The amount of variation, over or under the required size, permitted on a piece of machined work.</td>
</tr>
<tr>
<td><strong>V-Block</strong></td>
<td>A square or rectangular steel block with a 90 degree V-groove through the center, provided with a clamp for holding round stock for drilling, milling, and laying out operations.</td>
</tr>
<tr>
<td><strong>Word</strong></td>
<td>The programming expression formed when a letter (address) is combined with a number.</td>
</tr>
</tbody>
</table>

**Day-by-Day Plans**

*Time: 38 Days*

**NOTE:** In preparation for teaching this lesson, it is strongly recommended that the teacher read the Lesson 2.3 Teacher Notes.

**Day 1 – 2:**

- The teacher will present Concepts, Key Terms, and Essential Questions in order to provide a lesson overview.
- The teacher will present Machines.ppt.
- Students will take notes using Activity 2.3.1 Introduction to Machines.
- Students will work on Activity 2.3.1 Introduction to Machines.
- The teacher will assess Activity 2.3.1 Introduction to Machines based on completion.
- The teacher will present Jig and Fixture.ppt.
- Students will take notes in their journal.
- **Optional:** The teacher may wish to assign Key Terms 2.3 Crossword Puzzle after all key terms have been introduced.

**Day 3-4:**

- The teacher will present Speeds and Feeds.ppt.
- Students will take notes in their journals.
- The teacher will distribute Activity 2.3.2 Speeds & Feeds.
- Students will work on Activity 2.3.2 Speeds & Feeds.
- The teacher will assess understanding using Activity 2.3.2 Speeds & Feeds Answer Key.
- The teacher will present Milling Machine Setup.ppt.
- Students will take notes in their journals.
- The teacher will demonstrate setup and use of the milling machine.

**NOTE:** Because there are different milling machines being used, the teacher may want to create a startup checklist outlining the steps to take in the successful use of the milling machine.
Day 5:

The teacher will distribute G & M Code Reference.
The teacher will present G & M Codes.ppt.
Students will take notes in their journal.

NOTE: If students need instruction or a review of trigonometry then present Trigonometry.ppt.

Day 6:

The teacher will distribute and explain Project 2.3.3 G & M Codes.
Students will complete up to page four using prior knowledge gained during the last lesson.
Extra Project 2.3.3 G & M Codes Layout and G & M Code Planning pages are available if needed.
The teacher will assess understanding with G & M Codes Quiz.
The teacher will verify responses to G & M Codes Quiz using the G & M Codes Quiz Answer Key.

Day 7-13:

Students will work on and complete Project 2.3.3 G & M Codes.
The teacher will assess students using Project 2.3.3 G & M Answer Key and Project 2.3.3 G & M Rubric.

Students will verify their parts in CNC simulation software.

NOTE: The teacher may want to present the CNC Motion Setup and Operation.ppt to aid students in the completion of their part verification using the CNC simulation software.
The teacher should distribute Tool Attribute Worksheet to assist students to document tool selection.

Students will machine their parts using the hand code they created from Project 2.3.3 G & M Codes.
The teacher will assess student progress and assign homework pertaining to the project as necessary.

Day 14-22:

The teacher will present Introduction to CAM software.ppt.
Students will take notes in their journal.

NOTE: This presentation is long and is intended to be shown in intervals. The teacher should present only the slides necessary for student success during the next two projects.
The teacher will demonstrate how to use the CAM software and the commands needed to complete the next two projects.
The teacher will distribute Project 2.3.4 Practice Machining and Project 2.3.4 Practice Machining Layout.

Students will work on Project 2.3.4 Practice Machining individually or teams, documenting their progress in their engineer’s notebooks.

Students will complete Project 2.3.4 Practice Machining.

NOTE: The teacher may want to distribute the Practice Machining Tutorial if students struggle with this project. Examples are also located in the Lesson 2.3 Teacher Notes. The teacher will determine based on time what project students will machine.
The teacher will assess students according to Project 2.3.4 Machining Rubric.

Day 23-38:

The teacher will distribute Project 2.3.5 Container Design.

**NOTE:** The teacher will need to define the dimension constraints prior to distributing the project. The teacher can distribute a CAD file to students to aid in the demonstration process.

Students will work on Project 2.3.5 Container Design, documenting progress in their engineer’s notebooks.

Students will complete Project 2.3.5 Container Design.

The teacher will assess students using Project 2.3.5 Container Design Rubric.

**NOTE:** The teacher should refer to the reference documents when setting up the CAM Software. The documents are located in the Lesson 2.3 Teacher Notes.

**NOTE:** The teacher may want add the following projects based upon student’s abilities: Project 2.3.5a Tic-Tac-Toe and Project 2.3.5b Triangular Puzzle.

### Instructional Resources

**Presentations**

- Machines
- Milling Machine Setup
- Speeds and Feeds
- G & M Codes
- Trigonometry
- Jigs and Fixtures
- CNC Motion Setup and Operation
- Introduction to CAM software

**Documents**

- Activity 2.3.1 Introduction to Machines
- Activity 2.3.2 Speeds and Feeds
- G & M Code Reference
- G & M Planning
- Project 2.3.3 G & M Codes
- Project 2.3.3 G & M Codes Layout
- Project 2.3.4 Practice Machining
- Project 2.3.4 Practice Machining Layout
- Project 2.3.5 Container Design
- Project 2.3.5a Tic-Tac-Toe
- Project 2.3.5b Triangular Puzzle
- Key Terms 2.3 Crossword Puzzle
Answer Keys and Rubric

- Activity 2.3.2 Speeds and Feeds Answer Key
- G & M Codes Quiz Answer Key
- Project 2.3.3 G & M Answer Key
- Project 2.3.3 G & M Rubric
- Project 2.3.4 Machining Rubric
- Project 2.3.5 Container Design Rubric
- Key Terms 2.3 Crossword Puzzle Answer Key

Teacher Guidelines

- Teacher Notes
- G & M Codes Quiz
- Tool Attribute Worksheet
- Practice Machining Tutorial
- CNC Initials Layout
- Custom Screen Configuration
- EdgeCAM Hole Cycle Repair
- Finishing Strategies
- Installing a Post Processor
- Metric to Inch in EdgeCAM
- EdgeCAM Configuration
- Milling Machine Check List
- Tools and Part Examples
- Flange Practice Machining Tutorial

Reference Sources


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for the English language arts*. Newark, DE: IRA; Urbana, IL: NCTE.


Unit 3 Elements of Automation

Preface

Automation has had a profound impact upon manufacturing and our daily lives. Robots as a form of automation perform tasks that may be too mundane, impossible, unsafe, or inefficient for humans to perform. Robots complete their tasks by following specific steps. These steps can be safely and efficiently simulated using software before deploying the robot. Robots can use a variety of power sources which impact their ability to perform a task. One possible power source is pneumatics, where a robot uses compressed air to power its movement.

In this unit students will explore the history of automation and program a robot using a simulator. These instructions will be deployed to a physical robot to test the effectiveness of the program. Students will design and build pneumatically powered models of automated systems.

Lessons

| Lesson 3.1 Introduction to Robotic Automation | htm | doc |
| Lesson 3.2 Elements of Automation Power | htm | doc |
| Lesson 3.3 Robotic Programming and Usage | htm | doc |

Concepts

1. Many factors have influenced the evolution of automation.
2. A variety of automation careers exist.
3. Robots are widely used in industry to assist in the production of manufactured goods.
4. Robots have distinct advantages over humans in some industrial settings (e.g., hazardous environments, repetitive motion or long hours).
5. Robots and machines communicate and coordinate their activities through a process called handshaking.
6. Power is produced in many ways and transmitted through various forms (e.g. electrical, pneumatic, hydraulic, and motion).
7. Fluid power is inversely proportional to the area upon which the force is being applied.
8. Sensors provide feedback to control systems and products used by consumers.
9. Pneumatics is one form of fluid power that can be used to operate machines and products.
10. Basic programming skills include variable declaration, loops, and debugging.
11. A variety of robots and unique programming languages are used in the manufacturing industry.
12. Many everyday products use microcontrollers.
13. Robots are used to perform diverse functions and work in diverse environments.
14. The size of a robot is based on the work envelope and payload needed to perform the task.
Essential Questions

**Lesson 3.1 Introduction to Robotic Automation**

1. What were some early technologies that helped facilitate the development of robots?
2. What are some examples and uses of early robots?
3. Why are robots used in industry?
4. What effect does the robot have on the human worker?
5. What are the benefits of simulation software in industry?
6. What situations require robots to communicate with machines?

**Lesson 3.2 Elements of Automation Power**

7. What is work?
8. What is power?
9. How is torque related to power?
10. Why is Ohm’s Law important in finding electrical power?

**Lesson 3.3 Robotic Programming and Usage**

11. What is a microcontroller?
12. What is the programming language for the robot that you are using?
13. What are the different types of loops and how are they used?
14. What is the purpose of declaring variables and how are they used in programming?
15. How does an engineer determine the size of a robot designed to perform a specific task?

**Unit Evaluation**

The Essential Questions and Conclusion questions at the end of each activity may be used along with the Assessment suggestions provided in each lesson to develop summative assessment tools, such as tests or end of unit projects.
Lesson 3.1 Introduction to Robotic Automation

Preface

What impact has automation made on your life? Everywhere you look, automation is at work. Doors open as you approach them. Elevators transport you from one floor of a building to another. Airports use automation to transfer your luggage and even your body.

The face of manufacturing has changed drastically with the advent of automation. Robots play a significant role in the process of automation.

In this lesson students will explore the history of automation and automation careers. They will use simulation software to program a virtual robot to perform various tasks commonly used in manufacturing.

Concepts

1. Many factors have influenced the evolution of automation.
2. A variety of automation careers exist.
3. Robots are widely used in industry to assist in the production of manufactured goods.
4. Robots have distinct advantages over humans in some industrial settings (e.g., hazardous environments, repetitive motion or long hours).
5. Robots and machines communicate and coordinate their activities through a process called handshaking.

Standards and Benchmarks Addressed

Standards for Technological Literacy

Standard 2: Students will develop an understanding of the core concepts of technology. BM Y: The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop. BM Z: Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste. BM FF: Complex systems have many layers of controls and feedback loops to provide information.

Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology. BM I: Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.

Standard 8: Students will develop an understanding of the attributes of design. BM J: The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved. BM K: Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

Standard 9: Students will develop an understanding of engineering design. BM K: A prototype is a working model used to test a design concept by making actual observations and necessary adjustments. BM L: The process of engineering design takes into account a number of factors.

Standard 11: Students will develop abilities to apply the design process.
BM R: Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

Standard 12: Students will develop the abilities to use and maintain technological products and systems.

BM L: Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

BM O: Operate systems so that they function in the way they were designed.

Standard 16: Students will develop an understanding of and be able to select and use energy and power technologies.

BM N: Power systems must have a source of energy, a process, and loads.

Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.

BM M: Information and communication systems allow information to be transferred from human to human, human to machine, machine to human, and machine to machine.

BM O: Communication systems are made up of source, encoder, transmitter, receiver, decoder, storage, retrieval, and destination.

BM P: There are many ways to communicate information, such as graphic and electronic means.

BM Q: Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

Standard 18: Students will develop an understanding of and be able to select and use transportation technologies.

BM J: Transportation plays a vital role in the operation of other technologies, such as manufacturing, construction, communication, health and safety, and agriculture.

BM M: The design of intelligent and non-intelligent transportation systems depends on many processes and innovative techniques.

National Science Education Standards

Science and Technology Standard E: As a result of activities in grades 9-12, all students should develop

- Abilities of technological design
- Understandings about science and technology

Standard E: Science and Technology: As a result of activities in grades 9-12, all students should develop

- Abilities of technological design
- Understandings about science and technology

Science in Personal and Social Perspectives Standard F: As a result of activities in grades 9-12, all students should develop understanding of

- Natural and human-induced hazards
- Science and technology in local, national, and global challenges
History and Nature of Science Standard G: As a result of activities in grades 9-12, all students should develop understanding of

Science as a human endeavor
Nature of scientific knowledge
Historical perspectives

Principles and Standards for School Mathematics

Number and Operations: Instructional programs from pre-kindergarten through grade 12 should enable all students to; understand numbers, ways of representing numbers, relationships among numbers, and number systems; understand meanings of operations and how they relate to one another; compute fluently and make reasonable estimates.

Algebra: Instructional programs from pre-kindergarten through grade 12 should enable all students to represent and analyze mathematical situations and structures using algebraic symbols, use mathematical models to represent and understand quantitative relationships, and analyze change in various contexts.

Geometry: Instructional programs from pre-kindergarten through grade 12 should enable all students to analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships; specify locations and describe spatial relationships using coordinate geometry and other representational systems; apply transformations and use symmetry to analyze mathematical situations; use visualization, spatial reasoning, and geometric modeling to solve problems.

Standards for English Language Arts

Standard 4: Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 5: Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences and for a variety of purposes.

Standard 7: Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g. print and nonprint texts, artifacts, and people) to communicate their discoveries in ways that suit their purpose and audience.

Standard 12: Students use spoken, written and visual language to accomplish their own purposes (e.g. for learning, enjoyment, persuasion, and the exchange of information).
Performance Objectives

*It is expected that students will:*

- Research a topic in automation.
- Explore automation careers.
- Identify the advantages and disadvantages of robotic labor versus human labor.
- Explore materials handling.
- Create and program virtual robotic work cells with simulation software.
- Program the interface between a robot and another machine.

Assessment

*Explanation*

1. Students will explain how a given historical automated device has influenced the development of automation.
2. Students will identify the requirements for a career in automation, a starting salary, and benefits.
3. Students will explain how automation is used in modern manufacturing.
4. Students will explain the impact that automation has on the human worker.
5. Students will explain the benefits of using simulation software.

*Application*

6. Students will complete various activities using robotic simulation software.
7. Students will model a virtual robot system that communicates with another machine.

*Empathy*

8. Students will analyze a scenario and determine if a using a robot or human operator would be the best decision.

Essential Questions

1. What were some early technologies that helped facilitate the development of robots?
2. What are some examples and uses of early robots?
3. Why are robots used in industry?
4. What effect does the robot have on the human worker?
5. What are the benefits of simulation software in industry?
6. What situations require robots to communicate with machines?

Key Terms

<table>
<thead>
<tr>
<th>Automated Guided Vehicle (AGV)</th>
<th>A driverless computer-controlled system, typically with a predefined path, that uses pallets and other interface equipment to transport workpieces to NC machine tools and other equipment in a flexible manufacturing system.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automated Storage and Retrieval</td>
<td>A system that moves material either vertically or</td>
</tr>
</tbody>
</table>

7/9/2012

BVSD Curriculum Essentials
<table>
<thead>
<tr>
<th><strong>System (ASRS)</strong></th>
<th>horizontally between a storage compartment and a transfer station or within a process.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Automation</strong></td>
<td>The use of technology to ease human labor or extend the mental or physical capabilities of humans.</td>
</tr>
<tr>
<td><strong>Computer Aided Manufacturing (CAM)</strong></td>
<td>The use of computers in converting engineering designs into finished products.</td>
</tr>
<tr>
<td><strong>Degrees of Freedom</strong></td>
<td>Motion variable for a robot axis; each requires a joint.</td>
</tr>
<tr>
<td><strong>Flexible Manufacturing System</strong></td>
<td>Groups of CNC machine tools that are highly integrated with automated material handling and computerized control systems.</td>
</tr>
<tr>
<td><strong>Gripper</strong></td>
<td>End effector that is designed to pick up, hold, and/or release an object or to move it.</td>
</tr>
<tr>
<td><strong>Inventory Control</strong></td>
<td>Systematic management of the balance on hand of inventory items, involving the supply, storage, distribution, and recording of items.</td>
</tr>
<tr>
<td><strong>Materials Handling</strong></td>
<td>The loading, moving, and unloading of materials.</td>
</tr>
<tr>
<td><strong>Robot</strong></td>
<td>A mechanical device that can be programmed to perform a variety of tasks of manipulation and locomotion under automatic control.</td>
</tr>
<tr>
<td><strong>Robotics</strong></td>
<td>The science and technology of robots, their design, manufacture, and application.</td>
</tr>
<tr>
<td><strong>Servo Motor</strong></td>
<td>Any motor that is modified to give feedback concerning the motor’s speed, direction of rotation, and number of revolutions.</td>
</tr>
<tr>
<td><strong>Stepper Motor</strong></td>
<td>Rotate in short and essentially uniform angular movements. These angles are typically 30, 45, or 90 degrees.</td>
</tr>
</tbody>
</table>

**Day-by-Day Plans**

*Time: 19 Days*

**NOTE:** In preparation for teaching this lesson, it is strongly recommended that the teacher read the [Lesson 3.1 Teacher Notes](#).

**Day 1 – 2:**

The teacher will present **Concepts, Key Terms, and Essential Questions** in order to provide a lesson overview.

The teacher will present **Robotics Overview.ppt** slides 1-9.

Students will take notes in their journals.

The teacher will distribute **Project 3.1.1 History of Automation**.

Students will choose and research a topic.

**Optional:** The teacher may wish to assign **Key Terms 3.1 Crossword Puzzle** after all key terms have been introduced.

**Day 3 – 4:**

Students will complete research for **Project 3.1.1 History of Automation**.

Students will create a single timeline from 500 BC to today for all students to post their sticky notes onto.

The teacher will assess students using **Project 3.1.1 History of Automation Rubric**.
Day 5-6:

The teacher will distribute and discuss RoboCell Background Information Sheet and RoboCell Planning.

The teacher will demonstrate how to use RoboCell simulation software. The teacher will show students how to record positions and write a program.

Students will start Activity 3.1.2a Pick and Place Routine.

NOTE: The teacher may want to walk students through this first activity as part of the demonstration on how to use the simulation software.

Students will complete Activity 3.1.2a Pick and Place Routine.

The teacher will assess student programs on the computer.

Day 7:

Students will complete Activity 3.1.2b Teaching Positions.

The teacher will assess student programs on the computer.

Day 8-12:

The teacher will distribute the following activities for students to complete.

Activity 3.1.2c Stacking Objects and Using Roll Angles
Activity 3.1.2d Relative Positions
Activity 3.1.2e Go Circular
Work Envelope Paper
RoboCell Planning

NOTE: The teacher may want to divide class into teams of two or three to save time. The teacher may also require students to choose from the available activities.

The teacher will assess student work based on completion.

Day 13-17:

The teacher will distribute and discuss Variable Programming information sheet.

The teacher will distribute the following activities for students to complete.

Activity 3.1.2f Variable Programming
Activity 3.1.2g Palletization & Storage
Activity 3.1.2h Handshaking

NOTE: The teacher may want to divide class into teams of two or three to save time. The teacher may also require students to choose from the available activities.

The teacher will assess student work based on completion.

Day 18:

The teacher will present Robots vs. Humans.ppt.

Students will take notes using Activity 3.1.3 Robots vs. Humans as a guide.

Students will complete the Conclusion questions for homework.

Day 19:

The teacher will present Materials Handling.ppt.

Students will take notes using Activity 3.1.4 Materials Handling as a guide.

Students will complete the Conclusion questions for homework.
Instructional Resources

Presentations
- Robots vs. Humans
- Materials Handling
- Robotics Overview

Documents
- Project 3.1.1 History of Automation
- RoboCell Background Information Sheet
- RoboCell Planning
- Activity 3.1.2a Pick and Place Routine
- Activity 3.1.2b Teaching Positions
- Activity 3.1.2c Stacking Objects and Using Roll Angles
- Activity 3.1.2d Relative Positions
- Activity 3.1.2e Go Circular
- Work Envelope Paper
- Work Envelope Paper.dwg
- Variable Programming
- Activity 3.1.2f Variable Programming
- Activity 3.1.2g Palletization & Storage
- Activity 3.1.2h Handshaking
- Activity 3.1.3 Robots vs. Humans
- Activity 3.1.4 Materials Handling
- Key Terms 3.1 Crossword Puzzle

Teacher Guidelines
- Teacher Notes

Answer Keys and Rubrics
- Key Terms 3.1 Crossword Puzzle Answer Key
- Project 3.1.1 History of Automation Rubric

Reference Sources


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for the English language arts*. Newark, DE: IRA; Urbana, IL: NCTE.


Lesson 3.2 Elements of Automation Power

Preface
Power is a concept with which students are familiar, at least at a basic level. They may have some sort of idea that power is a function of work and probably associate the word horsepower with automobiles. In automation, however, the concept of power is much more complex.

In this lesson students will learn the various types of automation power. They will learn about horsepower and how to calculate it. They will also learn about torque, electrical power, and fluid power. Students will apply formulas to solve power problems.

Concepts
1. Power is produced in many ways and transmitted through various forms (e.g. electrical, pneumatic, hydraulic, and motion).
2. Fluid power is inversely proportional to the area upon which the force is being applied.
3. Sensors provide feedback to control systems and products used by consumers.
4. Pneumatics is one form of fluid power that can be used to operate machines and products.

Standards and Benchmarks Addressed

Standards for Technological Literacy

Standard 2: Students will develop an understanding of the core concepts of technology.
BM W: Systems thinking applies logic and creativity with appropriate compromises in complex real-life problems.
BM X: Systems, which are the building blocks of technology, are embedded within larger technological, social, and environmental systems.
BM Y: The stability of a technological system is influenced by all of the components in the system especially those in the feedback loop.
BM Z: Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.
BM FF: Management is the process of planning, organizing, and controlling work.

Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
BM I: Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.

Standard 8: Students will develop an understanding of the attributes of design.
BM J: The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.
BM K: Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

Standard 9: Students will develop an understanding of engineering design.
BM K: A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.
BM L: The process of engineering design takes into account a number of factors.
Standard 11: Students will develop abilities to apply the design process.
BM R: Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

Standard 12: Students will develop the abilities to use and maintain technological products and systems.

BM L: Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

BM O: Operate systems so that they function in the way they were designed.

Standard 16: Complex systems have many layers of controls and feedback loops to provide information.

BM K: Energy can be grouped into major forms: thermal, radiant, electrical, mechanical, chemical, nuclear, and others.

BM N: Power systems must have a source of energy, a process, and loads.

Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.

BM M: Information and communication systems allow information to be transferred from human to human, human to machine, machine to human, and machine to machine.

BM P: There are many ways to communicate information, such as graphic and electronic means.

BM Q: Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.
National Science Education Standards

Standard K-12: Unifying Concepts and Processes: As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes;

- Systems, order, and organization
- Form and function

Science as Inquiry Standard A: As a result of activities in grades 9-12, all students should develop

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Physical Science Standard B: As a result of activities in grades 9-12, all students should develop an understanding of

- Motions and forces

Standard E: Science and Technology: As a result of activities in grades 9-12, all students should develop

- Abilities of technological design
- Understandings about science and technology

Principles and Standards for School Mathematics

Number and Operations:
Instructional programs from pre-kindergarten through grade 12 should enable all students to; understand numbers, ways of representing numbers, relationships among numbers, and number systems; understand meanings of operations and how they relate to one another; compute fluently and make reasonable estimates.

Algebra:
Instructional programs from pre-kindergarten through grade 12 should enable all students to represent and analyze mathematical situations and structures using algebraic symbols, use mathematical models to represent and understand quantitative relationships, and analyze change in various contexts.

Geometry:
Instructional programs from pre-kindergarten through grade 12 should enable all students to analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships.

Measurement
Instructional programs from pre-kindergarten through grade 12 should enable all students to understand measurable attributes of objects and the units, systems, and processes of measurement and apply appropriate techniques, tools, and formulas to determine measurements.

Problem Solving
Instructional programs from pre-kindergarten through grade 12 should enable all students to build new mathematical knowledge through problem solving, solve problems that arise in mathematics and in other contexts, apply and adapt a variety of appropriate strategies to solve problems, and monitor and reflect on the process of mathematical problem solving.

Communication Standard:
Instructional programs from pre-kindergarten through grade 12 should enable all students to; organize and consolidate their mathematical thinking through communication; communicate their
mathematical thinking coherently and clearly to peers, teachers, and others; use the language of mathematics to express mathematical ideas precisely.

**Connections Standard:** Instructional programs from pre-kindergarten through grade 12 should enable all students to; recognize and use connections among mathematical ideas; understand how mathematical ideas interconnect and build on one another to produce a coherent whole; recognize and apply mathematics in contexts outside of mathematics.

**Representation Standard:** Instructional programs from pre-kindergarten through grade 12 should enable all students to; create and use representations to organize, record, and communicate mathematical ideas; select, apply, and translate among mathematical representations to solve problems; use representations to model and interpret physical, social, and mathematical phenomena.

**Standards for English Language Arts**

**Standard 4:** Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

**Performance Objectives**

*It is expected that students will:*

- Identify the three main power types.
- Solve problems involving electrical, pneumatic, and mechanical power.
- Convert power between units.
- Calculate torque and use it to calculate power.
- Solve problems involving fluid power.
- Construct a system to convert pneumatic power into mechanical power.
Assessment

Explanation

1. Explain the characteristics of different types of power.
2. Explain how power can be converted from one form to another.

Application

3. Apply knowledge of power calculations to solve problems.
4. Convert power between various units.

Essential Questions

1. What is work?
2. What is power?
3. How is torque related to power?
4. Why is Ohm’s Law important in finding electrical power?

Key Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ampere</td>
<td>The unit of electric current in the meter-kilogram-second (MKS) system of units.</td>
</tr>
<tr>
<td>Electrical Current (I)</td>
<td>The net transfer of electrical charge per unit time.</td>
</tr>
<tr>
<td>Force</td>
<td>The influence on a body which causes it to accelerate.</td>
</tr>
<tr>
<td>Horsepower (HP)</td>
<td>The unit of power in the British engineering system equal to 550 foot-pounds per second.</td>
</tr>
<tr>
<td>Hydraulic</td>
<td>Operated or affected by the action of water or other fluid of low viscosity.</td>
</tr>
<tr>
<td>Joule</td>
<td>The unit of energy or work in the MKS system of units, equal to the work done by a force of one Newton-meter.</td>
</tr>
<tr>
<td>Pounds per Square Inch (PSI)</td>
<td>Pounds per square inch, a unit of pressure.</td>
</tr>
<tr>
<td>Pneumatic</td>
<td>Pertaining to or operated by air or other gas.</td>
</tr>
<tr>
<td>Power</td>
<td>The rate at which work is done.</td>
</tr>
<tr>
<td>Revolutions per Minute (RPM)</td>
<td>Revolutions per minute, a unit of velocity.</td>
</tr>
<tr>
<td>Servo Motor</td>
<td>Any motor that is modified to give feedback concerning the motor's speed, direction of rotation, and number of revolutions.</td>
</tr>
<tr>
<td>Stepper Motor</td>
<td>A motor that rotates a predefined angle with every electrical impulse.</td>
</tr>
<tr>
<td>Torque</td>
<td>A twisting force.</td>
</tr>
<tr>
<td>Velocity</td>
<td>The time rate of change of position of a body. Also known as linear velocity.</td>
</tr>
<tr>
<td>Viscosity</td>
<td>A measure of the thickness of a liquid. The higher the viscosity, the thicker the liquid.</td>
</tr>
<tr>
<td>Voltage (V)</td>
<td>Push or force used to move electrons.</td>
</tr>
<tr>
<td>Watt</td>
<td>A measure of power equal to one joule of work per second.</td>
</tr>
<tr>
<td>Work</td>
<td>The physical or mental effort expended in the performance of a task.</td>
</tr>
</tbody>
</table>
Day-by-Day Plans

Time: 10 days

NOTE: There are two sets of resources available based on whether you are using the VEX® robotics platform or the fischertechnik® platform. Choose the appropriate resource as indicated by (VEX) or (FT) at the end of each resource.

NOTE: In preparation for teaching this lesson, it is strongly recommended that the teacher read the Lesson 3.2 Teacher Notes.

Day 1:

The teacher will present Concepts, Key Terms, and Essential Questions in order to provide a lesson overview.

The teacher will present Elements of Power.ppt.

Students will take notes using Activity 3.2.1 Elements of Power as a guide.

Optional: The teacher may wish to assign Key Terms 3.2 Crossword Puzzle after all key terms have been introduced.

Day 2:

The teacher will finish Elements of Power.ppt.

Students will work on Activity 3.2.1 Elements of Power.

Students will complete Activity 3.2.1 Elements of Power for homework, if necessary.

Day 3:

The teacher will assess students using Activity 3.2.1 Elements of Power Answer Key.

The teacher will review the formulas and exercises from Elements of Power.ppt.

The teacher will announce assessment for tomorrow on the elements of power.

Day 4:

The teacher will distribute Elements of Power Assessment.

The teacher will assess students using Elements of Power Assessment Answer Key.

Day 5-10:

VEX platform:

The teacher will determine which activity the students will complete. It is not necessary for students to complete both activities.

The teacher will distribute either Problem 3.2.3a Hydraulic Part Feeder (VEX) or Problem 3.2.3b Hydraulic Manipulator (VEX).

Students will work on either Problem 3.2.3a Hydraulic Part Feeder or Problem 3.2.3b Hydraulic Manipulator documenting progress in their engineering notebooks.

Students will complete work on either Problem 3.2.3a Hydraulic Part Feeder or Problem 3.2.3b Hydraulic Manipulator.
Students will present their prototypes.

The teacher will assess students using either Problem 3.2.3a Hydraulic Part Feeder Rubric (VEX) and Problem 3.2.3a Hydraulic Part Feeder ROBOTC Program (VEX) or Problem 3.2.3b Hydraulic Manipulator Rubric (VEX) and Problem 3.2.3b Hydraulic Manipulator Rubric ROBOTC Program (VEX).

fischertechnik platform:

The teacher will distribute Activity 3.2.2 Pneumatic Compressor Construction (FT).

Students will complete Activity 3.2.2 Pneumatic Compressor Construction (FT). This will serve as the basis for upcoming activities within this lesson.

The teacher will determine which activity the students will complete. It is not necessary for students to complete both activities.

The teacher will distribute either Problem 3.2.3a Pneumatic Part Feeder (FT) or Problem 3.2.3b Pneumatic Manipulator (FT).

Students will work on either Problem 3.2.3a Pneumatic Part Feeder (FT) or Problem 3.2.3b Pneumatic Manipulator (FT) documenting progress in their engineering notebooks.

Students will present their prototypes.

The teacher will assess students using either Problem 3.2.3a Pneumatic Part Feeder Rubric (FT) or Problem 3.2.3b Pneumatic Manipulator Rubric (FT).

Instructional Resources

NOTE: There are two sets of resources available based on whether you are using the VEX robotics platform or the fischertechnik platform. Choose the appropriate resource as indicated by (VEX) or (FT) at the end of each resource.

Presentations

Elements of Power

Documents

Activity 3.2.1 Elements of Power

VEX platform:

Problem 3.2.3a Hydraulic Part Feeder (VEX)
Problem 3.2.3b Hydraulic Manipulator (VEX)

fischertechnik platform:

Activity 3.2.2 Pneumatic Compressor Construction (FT)

Problem 3.2.3a Pneumatic Part Feeder (FT)
Problem 3.2.3b Pneumatic Manipulator (FT)

Key Terms 3.2 Crossword Puzzle
Answer Keys and Rubrics

**Key Terms 3.2 Crossword Puzzle Answer Key**

**Activity 3.2.1 Elements of Power Answer Key**

VEX platform:
- Problem 3.2.3a Hydraulic Part Feeder Rubric (VEX)
- Problem 3.2.3a Hydraulic Part Feeder ROBOTC Program (VEX)
- Problem 3.2.3b Hydraulic Manipulator Rubric (VEX)
- Problem 3.2.3b Hydraulic Manipulator Rubric ROBOTC Program (VEX)

fischertechnik platform:
- Problem 3.2.3a Pneumatic Part Feeder Rubric (FT)
- Problem 3.2.3b Pneumatic Manipulator Rubric (FT)

**Elements of Power Assessment Answer Key**

Teacher Guidelines

**Teacher Notes**

Elements of Power Assessment

**Reference Sources**


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for the English language arts*. Newark, DE: IRA; Urbana, IL: NCTE.


Lesson 3.3 Robotic Programming and Usage

Preface
As we have seen, automation has changed the face of manufacturing. How are automated robotic devices controlled? What is involved in creating a robotic device that can be used in manufacturing?

In this lesson students will be introduced to robot programming. Once students have learned how to program, they will manipulate the robot to follow several sets of commands. The knowledge that students gain in this lesson will prepare them for Unit 4, at which time students will create a class CIM cell.

Concepts
1. Basic programming skills include variable declaration, loops, and debugging.
2. A variety of robots and unique programming languages are used in the manufacturing industry.
3. Many everyday products use microcontrollers.
4. Robots are used to perform diverse functions and work in diverse environments.
5. The size of a robot is based on the work envelope and payload needed to perform the task.

Standards and Benchmarks Addressed

Standards for Technology and Literacy

Standard 2: Students will develop an understanding of the core concepts of technology.
BM Y: The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop.
BM Z: Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.
BM FF: Complex systems have many layers of controls and feedback loops to provide information.

Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
BM I: Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.

Standard 8: Students will develop an understanding of the attributes of design.
BM J: The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.
BM K: Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

Standard 9: Students will develop an understanding of engineering design.
BM K: A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.
BM L: The process of engineering design takes into account a number of factors.

Standard 11: Students will develop abilities to apply the design process.
BM R: Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.
Standard 12: Students will develop the abilities to use and maintain technological products and systems.

BM L: Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

BM O: Operate systems so that they function in the way they were designed.

Standard 16: Students will develop an understanding of and be able to select and use energy and power technologies.

BM N: Power systems must have a source of energy, a process, and loads.

Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.

BM M: Information and communication systems allow information to be transferred from human to human, human to machine, machine to human, and machine to machine.

BM O: Communication systems are made up of source, encoder, transmitter, receiver, decoder, storage, retrieval, and destination.

BM P: There are many ways to communicate information, such as graphic and electronic means.

BM Q: Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

Standard 19: Students will develop an understanding of and be able to select and use manufacturing technologies.

BM L: Servicing keeps products in good operating condition.

BM P: The interchangeability of parts increases the effectiveness of manufacturing processes.

National Science Education Standards

Standard K-12: Unifying Concepts and Processes: As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes;

Form and function

Standard E: Science and Technology: As a result of activities in grades 9-12, all students should develop

Abilities of technological design
Understandings about science and technology

Principles and Standards for School Mathematics

Number and Operations: Instructional programs from pre-kindergarten through grade 12 should enable all students to; understand numbers, ways of representing numbers, relationships among numbers, and number systems; understand meanings of operations and how they relate to one another; compute fluently and make reasonable estimates.

Algebra Standard: Instructional programs from pre-kindergarten through grade 12 should enable all students to represent and analyze mathematical situations and structures using algebraic symbols, use mathematical models to represent and understand quantitative relationships, and analyze change in various contexts.

Measurement Standard: Instructional programs from pre-kindergarten through grade 12 should enable all students to; understand measurable attributes of objects and the units, systems, and processes of measurement; apply appropriate
techniques, tools, and formulas to determine measurements.

**Problem Solving Standard:** Instructional programs from pre-kindergarten through grade 12 should enable all students to; build new mathematical knowledge through problem solving; solve problems that arise in mathematics and in other contexts; apply and adapt a variety of appropriate strategies to solve problems; monitor and reflect on the process of mathematical problem solving.

**Standards for English Language Arts**

**Standard 4:** Students adjust their use of spoken, written, and visual language (e.g. conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

**Performance Objectives**

It is expected that students will:
- Build the Lynxmotion robot if the robots are not already built.
- Learn the programming language needed to operate the Lynx robot.
- Create programs using robotic software that will allow the robot to perform a set of tasks.
- Configure servo motors to operate the Lynxmotion robot.
- Formulate a list of tasks in which the robot used in class can be used in a large scale CIM cell operation.

**Assessment**

*Explanation*

1. Students will explain what a microcontroller is and how it is used.
2. Students will learn the programming language needed to operate the robot used in class.

*Application*

3. Students will apply their knowledge of syntax by writing programs that operate servo motors.

**Essential Questions**

1. What is a microcontroller?
2. What is the programming language for the robot that you are using?
3. What are the different types of loops and how are they used?
4. What is the purpose of declaring variables and how are they used in programming?
5. How does an engineer determine the size of a robot designed to perform a specific task?

**Key Terms**

<table>
<thead>
<tr>
<th>Code</th>
<th>A set of computer instructions to perform a given operation or solve a given problem.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comment</td>
<td>A line of text in a computer program that is ignored by the computer. Comments are used to explain programs to humans.</td>
</tr>
<tr>
<td>Debug</td>
<td>The process of detecting and eliminating a device’s malfunctions.</td>
</tr>
<tr>
<td><strong>Declare</strong></td>
<td>The process of letting a program know that you plan to use a variable, what you want to call it, and how big it is.</td>
</tr>
<tr>
<td>-------------</td>
<td>---------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>End Effector</strong></td>
<td>A tool or gripper attached to the end of a robotic arm.</td>
</tr>
<tr>
<td><strong>Home</strong></td>
<td>A reference point from which all of the robot’s movements are measured.</td>
</tr>
<tr>
<td><strong>Input</strong></td>
<td>The data supplied to the computer for processing.</td>
</tr>
<tr>
<td><strong>Joint</strong></td>
<td>A single degree of arm rotation or translation.</td>
</tr>
<tr>
<td><strong>Loop</strong></td>
<td>The repeated execution of a series of instructions for a variable number of times.</td>
</tr>
<tr>
<td><strong>Microcontroller</strong></td>
<td>A microcomputer used for precise process control in data handling, communication, or manufacturing.</td>
</tr>
<tr>
<td><strong>Output</strong></td>
<td>Information transferred from the robot controller through the module to control external devices.</td>
</tr>
<tr>
<td><strong>Payload</strong></td>
<td>The maximum weight that can be carried by a robot in normal and continuous operation.</td>
</tr>
<tr>
<td><strong>Project</strong></td>
<td>The place to store what the arm does in the RIOS software.</td>
</tr>
<tr>
<td><strong>Reliability</strong></td>
<td>The probability that a component part, equipment, or system will satisfactorily perform its intended task.</td>
</tr>
<tr>
<td><strong>Repeatability</strong></td>
<td>A measurement of the deviation between a taught location point and the played-back location, under identical conditions of load and velocity.</td>
</tr>
<tr>
<td><strong>RIOS</strong></td>
<td>Robotic arm Interactive Operating System.</td>
</tr>
<tr>
<td><strong>Roll</strong></td>
<td>Circular motion at an axis, a rotation about the link axis of a robot’s wrist.</td>
</tr>
<tr>
<td><strong>Sequence</strong></td>
<td>A series of movement positions, or steps used in the RIOS software.</td>
</tr>
<tr>
<td><strong>Servo Motor</strong></td>
<td>Any motor that is modified to give feedback concerning the motor’s speed, direction of rotation, and number of revolutions.</td>
</tr>
<tr>
<td><strong>Stepper Motor</strong></td>
<td>A motor that rotates a predefined angle with every electrical impulse.</td>
</tr>
<tr>
<td><strong>Step</strong></td>
<td>The position that the arm moves to in the RIOS software.</td>
</tr>
<tr>
<td><strong>Subroutine</strong></td>
<td>A small program inside a large one. Used when the same series of commands are repeated multiple times.</td>
</tr>
<tr>
<td><strong>Syntax</strong></td>
<td>The rules governing the structure of statements used in a program.</td>
</tr>
<tr>
<td><strong>Work Envelope</strong></td>
<td>The outline surface of a robot’s work volume or the extreme point that it can reach.</td>
</tr>
</tbody>
</table>

**Day-by-Day Plans**

*Time: 17 days (If you are operating CIM for the first time, you will need to build or have the students build the robots prior to teaching this lesson.)*

**NOTE:** There are two sets of resources available based on whether you are using the VEX® robotics platform or the fischertechnik® platform. Choose the appropriate resource as indicated by (VEX) or (FT) at the end of each resource.

**NOTE:** In preparation for teaching this lesson, it is strongly recommended that the teacher read the Lesson 3.3 Teacher Notes.

**Day 1:**

The teacher will present Concepts, Key Terms, and Essential Questions in order to provide a lesson overview.

The teacher will present Robotics Overview.ppt slides 10-51.

Students will take notes in their journals.
Optional: The teacher may wish to assign Key Terms 3.3 Crossword Puzzle after all key terms have been introduced.

Day 2:

The teacher will present Lynxmotion Robotic Arm.ppt.
Students will take notes in their journals.
The teacher will access the Lynxmotion Arm Assembly link if Lynx robots are to be built.

Day 3-16:

The teacher will lead a discussion with the students on how to use the RIOS software. The teacher can use the Introduction to Rios.ppt to lead the discussion.

NOTE: The teacher may want to walk students through the first activity step by step.
The teacher will distribute the following activities for the students to complete while referring to the rubric.

Activity 3.3.1 Configuring the Lynxmotion Arm
Activity 3.3.2 Robot Arm Motions
Activity 3.3.3 Pick & Place

VEX platform:
Activity 3.3.4 Repeating a Sequence (VEX)
Lynx Robot Activity Rubric
Activity 3.3.5 Handshaking Configuration (VEX)
Activity 3.3.5 Handshaking Configuration Schematic (VEX)
Project 3.3.6 Handshaking (VEX)

fischertechnik platform:
Activity 3.3.4 Repeating a Sequence (FT)
Lynx Robot Activity Rubric
Activity 3.3.5 Handshaking Configuration (FT)
Activity 3.3.5 Handshaking Configuration Schematic (FT)
Project 3.3.6 Handshaking (FT)

Students will complete the Going Beyond activities below as time allows.

VEX platform:
Project 3.3.7 Coat Weld XYZ (VEX)
Project 3.3.8 Chemical Treating (VEX)

fischertechnik platform:
Project 3.3.7 Coat Weld XYZ (FT)
Project 3.3.8 Chemical Treating (FT)

The teacher will evaluate Activities 3.3.1 – 3.3.8 using the Lynxmotion Arm Activity Rubric.

Note: The teacher can access other resources for this lesson using the L3.3 Resource link. There is also a video titled Lynxmotion Arm Demonstration available which shows Lynxmotion Robot performing functions. Refer to the Lesson 3.3 Teacher Notes for instructions.
Day 17:

Students will complete the activity or project that they are currently working on.

The teacher will explain the upcoming CIM Cell Project to be completed during Unit 4.

Students will begin to formulate ways in which the robots can be used together and how their functions can be used in the CIM Cell in the next unit.

Instructional Resources

NOTE: There are two sets of resources available based on whether you are using the VEX robotics platform or the fischertechnik platform. Choose the appropriate resource as indicated by (VEX) or (FT) at the end of each resource.

Presentations

Robotics Overview
Lynxmotion Robotic Arm
Introduction to Rios

Documents

Activity 3.3.1 Configuring the Lynxmotion Arm
Activity 3.3.2 Robot Arm Motions
Activity 3.3.3 Pick & Place

VEX Platform

Activity 3.3.4 Repeating a Sequence (VEX)
Activity 3.3.5 Handshaking Configuration (VEX)
Activity 3.3.5 Handshaking Configuration Schematic (VEX)
Project 3.3.6 Handshaking (VEX)
Project 3.3.7 Coating Welding (VEX)
Project 3.3.8 Chemical Treating (VEX)

fischertechnik Platform

Activity 3.3.4 Repeating a Sequence (FT)
Activity 3.3.5 Handshaking Configuration (FT)
Activity 3.3.5 Handshaking Configuration Schematic (FT)
Project 3.3.6 Handshaking (FT)
Project 3.3.7 Coating Welding (FT)
Project 3.3.8 Chemical Treating (FT)

Key Terms 3.3 Crossword Puzzle

Teacher Guidelines

Teacher Notes
L3.3 Resource
Lynx Assembly Guides or www.lynxmotion.com
RIOS Setup
Answer Keys and Rubrics

Key Terms 3.3 Crossword Puzzle Answer Key
Lynxmotion Arm Activity Rubric

Reference Sources


National Council of Teachers of English (NCTE) and International Reading Association (IRA) (1996). *Standards for the English language arts*. Newark, DE: IRA; Urbana, IL: NCTE.


Preface

Many types of computer integrated manufacturing systems exist. The goal of such systems is to use computers to control a system that makes products safely and efficiently. As manufacturing systems have become more complex, so too has the diversity of career opportunities available in the manufacturing industry.

In this unit students will explore a manufacturing career and visit a manufacturing facility. Students will design, build, and test a manufacturing work cell while integrating concepts and skills learned throughout this course.

Lessons

| Lesson 4.1 Types of CIM Systems | htm | doc |
| Lesson 4.2 Integration of Manufacturing Elements | htm | doc |

Concepts

1. The process of mass production is used when the same product is created repeatedly.
2. A workcell is a group of machines in which each individual machine has its own specialty.
3. A flexible manufacturing system is one that can adapt to a wide variety of products.
4. Tradeoffs are made when one system is utilized over another.
5. Process flow design has a major impact on overall production time and product profit.
6. During the design and development process, flowcharting is used to plan and depict the detailed process flow for an entire system and all of its subsystems.
7. Flowcharting can be used to illustrate the phases of the product development process.
8. Manufacturing and automation careers are varied in scope and location.
9. Process flow design has a major impact on overall production time and product profit.
10. During the design and development process, flowcharting is used to plan and depict the detailed process flow for an entire system as well as all of its subsystems.
11. Flowcharting can be used to illustrate the overall phases of the product development process.
12. Safe operating procedures must be addressed in a CIM environment at all times to avoid serious injury.
13. Tradeoffs occur between efficiency and cost when choosing a manufacturing system.
14. Engineers choose appropriate sensors to ensure high quality part production.
15. Proper sequencing of automated operations is important in factory design.
16. Identification of correct electrical and fluid power systems is required to complete the desired manufacturing system.
Essential Questions

Lesson 4.1 Types of CIM Systems

1. What is an FMS?
2. What advantages do FMS systems have over mass production systems?
3. What components comprise an FMS?
4. What is a process design chart? How can it help streamline a manufacturing process?
5. What manufacturing or automation career(s) is appealing?

Lesson 4.2 Integration of Manufacturing Elements

6. What safety issues are common in CIM systems?
7. How do engineers choose power systems that will integrate within a CIM system?
8. Which machine tools are necessary to fabricate the part or parts?
9. What are the appropriate sensors to ensure quality parts and smooth process flow?
10. How can a CIM system be automated?

Unit Evaluation

The Essential Questions and Conclusion questions at the end of each activity may be used along with the Assessment suggestions provided in each lesson to develop summative assessment tools, such as tests or end of unit projects.
Lesson 4.1 Types of CIM Systems

Preface

Computer Integrated Manufacturing (CIM) is the computer-based network that binds every component of the manufacturing plant operations, such as machine operations, material handling, process flow, inventory, and parts ordering.

An ideal CIM plant should be capable of making a wide variety of items in the same day. Such a CIM system can keep track of the inventory so that the appropriate materials are supplied on a continuous basis. A CIM system will also coordinate the different programs needed to produce parts. The system should be capable of changing from the production of one item to another in very little time.

In this lesson students will study the different CIM systems and determine how they are used in industry. Students will also learn about process flow and apply this to production.

Concepts

1. The process of mass production is used when the same product is created repeatedly.
2. A workcell is a group of machines in which each individual machine has its own specialty.
3. A flexible manufacturing system is one that can adapt to a wide variety of products.
4. Tradeoffs are made when one system is utilized over another.
5. Process flow design has a major impact on overall production time and product profit.
6. During the design and development process, flowcharting is used to plan and depict the detailed process flow for an entire system and all of its subsystems.
7. Flowcharting can be used to illustrate the phases of the product development process.
8. Manufacturing and automation careers are varied in scope and location.

Standards and Benchmarks Addressed

Standards for Technological Literacy

Standard 1: Students will develop an understanding of the characteristics and scope of technology.

BM J: The nature and development of technological knowledge and processes are functions of the setting.

BM K: The rate of technological development and diffusion is increasing rapidly.

Standard 12: Students will develop the abilities to use and maintain technological products and systems.

BM L: Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.
National Science Education Standards

Content Standard A: Science As Inquiry: As a result of activities in grades 9-12, all students should develop;

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Standard E: Science and Technology: As a result of activities in grades 9-12, all students should develop

- Abilities of technological design
- Understandings about science and technology

Standard F: Science in Personal and Social Perspectives: As a result of activities in grades 9-12, all students should develop understanding of;

- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

History and Nature of Science Standard G: As a result of activities in grades 9-12, all students should develop understanding of

- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

Standards for English Language Arts

Standard 1: Students read a wide range of print and non-print texts to acquire new information and to respond to the needs and demands of society and the workplace.

Standard 4: Students adjust their use of spoken, written, and visual language (e.g. conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 5: Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences and for a variety of purposes.

Standard 8: Students use a variety of technological and informational resources (e.g. libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Standard 12: Students use spoken, written and visual language to accomplish their own purposes (e.g. for learning, enjoyment, persuasion, and the exchange of information).

Performance Objectives

*It is expected that students will:*

- Identify the three categories of CIM systems.
- Compare and contrast the benefits and drawbacks of the three categories of CIM systems.
- Identify the components of a FMS.
- Create a process design chart for a manufacturing process.
Explore a manufacturing or automation career of interest and determine the appropriateness and steps required to be a professional in that role.

**Assessment**

*Explanation*

1. Explain the three types of CIM systems.
2. Explain the advantages and disadvantages of the three systems.

*Application*

3. Apply knowledge of the three manufacturing systems to identify an actual manufacturing system.
4. Apply knowledge of process flow to create a design chart for a manufacturing process.

*Self-Knowledge*

5. Students will prepare an outline of steps needed to become a manufacturing or automation professional.

**Essential Questions**

1. What is an FMS?
2. What advantages do FMS systems have over mass production systems?
3. What components comprise an FMS?
4. What is a process design chart? How can it help streamline a manufacturing process?
5. What manufacturing or automation career(s) is appealing?

**Key Terms**

| **Flexible Manufacturing System (FMS)** | Groups of CNC machine tools that are highly integrated with automated material handling and computerized control systems. |
| **Mass Production** | A manufacturing process that can include specialized and single-purpose machines to produce a great many identical parts. |
| **Process Design Chart** | A graphic representation of events occurring in production. |
| **Stand-alone** | A multi-pallet system that can work on several types of parts at the same time but is independent of other systems. A stand-alone system can be integrated into an FMS. |
| **Workcell** | A manufacturing unit consisting of a group of work stations and their interconnecting materials-transport mechanisms. |

**Day-by-Day Activities**

*Time: 10 Days*

**NOTE:** In preparation for teaching this lesson, it is strongly recommended that the teacher read the Lesson 4.1 Teacher Notes.
Day 1 – 2:

The teacher will present **Concepts, Key Terms**, and **Essential Questions** and provide a lesson overview.

The teacher will present **Types of CIM Systems.ppt**.

Students will take notes in their journals.

Optional: The teacher may wish to assign **Key Terms 4.1 Crossword Puzzle** after all key terms have been introduced.

Day 3-10:

Students will tour a local manufacturing facility or participate in a virtual tour.

Students will complete **Activity 4.1.1 Manufacturing Field Trip**.

The teacher will assess students according to completion.

The teacher will distribute **Project 4.1.2 Manufacturing and Automation Careers**.

Optional: The teacher can distribute the **Citations APA Styles**.

The teacher will assess the students using the **Project 4.1.2 Manufacturing and Automation Careers Written Report Rubric** and **Project 4.1.2 Manufacturing and Automation Careers Presentation Rubric**.

Students will complete **Lesson 4.1 Assessment**.

The teacher will assess students using the **Lesson 4.1 Assessment Answer Key**.

### Instructional Resources

**Presentations**

Types of CIM Systems

**Documents**

Key Terms 4.1 Crossword Puzzle

Activity 4.1.1 Manufacturing Field Trip

Project 4.1.2 Manufacturing and Automation Careers

Citations APA Styles

**Answer Keys and Rubrics**

Key Terms 4.1 Crossword Puzzle Answer Key

Project 4.1.2 Manufacturing and Automation Careers Written Report Rubric

Project 4.1.2 Manufacturing and Automation Careers Presentation Rubric

Lesson 4.1 Assessment Answer Key

**Teacher Guidelines**

Teacher Notes

Lesson 4.1 Assessment
Reference Sources


Lesson 4.2 Integration of Manufacturing Elements

Preface
Students should now know the various components of a manufacturing system. Now it is time to combine the components. If students are to fully understand a complete manufacturing experience, it is critical that they take an active role in the process from beginning to end.

In this lesson students will choose a product to manufacture. Within their teams, they will decide the best approach for manufacturing their products, with the constraint that the production must include at least two automated elements. Students will take on team roles and assess themselves and their teammates.

Concepts
1. Process flow design has a major impact on overall production time and product profit.
2. During the design and development process, flowcharting is used to plan and depict the detailed process flow for an entire system as well as all of its subsystems.
3. Flowcharting can be used to illustrate the overall phases of the product development process.
4. Safe operating procedures must be addressed in a CIM environment at all times to avoid serious injury.
5. Tradeoffs occur between efficiency and cost when choosing a manufacturing system.
6. Engineers choose appropriate sensors to ensure high quality part production.
7. Proper sequencing of automated operations is important in factory design.
8. Identification of correct electrical and fluid power systems is required to complete the desired manufacturing system.

Standards and Benchmarks Addressed
Standards for Technological Literacy

Standard 2: Students will develop an understanding of the core concepts of technology.
BM W: Systems’ thinking applies logic and creativity with appropriate compromises in complex real-life problems.
BM X: Systems, which are the building blocks of technology, are embedded within larger technological, social, and environmental systems.
BM Y: The stability of a technological system is influenced by all of the components in the system especially those in the feedback loop.
BM Z: Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.
BM AA: Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.
BM BB: New technologies create new processes.
BM DD: Quality control is a planned process to ensure that a product, service, or system meets established criteria.
BM EE: Management is the process of planning, organizing, and controlling work.
BM FF: Complex systems have many layers of controls and feedback loops to provide information.

Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
BM I: Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.

Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

BM F: Troubleshooting is a problem-solving method used to identify the cause of a malfunction in a technological system.

BM G: Invention is a process of turning ideas and imagination into devices and systems.

BM H: Some technological problems are best solved through experimentation.

BM I: Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace.

BM J: Technological problems must be researched before they can be solved.

BM L: Many technological problems require a multidisciplinary approach.

Standard 8: Students will develop an understanding of the attributes of design.

BM J: The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

BM K: Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

Standard 9: Students will develop an understanding of engineering design.

BM K: A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

BM L: The process of engineering design takes into account a number of factors.

Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

BM L: Many technological problems require a multidisciplinary approach.

Standard 11: Students will develop abilities to apply the design process.

BM M: Identify the design problem to solve and decide whether or not to address it.

BM N: Identify criteria and constraints and determine how these will affect the design process.

BM O: Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

BM P: Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

BM Q: Develop and produce a product or system using a design process.

BM R: Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

Standard 12: Students will develop the abilities to use and maintain technological products and systems.

BM L: Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

BM M: Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.

BM N: Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.

BM O: Operate systems so that they function in the way they were designed.
Standard 16: Complex systems have many layers of controls and feedback loops to provide information.

BM K: Energy can be grouped into major forms: thermal, radiant, electrical, mechanical, chemical, nuclear, and others.

BM N: Power systems must have a source of energy, a process, and loads.

Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.

BM M: Information and communication systems allow information to be transferred from human to human, human to machine, machine to human, and machine to machine.

BM O: Communication systems are made up of source, encoder, transmitter, receiver, decoder, storage, retrieval, and destination.

BM P: There are many ways to communicate information, such as graphic and electronic means.

BM Q: Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

Standard 19: Students will develop an understanding of and be able to select and use manufacturing technologies.

BM L: Servicing keeps products in good operating condition.

BM P: The interchangeability of parts increases the effectiveness of manufacturing processes.

National Science Education Standards

Standard K-12: Unifying Concepts and Processes: As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes:

- Systems, order, and organization
- Form and function

Content Standard A: Science As Inquiry: As a result of activities in grades 9-12, all students should develop:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Physical Science Standard B: As a result of activities in grades 9-12, all students should develop an understanding of

- Motions and forces

Standard E: Science and Technology: As a result of activities in grades 9-12, all students should develop

- Abilities of technological design
- Understandings about science and technology
Principles and Standards for School Mathematics

Number and Operations: Instructional programs from pre-kindergarten through grade 12 should enable all students to; understand numbers, ways of representing numbers, relationships among numbers, and number systems; understand meanings of operations and how they relate to one another; compute fluently and make reasonable estimates.

Algebra: Instructional programs from pre-kindergarten through grade 12 should enable all students to represent and analyze mathematical situations and structures using algebraic symbols and use mathematical models to represent and understand quantitative relationships.

Geometry: Instructional programs from pre-kindergarten through grade 12 should enable all students to analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships; specify locations and describe spatial relationships using coordinate geometry and other representational systems; apply transformations and use symmetry to analyze mathematical situations; use visualization, spatial reasoning, and geometric modeling to solve problems.

Measurement: Instructional programs from pre-kindergarten through grade 12 should enable all students to understand measurable attributes of objects and the units, systems, and processes of measurement; apply appropriate techniques, tools, and formulas to determine measurements.

Data Analysis and Probability: Instructional programs from pre-kindergarten through grade 12 should enable all students to formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them; select and use appropriate statistical methods to analyze data; develop and evaluate inferences and predictions that are based on data; understand and apply basic concepts of probability.

Problem Solving: Instructional programs from pre-kindergarten through grade 12 should enable all students to build new mathematical knowledge through problem solving; solve problems that arise in mathematics and in other contexts; apply and adapt a variety of appropriate strategies to solve problems; monitor and reflect on the process of mathematical problem solving.

Communication: Instructional programs from pre-kindergarten through grade 12 should enable all students to organize and consolidate their mathematical thinking through communication; communicate their mathematical thinking coherently and clearly to peers, teachers, and others; analyze and evaluate the mathematical thinking and strategies of others; use the language of mathematics to express mathematical ideas precisely.

Connections: Instructional programs from pre-kindergarten through grade 12 should enable all students to recognize and use connections among mathematical ideas; understand how mathematical ideas interconnect and build on one another to produce a coherent whole; recognize and apply mathematics in contexts outside of mathematics.

Representation: Instructional programs from pre-kindergarten through grade 12 should enable all students to create and use representations to organize, record, and communicate mathematical ideas; select, apply, and translate among mathematical representations to solve problems; use representations to model and interpret physical, social, and mathematical phenomena.
English Standards for English Language Arts

Standard 4: Students adjust their use of spoken, written, and visual language (e.g. conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 12: Students use spoken, written and visual language to accomplish their own purposes (e.g. for learning, enjoyment, persuasion, and the exchange of information).

Performance Objectives

*It is expected that students will:*

- Identify the potential safety issues with a CIM system and identify solutions for these problems.
- Understand the significance of teamwork and communication.
- Design a manufacturing system that contains at least two automated components.
- Complete the construction of each individual component of the miniature FMS and verify that each component works.
- Assemble components into a working miniature FMS.
- Refine each component to improve the total process flow and cycle time.
- Start and maintain a journal that documents daily work.

Assessment

Explanation

1. Students will explain the safety issues associated with CIM systems.
2. Students will identify team roles and the significance of communication within a team.

Application

3. Students will apply their knowledge of CIM systems to create a miniature FMS.

Self-Knowledge

4. Students will select appropriate machine tools for the part being produced.
5. Students will determine appropriate sensors for producing quality parts and regulating the process flow.
6. Students will determine the required automation necessary to control the entire process.
7. Students will determine the most logical sequence for processing operations.
8. Students will determine which power systems are required for their automated system.
9. Students will present their final system layout and answer any essential questions as to why they chose certain components.
10. Students will construct an actual working system.

Essential Questions

1. What safety issues are common in CIM systems?
2. How do engineers choose power systems that will integrate within a CIM system?
3. Which machine tools are necessary to fabricate the part or parts?
4. What are the appropriate sensors to ensure quality parts and smooth process flow?
5. How can a CIM system be automated?

**Key Terms**

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay</td>
<td>Pause in the manufacturing process; material is held for the next operation.</td>
</tr>
<tr>
<td>Flow Process Chart</td>
<td>A diagram that indicates the sequence of events in a manufacturing cell. The type of machines and tools are also listed.</td>
</tr>
<tr>
<td>Inspection</td>
<td>Quality control.</td>
</tr>
<tr>
<td>Operation</td>
<td>The material is changed. That is, it undergoes a manufacturing process, such as being cut, sanded, etc.</td>
</tr>
<tr>
<td>Process Flow</td>
<td>The order of tasks which occur in a manufacturing system. It allows for improvement of the process.</td>
</tr>
<tr>
<td>Storage</td>
<td>Placing of the material in a protected location.</td>
</tr>
<tr>
<td>Transportation</td>
<td>Movement of the object from one location to another.</td>
</tr>
</tbody>
</table>

**Day-by-Day Plans**

*Time: 37 Days*

**NOTE:** In preparation for teaching this lesson, it is strongly recommended that the teacher read the Lesson 4.2 Teacher Notes.

**NOTE:** There are two sets of resources available based on whether you are using the VEX® robotics platform or the fischertechnik® platform. Choose the appropriate resource as indicated by (VEX) or (FT) at the end of each resource.

**Day 1 – 3:**

The teacher will present **Concepts, Key Terms, and Essential Questions** and provide a lesson overview.

- The teacher will present **Process Flow.ppt**.
- The teacher will introduce and distribute **Activity 4.2.1 Process Flow** and **Activity 4.2.1 Process Flow Worksheet**.
- Students will work on **Activity 4.2.1 Process Flow**.
- The teacher will assess students based on completion.

**Optional:** The teacher may wish to assign **Key Terms 4.2 Crossword Puzzle** after all key terms have been introduced.

**Days 4 – 35:**

**VEX platform:**

- The teacher will introduce and distribute **Problem 4.2.2 Factory System (VEX)** and **Problem 4.2.2 Factory System Rubric**.
- Students will work on Problem 4.2.2 Factory System (VEX).

**Fischertechnik platform:**

- The teacher will introduce and distribute **Problem 4.2.2 Factory System (FT)** and **Problem 4.2.2 Factory System Rubric**.
Students will work on Problem 4.2.2 Factory System.

Day 36 – 37:
The students will complete and present the Problem 4.2.2 Factory System.
The teacher will assess students using Problem 4.2.2 Factory System Rubric.

Instructional Resources
Presentations
Process Flow
Documents
Activity 4.2.1 Process Flow
Activity 4.2.1 Process Flow Worksheet
Problem 4.2.2 Factory System (VEX)
Problem 4.2.2 Factory System (FT)
Key Terms 4.2 Crossword Puzzle
Answer Keys and Rubrics
Key Terms 4.2 Crossword Puzzle Answer Key
Problem 4.2.2 Factory System Rubric
Teacher Guidelines
Lesson 4.2 Teacher Notes

Reference Sources

**Glossary**

**3D Printing**
1) Rapid prototyping processes use systems that are low cost, small in size, fast, easy to use, and often suitable for an office environment. 2) Collective term for all rapid prototyping activities.

**A**

**Absolute**
System in which positions are given with respect to a fixed point, usually the origin.

**Additive Process**
Fabrication of a part by adding material.

**Address Character**
A letter used in G & M code programming to designate a class of functions.

**Ampere**
The unit of electric current in the meter-kilogram-second (MKS) system of units.

**Assembling**
The process of putting a product together out of separate parts.

**Automated Guidance Vehicle (AGV)**
A computer-controlled system that uses pallets and other interface equipment to transport work pieces to NC machine tools and other equipment in a flexible manufacturing system.

**Automated Storage and Retrieval System (ASRS)**
A system that moves material either vertically or horizontally between a storage compartment and a transfer station or within a process.

**Automation**
The use of technology to ease human labor or extend the mental or physical capabilities of humans.

**B**

**Bench Grinder**
A grinding machine that has been mounted to a bench or table. The grinding wheels mount directly onto the motor shaft. Normally one wheel is coarse, for roughing, and the other is fine, for finishing.

**Block**
A single line of code in an NC part program.

**Build Time**
Length of time for the physical construction of a rapid prototype, excluding preparation and post-processing time. Also known as run time.

**C**

**Casting**
The process in which a solid material is made into a liquid, poured into a mold, and allowed to harden in the shape of the mold.

**Ceramics**
Any of various hard, brittle, heat-resistant, and corrosion-resistant materials made by shaping and then firing a nonmetallic mineral, such as clay, at a high temperature.

**Closed Loop**
A system that uses feedback from the output to control the input.

**Competent**
Properly or sufficiently qualified; capable or efficient.

**Computer Aided Design (CAD)**
The use of computers in converting the initial idea for a product into a detailed engineering design.

**Computer Aided Manufacturing (CAM)**
The use of computers in converting engineering designs into finished products.

**Computer Integrated Manufacturing (CIM)**
A company-wide management philosophy for planning, integration, and implementation of automation.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer Numerical Control (CNC)</td>
<td>A numerical control method in which one computer is linked with one machine tool to perform NC functions.</td>
</tr>
<tr>
<td>Concept Model</td>
<td>Physical model intended primarily for design review and not meant to be sufficiently accurate or durable for full functional or physical testing.</td>
</tr>
<tr>
<td>Conditioning Process</td>
<td>Process in which the properties of a material are changed using mechanical, thermal, or chemical means.</td>
</tr>
<tr>
<td>Control System</td>
<td>A system in which one or more outputs are forced to change in a desired manner as time progresses.</td>
</tr>
<tr>
<td>Decision Block</td>
<td>The diamond-shaped block used for YES/NO questions. These blocks have two outputs, 1 (for yes) and 2 (for no).</td>
</tr>
<tr>
<td>Defective</td>
<td>Imperfect in form or function.</td>
</tr>
<tr>
<td>Degrees of Freedom</td>
<td>Motion variable for a robot axis; each requires a joint.</td>
</tr>
<tr>
<td>Dependent Variable</td>
<td>A variable whose value depends on the value of another variable.</td>
</tr>
<tr>
<td>Design Flaws</td>
<td>An imperfection in an object or machine.</td>
</tr>
<tr>
<td>Die Casting</td>
<td>Similar to permanent mold casting except that the metal is injected into the mold under high pressure.</td>
</tr>
<tr>
<td>Durability</td>
<td>The quality of equipment or goods of continuing to be useful after an extended period of time and usage.</td>
</tr>
<tr>
<td>Economics</td>
<td>Dealing with production, distribution, and consumption of products or wealth.</td>
</tr>
<tr>
<td>Electrical Current (I)</td>
<td>The net transfer of electrical charge per unit time.</td>
</tr>
<tr>
<td>Electrical Discharge</td>
<td>A process by which an electrode spark is used to erode small amounts of material from a work piece.</td>
</tr>
<tr>
<td>Machining (EDM)</td>
<td>A process by which an electrode spark is used to erode small amounts of material from a work piece.</td>
</tr>
<tr>
<td>Electrochemical Machining (ECM)</td>
<td>A process in which a stream of electrolyte (typically salt water) is pumped at high pressure through a gap between the positively charged work and the negatively charged tool (electrode).</td>
</tr>
<tr>
<td>Ethics</td>
<td>The standards for ethical or moral behavior of a particular group. In our case it will be the Engineering Code of Ethics.</td>
</tr>
<tr>
<td>Exhaustible Resources</td>
<td>Resources of which there are a limited supply.</td>
</tr>
<tr>
<td>Feed</td>
<td>The distance advanced by the cutting tool along the length of the work for every revolution of the spindle.</td>
</tr>
<tr>
<td>Finishing Process</td>
<td>Machining a surface to size with a fine feed produced in a lathe, milling machine, or grinder.</td>
</tr>
<tr>
<td>Fixed Costs</td>
<td>A periodic cost that remains (more or less) unchanged irrespective of the output level or sales revenue of a firm.</td>
</tr>
<tr>
<td>Fixture</td>
<td>A device designed and built for holding a particular piece of work for machining operations.</td>
</tr>
<tr>
<td>Flexible Manufacturing System (FMS)</td>
<td>A group of processing or work stations connected by an automated material handling system and operated as an integrated system under computer control.</td>
</tr>
<tr>
<td>Flow Chart</td>
<td>A graphical representation of the progress of a system for the definition, analysis, or solution of a data-processing or manufacturing problem.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>------</td>
<td>------------</td>
</tr>
<tr>
<td><strong>Flow Lines</strong></td>
<td>The connecting line or arrow between symbols on a flow chart.</td>
</tr>
<tr>
<td><strong>Forming Process</strong></td>
<td>A process that changes the size and shape of a material by a combination of force and a shaped form.</td>
</tr>
<tr>
<td><strong>Force</strong></td>
<td>The influence on a body which causes it to accelerate.</td>
</tr>
<tr>
<td><strong>Forging</strong></td>
<td>A process by which metal is heated and shaped by plastic deformation by suitably applying compressive force.</td>
</tr>
<tr>
<td><strong>Functionality</strong></td>
<td>The ability of a product to do the job for which it was intended.</td>
</tr>
<tr>
<td><strong>G &amp; M Codes</strong></td>
<td>Programming code used to control CNC machines.</td>
</tr>
<tr>
<td><strong>Grinding</strong></td>
<td>An operation that removes material by rotating an abrasive wheel or belt against the work.</td>
</tr>
<tr>
<td><strong>Gripper</strong></td>
<td>End effector that is designed to pick up, hold, and/or release an object or to move it.</td>
</tr>
<tr>
<td><strong>Horsepower (HP)</strong></td>
<td>The unit of power in the British engineering system equal to 550 foot-pounds per second.</td>
</tr>
<tr>
<td><strong>Hydraulic</strong></td>
<td>Operated or affected by the action of water or other fluid of low viscosity.</td>
</tr>
<tr>
<td><strong>Incremental</strong></td>
<td>A system in which each position is taken from the one prior. Also called relative.</td>
</tr>
<tr>
<td><strong>Independent Variable</strong></td>
<td>The controlling factor between variables, on which the value of the other variable depends.</td>
</tr>
<tr>
<td><strong>Industrial Material</strong></td>
<td>Material that has been changed from raw material so that it is ready to be used in manufacturing. Also referred to as standard stock.</td>
</tr>
<tr>
<td><strong>Injection Molding</strong></td>
<td>A process during which plastic is heated in a machine and forced into a cavity by a screw or ram. The material solidifies and is then ejected.</td>
</tr>
<tr>
<td><strong>Input/Output Block</strong></td>
<td>A function that makes information available for processing or records processed information.</td>
</tr>
<tr>
<td><strong>Interface</strong></td>
<td>The connection between the computer and the control system.</td>
</tr>
<tr>
<td><strong>Inventory Control</strong></td>
<td>Systematic management of the balance on hand of inventory items, involving the supply, storage, distribution, and recording of items.</td>
</tr>
<tr>
<td><strong>Iterative</strong></td>
<td>Process flow that may repeat or skip steps until some condition is satisfied.</td>
</tr>
<tr>
<td><strong>Jig</strong></td>
<td>A device that holds and locates a piece of work and guides the tools that operate upon it.</td>
</tr>
<tr>
<td><strong>Joule</strong></td>
<td>The unit of energy or work in the MKS system of units, equal to the work done by a force of one Newton-meter.</td>
</tr>
<tr>
<td><strong>Just in Time (JIT)</strong></td>
<td>A system that eliminates work-in-process (WIP) inventory by scheduling arrival of parts and assemblies for an operation at the time they are needed and not before.</td>
</tr>
</tbody>
</table>
K

Kaizen
Continuous improvement that involves all participants.

L

Laser
An acronym for Light Amplification by Stimulated Emission of Radiation. Some common uses for lasers are cutting, measuring, and guidance systems.

Lathe
A machine tool used for turning cylindrical forms on work pieces. Modern lathes are often equipped with digital readouts and numerical controls.

Lean Manufacturing
The systematic elimination of waste.

M

Machinability
The ease or difficulty of machining as it relates to the hardness of a material to be cut.

Manufacturing
A series of interrelated activities and operations that involve product design and the planning, producing, materials control, quality assurance, management, and marketing of that product.

Mass Production
A manufacturing process that can include specialized and single-purpose machines to produce a great many identical parts.

Materials Handling
The loading, moving, and unloading of materials.

Metals
Any of a category of electropositive elements that usually have a shiny surface, are generally good conductors of heat and electricity, and can be melted or fused, hammered into thin sheets, or drawn into wires.

Milling Machine
A machine that removes material from work by means of a rotary cutter.

Modal
Information that is retained by the system until new information is obtained.

Molding
A manufacturing process in which the industrial material is made into a liquid. The liquid is then introduced (poured or forced) into a prepared mold of proper design.

Morality
Rules relating to principles of right and wrong in behavior.

N

Non-Value Added (NVA)
Typically generates a zero or negative return on the investment of resources and usually can be eliminated without impairing a process.

Numerical Control (NC)
Any controlled equipment that allows an operator to program its movements through a series of coded instructions consisting of numbers, letters, symbols, etc.

Open Loop
A control system that has no means for comparing the output with input for control purposes. An open-loop system often requires human intervention.

Overhead
The general, fixed cost of running a business, such as rent, lighting, and heating expenses, which cannot be charged or attributed to a specific product or part of the work operation.
<table>
<thead>
<tr>
<th><strong>Parameter</strong></th>
<th>Attribute of a feature, such as a dimension, that can be modified.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Part Program</strong></td>
<td>The instructions written by the programmer to produce a workpiece.</td>
</tr>
<tr>
<td><strong>Photopolymer</strong></td>
<td>Liquid resin material that utilizes light (visible or ultra-violet) as a catalyst to initiate polymerization, in which the material cross-links and solidifies. This technique is used by various rapid prototyping technologies.</td>
</tr>
<tr>
<td><strong>Plastics</strong></td>
<td>Materials that undergo a permanent change in shape or size when subjected to a particular amount of stress.</td>
</tr>
<tr>
<td><strong>Pneumatic</strong></td>
<td>Pertaining to or operated by air or other gas.</td>
</tr>
<tr>
<td><strong>Post Processing</strong></td>
<td>A common practice that includes clean up and finishing procedures on models after they are removed from the rapid prototyping machine. It may also include mechanical or chemical removal of support structures, powder removal, and surface finishing.</td>
</tr>
<tr>
<td><strong>Potentiometer</strong></td>
<td>A variable resistor.</td>
</tr>
<tr>
<td><strong>Pounds per Square Inch (PSI)</strong></td>
<td>Pounds per square inch, a unit of pressure.</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>The rate at which work is done.</td>
</tr>
<tr>
<td><strong>Preparatory Code</strong></td>
<td>Codes that carry out machining operations or establish machine settings; G-codes.</td>
</tr>
<tr>
<td><strong>Primary Processing</strong></td>
<td>The first step in manufacturing where raw materials are processed into a usable form for further manufacture.</td>
</tr>
<tr>
<td><strong>Process Block</strong></td>
<td>Part of a flowchart that tells the program what action to take.</td>
</tr>
<tr>
<td><strong>Process Design Chart</strong></td>
<td>A graphic representation of events occurring in production.</td>
</tr>
<tr>
<td><strong>Profit</strong></td>
<td>The monetary surplus left to a producer or employer after deducting wages, rent, cost of raw materials, etc.</td>
</tr>
<tr>
<td><strong>Prototype</strong></td>
<td>A full-scale working model used to test a design concept by making actual observations and necessary adjustments.</td>
</tr>
<tr>
<td><strong>Purpose</strong></td>
<td>What one intends to do or bring about.</td>
</tr>
</tbody>
</table>

**Q**

| **Quality Control** | The process of making sure that products or services meet consistently high standards. |

**R**

| **Rapid Prototyping** | Computer-controlled additive fabrication. Commonly used synonyms for RP are three-dimensional printing, additive fabrication, freeform fabrication, solid freeform fabrication, and stereolithography. Note that most of these synonyms are imprecise. |
| **Raw Materials** | Basic substance in its natural, modified, or semi-processed state, used as an input to a production process for subsequent modification or transformation into a finished good. |
| **Renewable Resources** | Biological materials that can be replaced. |
| **Revolutions per Minute (RPM)** | Revolutions per minute, a unit of velocity. |
| **Robot** | A mechanical device that can be programmed to perform a variety of tasks of manipulation and locomotion under automatic control. |
Robotics
The science and technology of robots, their design, manufacture, and application.

Sand Casting
A process of pressing moist sand around a pattern to make a mold. The pattern is removed, leaving a cavity in the sand. The cavity is the mold that will be filled with liquid metal. The result will be a casting that is identical in shape to the original pattern.

Schematic
A diagram that uses special symbols in place of actual pictures. In a wiring schematic, for example, a squiggly line is used to represent a resistor.

Separating
A process that removes excess material to change the size, shape, or surface.

Sequential
Occurring in regular succession without gaps.

Servo Motor
Any motor that is modified to give feedback concerning the motor's speed, direction of rotation, and number of revolutions.

Simulation
A representation of a situation or problem with a similar but simpler model or a more easily manipulated model in order to determine experimental results.

Six SIGMA
Six Sigma at many organizations is a measure of quality that strives for near perfection. To achieve Six Sigma, a process must not produce more than 3.4 defects per million opportunities.

Spindle Speed
The number of revolutions per minute (RPM) that is made by the cutting tool of a machine.

Stand-alone
A multi-pallet system that can work on several types of parts at the same time but is independent of other systems. A stand-alone system can be integrated into an FMS.

Step
The position that the arm moves to in the RIOS software.

Stepper Motor
Rotate in short and essentially uniform angular movements. These angles are typically 30, 45, or 90 degrees.

Stereolithography
A rapid prototyping process that fabricates a part layer-wise by hardening a photopolymer with a guided laser beam.

Subroutine
A small program inside a large one. Used when the same series of commands are repeated multiple times.

Subtractive Process
Processes that remove material to change the size, shape, or surface of a part. There are two groups of separating processes: machining and shearing.

Syntax
The rules governing the structure of statements used in a program.

T

Tolerance
The amount of interference required for two or more parts that are in contact. The amount of variation, over or under the required size, permitted on a piece of machined work.
**V**

**V-Block**
A square or rectangular steel block with a 90 degree V-groove through the center, provided with a clamp for holding round stock for drilling, milling, and laying out operations.

**Vacuum Forming**
Process to heat a thermoplastic sheet until it softens and then force the hot and pliable material against the contours of a mold using vacuum pressure.

**Value-Added**
The difference between the price at which goods are sold and the cost of the materials used to make them.

**Variable**
A quantity that can assume any of a set of values.

**Variable Costs**
Periodic cost that varies, more or less, in step with the output or the sales revenue of a firm. Such costs include raw material, energy usage, labor (wages), distribution costs, etc.

**W**

**Water Jet Cutting**
A process that uses a high speed jet of water emitted from a nozzle under high pressure (10,000-60,000 psi or greater). The advantage of water jet cutting is that it does not create a burr and it is a low temperature process.

**Word**
The programming expression formed when a letter (address) is combined with a number.

**Workcell**
A manufacturing unit consisting of a group of work stations and their interconnecting materials-transport mechanisms.

**Work Envelope**
The outline surface of a robot’s work volume or the extreme point that it can reach.

**X**

**Y**

**Z**