Manufacture Your FUTURE

ARCONIC FOUNDATION

Discovery EDUCATION

Lesson 3 - Design a Shoe

GRADES 9-12

Duration

5-6 days (45 minutes each)
With extension, 6-7 days (45 minutes each)

Day 1 Lesson Plan
Day 2 Lesson Plan
Days 3-5 Lesson Plan
Day 6 Optional Lesson Plan

Lesson Summary

Students will learn about careers that are part of the modern manufacturing design process. They then will work in teams to simulate this process as they design shoes for a target audience. Team members will simulate aspects of market research, illustration, design, and biomechanical engineering to test out different materials, prototyping, and construction. Students will learn how manufacturers use computer-aided design to create 3D images to evaluate before constructing a physical model. In an optional extension, students will conduct tests to calculate the impact force of the shoes they have created.

Essential Questions

- How do manufacturers evaluate and select materials for products?
- What steps do manufacturers take to design and build a product?
- What factors influence product manufacturing?
- What are examples of manufacturing technologies?

Learning Objectives

Students will:

- Identify processes to evaluate materials for products.
- Explain factors that influence how products are manufactured.
- Explain how computerized 3D models are used in advanced manufacturing.
- Apply an understanding of modern manufacturing to design and build a product.

National Curriculum Standards

Explain science concepts and mathematical concepts applied in materials technology such as strength of shapes, forces, center of gravity, moments of inertia, stress, strain, deflection, and efficiency.

Technology and Society

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

Design
Standard 8. Students will develop an understanding of the attributes of design.
Standard 9. Students will develop an understanding of engineering design.

Abilities for a Technological World
Standard 11. Students will develop abilities to apply the design process.

Materials

- ◊ Computer access to display videos
- ◊ Access to Google SketchUp or similar computer software application

Activity Sheets

- ◊ Materials Testing (1 per group of four students)
- ◊ Materials Testing Capture Sheet (1 per student)
- ◊ Career Cards (1 set for four students)
- ◊ Client Profiles (1 per student)
- ◊ Interview Template (1 per group of four students)
- ◊ Engineering Process Card Sort (optional)
- ◊ Design Journal (1 per student)
- ◊ Gallery Walk Feedback Form (1 per group of four students)
- ◊ Shoe Design Rubric (1 per student)

To Construct Shoe

- ◊ Aluminum
- ◊ Canvas
- ◊ Cardboard
- ◊ Cotton
- ◊ Fabric
- ◊ Felt
- ◊ Foam
- ◊ Glue (rubber cement, hot glue gun, etc.)
- ◊ Hole puncher (to punch out material for laces)
- ◊ Nylon
- ◊ Paper
- ◊ Plaster of Paris
- ◊ Plastic
- ◊ Rubber
- ◊ Shoe laces
- ◊ Staples
- ◊ String
- ◊ Tacks

For Optional Extension

- ◊ Calculator
- ◊ Scale

Background for the Teacher

Advanced manufacturing is the use of technology to improve products and processes. Professionals involved in advanced manufacturing processes and systems must be able to identify problems, create solutions, think critically, effectively communicate as part of a team, and apply new technologies and skills. In this lesson, students will apply all of these skills to design a shoe to fit specific client driven constraints.

Materials scientists and engineers work with natural or synthetic materials to improve existing products or to develop novel products. Everything we use in our daily lives is made of material or a combination of materials, including metals, ceramics, polymers, semiconductors and composites. Materials science and engineering involves all the processes that turn natural resources into useful products in fields such as aerospace, electronics, energy, transportation, communication, construction, recreation, entertainment, and the environment.

Computer Aided Design (CAD) involves the use of computer hardware and graphics software to generate design drawings. Manufacturers use CAD equipment to quickly produce very accurate and realistic images of products before they are constructed out of raw materials. Students will use 3D design software in this lesson to create an image of their shoe. They then will evaluate different designs before constructing a physical prototype.

Advanced manufacturers often work within a larger company structure or consult with market researchers to find out consumer needs and wants before developing a new product.

In this lesson, students will take on the roles of a Materials Analyst, Manufacturing Manager, Manufacturing Engineer, and Design Engineer to learn about the different professionals who work collaboratively to develop new ideas into products as part of a modern manufacturing system.

DAY 1

Engage (20-30 minutes)

How do manufacturers evaluate and select materials for products?

1. Distribute sets of assorted materials to groups of four students. These sets should include materials from which students can later select to design their shoe. It might include materials such as aluminum, canvas, cardboard, cotton fabric, felt, foam, nylon, paper, plastic, and rubber.

2. Provide 5 minutes for students to explore the items. Ask students to brainstorm how they have observed the different materials used or explain how they might be used.

3. Explain to students that everything we use in our daily lives is made of material or a combination of materials. Manufacturers evaluate different kinds of materials to identify their properties and their suitability for different purposes.

4. Distribute Materials Testing. Explain to students that they will use the information on the Materials Testing chart to conduct simple tests to evaluate the materials available and identify which materials are appropriate to construct a shoe. They should consider the strengths and limits of each material.

5. Invite students to share out which material might be best to construct a shoe that is:
   - ◊ waterproof
   - ◊ can bounce
   - ◊ lightweight
   - ◊ slides easily
   - ◊ recyclable

6. Summarize by explaining to students they will use this information to manufacture a new shoe in this lesson.

DAY 2

Explore (40-50 minutes)

What factors influence product manufacturing?

1. Explain to students that manufacturers bring new ideas to life. They often work within a larger company structure or consult with market researchers to find out consumer needs and wants before developing a new product. Explain to students that they will be taking on different advanced manufacturing jobs to design and construct a shoe for a specific task.

2. Distribute the Client Profiles that outline requests from three potential clients. Explain that they will be working as part of a group to design a shoe that meets the needs of one of these clients. Ask students to rank which client they are most interested in working with based on the provided details.

3. Group the students based on their rankings and ask them to further sort into smaller groups of four.

4. Explain to students that they will be role-playing different advanced manufacturing careers throughout this lesson in order to manufacture their shoes. Distribute the Career Cards randomly within the groups of four students. Ask students to summarize in their small groups the similarities and differences between the careers on the cards. Ask what conclusions they can draw about the types of careers that are part of advanced manufacturing processes.

5. Highlight the first career, *Manufacturing Manager*. Explain to students that this role will facilitate learning more about the event and product before development. Groups of students will develop three to four questions for the *Manufacturing Manager* to ask the client. Students should consider the lens of their specific manufacturing career to develop their questions. For example:
   - ◊ Materials Analysts might ask questions about the materials that will be used in the design.
   - ◊ Design Engineers might ask questions for the client to expand on their design criteria.
   - ◊ Manufacturing Engineers might ask questions to clarify what the client wants the consumer to be able to do in the shoes in order for them to design tests to evaluate prototypes.
   - ◊ Managers might ask questions to understand the overall product design and constraints.

   Guide students to use the Interview Template to brainstorm their questions.

6. Role-play each client and allow groups of students to ask their questions, starting as Client 1. As you role-play each client, use the Client Profiles Teacher Key to guide your responses. Students who are working with Client 1 should take notes on other responses, even if those were not their questions. Students with other clients should listen for question ideas.

   Note: The Interview Template can also be collected. The teacher can respond to the questions and return responses back to the groups the next class period.

7. Explain to students that each client would like to receive a prototype to approve before a physical model is created. Ask students to summarize what additional details they learned about their client's request during their interview.

DAYS 3-5

Explain (90-130 minutes)

What are examples of manufacturing technologies?

1 Explain to students that they will continue working as part of a team to simulate a process manufacturers go through to design and construct a product based on information requested by the client. **Note:** If students need more targeted instruction around the design process, distribute the Design Process Card Sort cut and shuffled to pairs of students. Students can sequence the cards in the order of the design process. Direct pairs to start with, "Identify a Problem."

2 Distribute one Design Journal to each student. Explain that the Design Journal involves a series of steps that lead to the development of a new product or system. These steps simulate the process that many manufacturers take as they design and build new products. In this design challenge, students are to complete each step and document their work as they design and manufacture their shoes.

3 Explain to students that the first step in an advanced manufacturing system is often to identify a problem that needs to be solved. Guide groups to read and complete **Step 1** of their Design Journal using the Client Profile and Interview Template. Circulate around the room to answer questions and clarify directions.

4 Highlight the next career card, *Materials Analyst*, by clarifying that this role will test materials that could be used in their shoe designs. For this request the *Materials Analyst* needs to be informed about how the human body works in order to design products with better efficiency and comfort.

5 Post and review the following questions prior to watching the video Biomechanical Engineers. Then, share the video Biomechanical Engineers.

- ◊ What roles do biomechanical engineers play in advanced manufacturing?
- ◊ What steps in an engineering design process are explored in the video?
- ◊ How have biomechanical engineers helped to shift jobs within advanced manufacturing fields?
- ◊ What would you want to learn about biomechanical engineers, after viewing the video?
- ◊ What information about the human body would be useful to help construct your shoe design?

After watching the video, ask students to discuss the following questions in small groups. Students might suggest that the weight from our bodies should be insulated as part of the shoe design.

6 Invite groups to present answers to the questions. Then, direct student groups to use their Client Profiles and Interview Templates to outline their shoe's criteria and constraints in **Step 2** of their Design Journal. The *Materials Analysts* can lead their groups to explore available materials again and to conduct additional testing using the capture sheets from the engage section.

7 Refer back to the computer software that the biomechanical engineer used in the video. Ask students what other uses computers could play in the development of new products. Guide students to consider how computers could be used to create product prototypes. Explain that manufactures often use computer software to design a 3D image of their ideas before construction using raw materials. This helps them refine their products on a computer rather than using actual materials, which saves on time and cost. You may want to remind students that developing a product out of the materials a client requested can be costly if the client changes their mind.

8 Highlight the role of the *Design Engineer*. Clarify that *Design Engineers* use concept sketches and 3D design software to develop solutions and designs to be manufactured.

9 Guide students to break away from their groups and individually design a solution using **Step 3** of their Design Journal. In this step, students should consider which materials they want to use and start to sketch out and annotate their ideas.

10 When students are finished with a rough sketch, guide students to open Google SketchUp or a similar modeling software to develop a 3D model of their sketch. Computer models allow manufacturers to develop and view all angles of their design by rotating the image to different perspectives. 3D models can often highlight problem areas that be quickly addressed before construction. Guide students to annotate their designs with materials and dimensions. **Note:** There are several online tutorials students can use to get started using Google SketchUp. You do not need to be an expert on how to use the software. Students can work together to problem solve how to use different features and tools. If computers are not available, or there is limited time available, students can use their sketched design and move on to step 10.

11 Guide students to meet back with their groups to complete **Step 4** of their Design Journal. In this step, group members will evaluate each other's designs to determine which one to build. **Step 4** includes a chart for groups of students to evaluate each design by giving it a score. Students will use this score to guide which idea they would like to build. They might combine multiple ideas. Ask the *Design Engineer* to facilitate **Step 4** with their group. Once they have their final labeled sketch in **Step 5** of their Design Journal, they will need teacher initials to start construction.

12 Once students have their final labeled sketch in **Step 5** of their Design Journal, they will consult with their client (teacher) again who will sign off on the final shoe design for construction. **Note:** When students are ready for construction they should start with a pattern. There are examples available online to print or students can select a group member to use as their foot model. Students can trace around their group member's foot and/or shoe to collect data around their dimensions. Students also might want to consider forming a foot shape out of newspaper and build around that form with their materials.

13 Clarify the role of the *Manufacturing Engineering*. *Manufacturing Engineers* assist in prototyping and testing designs. Ask the *Manufacturing Engineer* to facilitate organizing **Step 6** of their Design Journal by completing the division of labor chart with their group. This will help the team work more efficiently to construct their shoe design.

14 Provide students the opportunity to build their shoe design in small groups, if time allows. If there is limited time, skip to step 15.

15 Once students are finished with their 3D computer model or constructed design, ask students to display their designs around the room.

16 Guide students to leave a copy of the Gallery Walk Feedback Form with their project. As students rotate around to the different projects in their group, they will provide commendations and considerations.

17 Guide students to break away from their groups and individually complete **Step 7** of their Design Journal to reflect on their project and propose a redesign using the Gallery Walk Feedback Form.

DAY 6

Extension (optional, 30 minutes)

1 Explain to students that calculating the impact force of a shoe can inform *Manufacturing Engineers* about the comfort of a product before it goes to market.

2 Guide students to calculate the impact force of each shoe type by having one student in the class wear each shoe design, created earlier in the lesson, and walk across the scale. Individual groups will record the data and calculate the impact force. (If different students wear the shoes, there will be too many variables that will influence final comparable calculations)

Note: If students did not construct their designs, they can test different shoes in the classroom.

3 Ask students to calculate the impact force of the shoe hitting the ground, using the steps below.

◊ **Measure the mass of the person wearing the shoe (in kg).**
m = ___ kg

Ask that same group member to walk across the scale.

◊ **What is the maximum weight recorded as they walked across?**
W = ____kg

◊ **Calculate the maximum force exerted on the scale, using Newton's second law.**
F = m * a = m * g

F = ___ kg * 9.8 m/s

F = ___ N

◊ **The average impact of the foot with the ground takes 0.03 seconds. Calculate the impulse of the step.**
I = F * t

I = ___ N * 0.02 s

I = ___ N * s

◊ **Calculate the impact velocity of the shoe with the ground.**
I = m * Δv

Δv = I / m

Δv = ___ N * s / ___ kg

Δv = ____ m/s

4 After each group calculates their impact force, graph each group's results. The lower impact force, the less strain the shoe has on the wearer. Ask students to list the shoes in order from lowest to greatest impact force and discuss the following in their groups:

- ◊ How can this information inform shoe design and manufacturing?
- ◊ Which of the shoes in the lesson would benefit most from having a lower impact force? Why?
- ◊ Can this data be applied to all consumers? Why or why not? Students should consider the variability in weight, shoe size, and walking gate.

OR

5 Provide students the opportunity to debrief the Career Cards they used throughout the lesson. Ask students to consider the following:

- ◊ Which job would you like to have? Why?
- ◊ Which job seems the most important? Why?
- ◊ What is a common requirement among many of the jobs?
- ◊ Which job seems the most difficult? Why?

Evaluate

- ◊ Students can be evaluated on their **Design Journal** using the provided **Shoe Design Rubric**.

Materials Testing

Use the chart below to guide your exploration of the provided materials.

Material Property	Testing Protocol
Toughness	Toughness is the resistance of a material to being broken in two, by a crack running across it - this is called “fracture” and absorbs energy. **Rate this:** **1** - does not fracture **2** - fractures, with faint crack line **3** - fractures with crack line **4** - fractures, with deep crack line **5** - fractures, and breaks in two
Stiffness	Stiffness is a measure of the resistance of a material to elastic (recoverable) deformation under load. **Rate this:** **1** - does not deform to **5** - permanently deformed
Strain	A force tending to pull or stretch something to an extreme or damaging degree **Rate this:** **1** - does not deform to **5** - permanently deformed

Materials Testing Capture Sheet

Record your testing results in the table below:

Materials	Toughness	Stiffness	Strain	Other characteristics observed	How could this material be used to construct a shoe?
Aluminum					
Cardboard					
Cotton					
Foam					
Nylon					
Paper					
Plastic					
Rubber					

Career Cards

As a **Materials Analyst**, you develop, process, and test materials used to create a range of products, from computer chips and aircraft wings to shoes and skateboards. You work with metals, ceramics, plastics, composites, and other substances to create new materials that meet certain mechanical, electrical, and chemical requirements.
As the **Manufacturing Manager,** you lead the design and development of new products and develop performance metrics. Your also work with market researchers to find out consumer needs and wants.
As a **Manufacturing Engineer,** you support the development of new processes and methods for manufacturing footwear components. You design and execute experiments to understand variables between materials and processes and assist in prototyping and testing.
As a **Design Engineer,** you lead product design and development to manufacture products, leverage experience in 3D design and engineering, and use concept sketches and 3D design software to develop solutions and designs to be manufactured.
As a **Production Specialist,** you program, operate, and maintain the machines that create manufactured goods, everything from computer chips to skateboards to aircraft engines. You are responsible for taking the design and making it a reality.

Client Profiles

Review each of the client profiles and rank them 1-3, 1 being the client you would most like to manufacture a product for.

Client	Ranking
Client Profile #1 Animal Conservation Awareness Animal Conservation Awareness is looking for key board members to wear conservation themed shoes for their 5K annual walk. The shoes need to make a statement and be visible in pictures among a crowd. Making them out of recyclable materials is necessary.	
Client Profile #2 World Traveller World Traveller is hosting a runway show in major cities around the world. A pair of shoes should depict famous landmarks or icons of each city they visit. Each shoe must weigh less than one pound. The shoes need to stay lightweight to pack and ship efficiently from city to city.	
Client Profile #3 Catch you Later Catch you Later is looking for a new sport in which shoes are an integral part of the game. The set of shoes can be limited to one-person play or a team sport. A pair of shoes must be attached securely to the wearer as a safety precaution in the game.	

Client Profiles-Teacher Key

Client	Anticipated Student Questions and Responses
Client Profile #1 Animal Conservation Awareness Animal Conservation Awareness is looking for key board members to wear conservation themed shoes for their 5K annual walk. The shoes need to make a statement and be visible in pictures among a crowd. Making them out of recyclable materials is necessary.	**What types of recyclable materials do you want used in your design?** newspaper, plastic, cans, aluminum **Are there specific animals you want featured on your design?** No, but our zoo patrons frequent the panda, shark, elephant, and bald eagle exhibits the most **Is the route of the 5K all the same terrain and are there hills?** The route is flat and all on concrete or asphalt **Is the event rain or shine?** Yes **Can you expand on the requirement that the shoes need to make a statement?** We want the shoes to showcase an animal that is easily recognizable. The design can be 3D but keep in mind that they are walking in a crowd that allows up to 5,000 participants. The design needs to be able to last for the entire walk and pictures before and after.
Client Profile #2 World Traveller World Traveller is hosting a runway show in major cities around the world. A pair of shoes should depict famous landmarks or icons of each city they visit. Each shoe must weigh less than one pound. The shoes need to stay lightweight to pack and ship efficiently from city to city.	**Paper, plastic, aluminum, and cotton are all lightweight materials that could be used in this design. Is there a preference of material for this event?** No, but a material that could also reflect light would be a dramatic addition. **What cities are featured in this runway show?** Tokyo, Miami, New York, London, Paris, Rio, Cairo **Are the models male or female?** Both **Can the designs extrude from the shoe?** Yes **How long will the models wear the shoes?** They will walk 28 feet, pose, and walk back 28 feet. Models will stand and wait for other models to walk the runway for 10 minutes, then will return to the stage at the end of the show and repeat the walk again.
Client Profile #3 Catch you Later Catch you Later is looking for a new sport in which shoes are an integral part of the game. The set of shoes can be limited to one-person play or a team sport. A pair of shoes must be attached securely to the wearer as a safety precaution in the game.	**Do the materials need to be waterproof?** It depends on the sport, but overall it would be preferred **Could the game include magnets?** Yes **Can the shoes have detachable parts?** Yes, but they must fit securely on **Can the shoes be large, like a boot?** Yes, but they still must weigh less than 3 pounds **Does the wearer need to be able to jump?** It depends on the game that is designed with the shoe. We are open to the wearer being able to jump, slide, kick, or grab with their shoe as part of the game.

Interview Template

Question	Purpose for Asking Question	Response

Other Notes:

Engineering Design Card Sort

generating ideas	*making a model or prototype*
identifying criteria and specifying constraints	*developing a design proposal*
communicating results	*selecting a design*
testing and evaluating a design	*refining a design*
identifying a problem	*creating or making it*

Design Journal

The engineering design process involves a series of steps that leads to the development of new products or systems. In this design challenge, you will complete each step and document your work as you manufacture your shoe design.

Step 1-Identify the Problem

1 What is the problem and/or the need that justifies the project?

2 Who is the target population and who will benefit from the solution?

3 How will the result of this solution impact peoples' lives, the educational community and/or the world?

Step 2-Review the Criteria and Constraints

◊ What are the criteria and constraints for the given problem?

Criteria	Constraint

Materials List

Step 3 - Generate Ideas

Additional considerations to guide your sketches:

In the boxes below sketch out your ideas but your final design should be created using computer software.

Step 4-Refine

Review and discuss each group member's ideas from step 3. Record your notes in the table below. Possible review could include testing experiments, simulations, peer review, etc. Be sure to include any data collected. The steps below can help to guide your discussions.

Enter the criteria and constraints of the project in the first column.
Use a numeric value to rate each solution against the criteria or constraint.
(2=totally meets the requirement, 1=somewhat meets the requirement, 0=does not meet the requirement)

Total the columns and circle the highest score.

Constraint	Sketch/Idea 1	Sketch/Idea 2	Sketch/Idea 3
Other criteria: A single rating for your own "nice-to-have", desirable criteria and universal design criteria, such as: **Robustness, Aesthetics Cost and Resources, Time, Skill Required, Safety**			
Total			

Step 5-Final Design

Sketch and label your final design below after consulting with your group.

Client Initials _____

Step 6-Creating or Making a Design

Division of Labor Chart

Team Members: _____

Directions: Use the chart below to keep track of how much time each team member spends on each task.

Description of Task	Person(s) Responsible	Amount of Time Spent on Task

Step 7-Communication and Redesign

Use evidence from your own reflection and the Gallery Walk Feedback Form to respond to questions 1-2.

1 What were the strongest features of your design?

2 What were the weaknesses of your design?

In the space below, explain what further work would need to be done to prepare the product for the marketplace/actual implementation. How would you re-design your product after reviewing your feedback?

Gallery Walk Feedback Form

Keep this paper with your project. Other teams will provide feedback as they walk around.

Team Name: _____ Project Name: _____

Team Name: _____ Team Feedback:	**Team Name:** _____ Team Feedback:
Team Name: _____ Team Feedback:	**Team Name:** _____ Team Feedback:
Team Name: _____ Team Feedback:	**Team Name:** _____ Team Feedback:
Team Name: _____ Team Feedback:	**Team Name:** _____ Team Feedback:

Shoe Design Rubric

As you evaluate student Design Journals, score each section.

	Emerging Descriptions and responses reflect beginning level of performance.	**Developing** Descriptions and responses reflect development and movement towards mastery of performance.	**Accomplished** Descriptions and responses reflect mastery of performance.	**Points Earned**
	1	**2**	**3**	
Identifying the Problem				
Identifying Criteria and Specifying Constraints				
Generating Ideas				
Refining an Idea				
Final Design				
Creating or Making a Design				
Communication and Redesign				
			TOTAL	