



6-8

Lesson Plan

The Everyday Science of Sports

Lesson Overview:

In this lesson, students will learn about the science behind golf ball design and the physics of aerodynamics related to golf balls. They will work in teams to evaluate the design of several golf balls and determine how design can impact a ball's spin, accuracy, trajectory, and distance. Finally, they will apply design and engineering concepts to improve a piece of sports equipment.

Learning Objectives:

Students will be able to:

- Apply concepts of aerodynamics, drag, air friction, and bounce to golf ball design.
- Learn how physics and engineering impact safety and performance related to sports equipment.
- Research how a piece of sporting equipment's design has evolved since it was invented.
- Use scientific concepts to propose an improved design or material for a piece of sporting equipment.

Academic Standards:

National Science Education Standards:

- Students should develop general abilities, such as systematic observation, making accurate measurements, and identifying and controlling variables. They should also develop the ability to clarify their ideas that are influencing and guiding the inquiry, and to understand how those ideas compare with current scientific knowledge. Students can learn to formulate questions, design investigations, execute investigations, interpret data, use evidence to generate explanations, propose alternative explanations, and critique explanations and procedures. (p. 145)
- The use of tools and techniques, including mathematics, will be guided by the question asked and the investigations students design. The use of computers for the collection, summary, and display of evidence is part of this standard. Students should be able to access, gather, store, retrieve, and organize data, using hardware and software designed for these purposes. (p. 145)
- Students should base their explanation on what they observed, and as they develop cognitive skills, they should be able to differentiate explanation from description—providing causes for effects and establishing relationships based on evidence and logical argument. This standard requires a subject matter knowledge base so the students can effectively conduct investigations, because developing explanations establishes connections between the content of science and the contexts within which students develop new knowledge. (p. 145)
- Thinking critically about evidence includes deciding what evidence should be used and accounting for anomalous data. Specifically, students should be able to review data from a

simple experiment, summarize the data, and form a logical argument about the cause-and-effect relationships in the experiment. (p. 145)

- With practice, students should become competent at communicating experimental methods, following instructions, describing observations, summarizing the results of other groups, and telling other students about investigations and explanations. (p. 148)
- An object that is not being subjected to a force will continue to move at a constant speed and in a straight line. (p. 154)
- If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object's motion. (p. 154)
- Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways. (p. 155)
- Students should develop their abilities by identifying a specified need, considering its various aspects, and talking to different potential users or beneficiaries. They should appreciate that for some needs, the cultural backgrounds and beliefs of different groups can affect the criteria for a suitable product. (p. 165)
- Students should make and compare different proposals in the light of the criteria they have selected. They must consider constraints—such as cost, time, trade-offs, and materials needed—and communicate ideas with drawings and simple models. (p. 165)
- Students should organize materials and other resources, plan their work, make good use of group collaboration where appropriate, choose suitable tools and techniques, and work with appropriate measurement methods to ensure adequate accuracy. (p. 165)
Students should use criteria relevant to the original purpose or need, consider a variety of factors that might affect acceptability and suitability for intended users or beneficiaries, and develop measures of quality with respect to such criteria and factors. (p. 165)

Benchmarks for Science Literacy

- Scientific investigations usually involve the collection of relevant data, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected data. 1B/M1b*
- If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one variable. It may not always be possible to prevent outside variables from influencing an investigation (or even to identify all of the variables). 1B/M2ab
- No matter who does science and mathematics or invents things, or when or where they do it, the knowledge and technology that result can eventually become available to everyone in the world. 1C/M3

Time Frame:

The lesson should be completed in two to three class periods.

Background Information for the Teacher:

Many technological advances have occurred in the game of golf over the years, including significant changes to the golf ball!

Early golf was played with a stitched leather ball stuffed with boiled goose feathers. This egg-shaped ball cost three times as much as a club! In 1848, the gutta percha ball was introduced. The gutta percha was made from the sap of the gutta tree (a tropical tree native to Asia) and was considerably more durable and affordable than its predecessor. Additionally, golfers realized that markings and patterns on the gutta percha enhanced its aerodynamics. The next advancement occurred in the early 1900s with the development of the Haskell rubber-cored ball which featured a gutty cover and a wound rubber core. It traveled up to 20 yards further than the gutta percha ball and delivered greater durability. The rest of the 20th century was spent refining the Haskell. In 1905, William Taylor introduced the first dimpled ball. The dimples improved flight because the dimple pattern maximized lift and minimized drag. By 1930, the current golf ball with dimples was accepted as the standard design. In 1972, the first two piece ball, the Executive, was introduced. Most modern golf balls consist of rubber thread wound around a rubber core and coated with dimpled enamel. Dimples are typically arranged in rows.

When a golf ball is hit, the impact determines its velocity, launch angle and spin rate, all of which influence its trajectory and behavior when it hits the ground. A ball moving through the air experiences two major aerodynamic forces: lift and drag. Drag slows the forward motion, and lift acts in a direction perpendicular to it. Every modern golf ball has dimples designed to increase and shape the lift and drag forces by modifying the behavior of the boundary layer (the layer of fluid in the immediate vicinity of the surface). Drag and lift forces also exist on smooth balls, but dimpled balls fly farther because the dimples maximize lift and minimize drag, similar to the aerodynamics of an airplane wing. Golf balls with small, shallow dimples tend to have a longer, lower flight path. Those with deeper dimples have a higher flight path. Golfers can choose their balls based on what they need for a particular shot or in particular weather.

Materials for the Teacher:

- Three signs: one that says, "A," one that says, "B," and one that says, "C"
- Flip chart paper

Materials for the Student:

- Several different types of golf balls (You can ask students to bring in balls from home or ask a golf facility to donate balls.)
- "All in the Ball Challenge" activity sheet
- "Closer Look at Golf Balls" activity sheet
- "Good Sports" activity sheet
- Scales
- Thread or string
- Rulers and meter sticks
- Flip chart paper
- Different pieces of sports equipment (optional) **or** different pictures of sports equipment

Classroom Activities:

Engage

Note: Before students enter the room, hang the three signs (A, B and C) in different corners of the room.

1. As students enter the room, hold up a golf ball and ask them to name and describe what they see. Then ask students if they have any idea how the golf ball design and use is based on science. List all answers on flip chart paper.
2. Distribute the “All in the Ball Challenge” activity sheet. Divide students into small groups and direct each group to circle the correct answer for each question. Encourage them to make educated guesses if they are unsure of the answer.
3. Once all groups have finished, read each question out loud and ask each group to send one group member to stand by the sign that corresponds with their answer.
4. Read the correct answers after each question (see answer sheet) and have students keep track of their scores. Name one group the “All in the Ball” champions!
5. Challenge each group to look back at the questions and draw conclusions/add to their original answers on the flip chart paper about how the golf ball design and its use relates to science.

Explore

6. Review with students what they know about golf balls, including the fact that all golf balls are round and have dimples. What students may not know is that the size, shape, dimple arrangement, depth and pieces of golf balls vary and can determine the flight of the ball, the distance it travels, and how it behaves once it lands. Experienced golfers choose their balls based on their desired shot.
7. Distribute three to five different golf balls to each student group to examine. Also distribute the “Closer Look at Golf Balls” activity sheet along with a scale, meter stick, tape measure, string and scissors.
8. Have students complete each step on the activity sheet for each ball. Instruct them to fill in the answers on the chart. Then challenge them to answer the questions that follow.

Explain

9. Once all groups have completed the activity sheet, compare and discuss answers. At this point, you may want to share some of the “Background Information” with students. This includes the fact that balls with small, shallow dimples tend to have a longer, lower flight path and those with deeper dimples have a higher flight path. Golfers can choose their balls based on what they need for a particular shot or in particular weather. When a golf ball is hit, the impact determines its velocity, launch angle and spin rate, all of which influence its trajectory and behavior when it hits the ground. A ball moving through the air experiences two major aerodynamic forces: lift and drag. Drag slows the forward motion, and lift acts in a direction perpendicular to it. Every modern golf ball has dimples designed to increase and shape the lift and drag forces by

modifying the behavior of the boundary layer (the layer of fluid in the immediate vicinity of the surface). Drag and lift forces also exist on smooth balls, but dimpled balls fly farther because the dimples maximize lift and minimize drag, similar to the aerodynamics of an airplane wing. Different construction can give balls different bounce-back ability. Balls with a harder core have a “higher” spring and are affected less at impact by the golf club.

10. Ask each group to summarize how they believe that the design of a golf ball impacts the game.

Elaborate

11. Share with students that engineers continually work to improve products made by every industry, including sports. In this last part of the lesson, student groups will select a piece of sports equipment, learn how engineering has impacted its design and develop a sketch or prototype that improves it. Before they begin, ask students for some examples of how engineering and design has impacted sports.
12. Create three columns on the flip chart paper: label the first column “sports”, the second “safety”, and the third “performance”. In the first column, ask students to name 5-8 different sports. Then, for each sport, challenge them to brainstorm technology that is engineered to keep athletes safe, and technology that is engineered to help athletes perform their best. For example, if they name baseball, a batting helmet that prevents concussions could keep a player safe while a bat made from titanium could create further distance for a hit. Continue this activity until students have a good idea of several ways that design and engineering can improve and impact sports.
13. Then divide students into groups, distribute the “Good Sports” activity sheet and review the directions with students. The activity sheet asks students to select a piece of sports equipment (ball, net, stick or club, shoe, apparel, helmet, etc.) and to conduct research to learn how the equipment has physically evolved over the last several years as a result of engineering. For example, has the shape, construction, size, or materials used to make the equipment changed? And how has the change impacted performance? Encourage students to use the piece of sports equipment **or** the picture of the sports equipment to help their analysis. Finally, each group is asked to use scientific principles to recommend one further change they would make to either enhance safety or performance. Several examples of enhanced equipment for Olympic athletes can be found at http://www.teachengineering.org/collection/cub_/lessons/cub_intro/cub_intro_lesson04_ExamplesEngineeringForOlympicAthletes.pdf.
14. Ask each group to present their ideas and sketches to the class and justify how their proposed change will impact safety or performance.

Evaluate

15. Finally, direct students to write a short paragraph describing how design and engineering can be used to help athletes perform their best or stay safe in a sport. Challenge them to include examples related to golf or other sports of their choice.

Home Connections

Parent Background Information:

Engineers play an important role in sports. The three goals of engineering sports equipment are typically known as lighter, faster, and stronger. Lighter equipment helps athletes move with as little extra weight as possible. Think about the lightness of a snowboard, BMX bike, or even a bathing suit. Faster equipment helps the athlete overcome as much friction as possible. Friction is the enemy of many sports! Think about skiers who put wax on the bottom of their skis to create less friction between the snow and the skis or the golfer who uses a certain glove to help with a smooth grip. Stronger equipment allows athletes to feel confident that their equipment won't break even under extreme force. Baseball bats, for example, have to be strong enough to absorb the impact of hitting the ball with great force. Football helmets and pads need to have the right materials so that players are protected from forceful hits. Different types of engineers work on different aspects of sports equipment: Materials engineers help to decide the best materials for equipment. Design engineers help to make protective gear comfortable and easy to use. And biomedical engineers analyze the body's motion in sports to find ways to reduce injury and optimize performance.

- Look through your garage, closets, or sports bags to find several pieces of sporting equipment or clothing. Pass the objects around and have each family member share one way that they think engineering and design have helped to make the equipment or apparel lighter, faster, stronger, or safer.

“All in the Ball Challenge” student activity sheet

Is your knowledge about golf balls “up to par”? Read the questions below and work with your group members to circle the correct answers. Then get ready to play a round with the answers!

1. Early golf balls were basically leather pouches filled with what?
 - a. Feathers
 - b. Pebbles
 - c. Cork

2. What shape were the first golf balls?
 - a. Round
 - b. Egg-shaped
 - c. Flat

3. What new feature was added to golf balls in 1905?
 - a. Different colors
 - b. Plastic coating
 - c. Dimples

4. Today most pros use balls are actually made of how many pieces?
 - a. One or two
 - b. Two or three
 - c. Three or four

5. A golf ball can be as big as you want, but it can't be smaller than what diameter?
 - a. 1.68 inches
 - b. 2.68 inches
 - c. 3.68 inches

6. A golf ball cannot be heavier than how many ounces?
 - a. .62
 - b. 1.62
 - c. 2.62

7. About how many dimples are on the average golf ball?
 - a. 100-150
 - b. 200-350
 - c. 300-450

8. True or false: A golf ball must be round.
 - a. True
 - b. False

9. No legal ball can exceed an initial velocity of what?
 - a. 50 feet per second
 - b. 150 feet per second

- c. 250 feet per second
10. Dimples on a golf ball increase what?
- a. Lift
 - b. Drag
 - c. Both Lift and Drag

“All in the Ball Challenge” student activity sheet ANSWER KEY

Is your knowledge about golf balls “up to par?!” Read the questions below and work with your group members to circle the correct answers. Then get ready to play a round with the answers!

1. Early golf balls were basically leather pouches filled with what?
 - a. Feathers
 - b. Pebbles
 - c. Cork

2. What shape were the first golf balls?
 - a. Round
 - b. Egg-shaped
 - c. Flat

3. What new feature was added to golf balls in 1905?
 - a. Different colors
 - b. Plastic coating
 - c. Dimples

4. Today most pros use balls are actually made of how many pieces?
 - a. One or two
 - b. Two or three
 - c. Three or four

5. A golf ball can be as big as you want, but it can't be smaller than what diameter?
 - a. 1.68 inches
 - b. 2.68 inches
 - c. 3.68 inches

6. A golf ball can not be heavier than how many ounces?
 - a. .62
 - b. 1.62
 - c. 2.62

7. About how many dimples are on the average golf ball?
 - a. 100-150
 - b. 200-350
 - c. 300-450

8. True or false: A golf ball must be round.
 - a. True
 - b. False

9. No legal ball can exceed an initial velocity of what?
 - a. 50 feet per second
 - b. 150 feet per second

- c. 250 feet per second
10. Dimples on a golf ball increase what?
- a. Lift
 - b. Drag
 - c. Both Lift and Drag

“A Closer Look” student activity sheet

All golf balls are round and have dimples, but their size, shape, depth and dimple arrangement may vary depending on a golfer’s desired distance, flight and behavior after landing.

1. Write a number on each golf ball that will correspond to the information in the chart below

Ball#	Weight (grams)	Diameter (centimeters)	Circumference (centimeters)	Observations about Dimples	Bounce Test (centimeters)

- a. Weigh each ball and record the weights in column two.
 - b. Calculate the diameter of each ball and record the diameters in column three.
 - c. Cut a piece of string and wrap it around each ball. Cut the string where the ends meet and measure it in centimeters to get the circumference. Record each ball’s circumference in column four.
 - d. Observe the dimple number and pattern and record anything of note in column five.
 - e. Drop each ball from about five feet and measure its bounce against a meter stick. You may want to get this measurement a few times so you can obtain an average. Record the average bounce for each ball in column six.
2. How do the measurements for the golf balls compare? How, if at all, do you think these measurements impact flight, distance, or behavior once the ball hits the ground?
 3. How do the dimples compare in terms of number, depth and pattern? How, if at all, do you think these differences impact flight, distance, or behavior once the ball hits the ground?
 4. Did the golf balls bounce the same height? What might account for any bounce differences? How could a ball’s bounce impact flight, distance, or behavior once the ball hits the ground?
 5. What conclusions can you draw about the way that a golf ball’s design can impact a golfer’s shot?

“Good Sports” student activity sheet

Engineering and design are continually applied to improve products made by every industry, including sports. Some technological advances help to keep athletes safe while others enhance performance. The advances to the golf ball you learned about throughout this lesson were designed to impact performance, specifically flight, lift and behavior once the ball hits the ground. In this activity, you will have the opportunity to learn about advances in a piece of sporting equipment or apparel and then come up with a design enhancement of your own.

1. With your group members, identify one piece of sporting equipment or apparel that you would like to research and improve.
2. Conduct research to learn when, where and by whom your equipment was invented. Then research and list major advancements from its invention to now. You can do this in a timeline, pictorial, or paragraph. Include any relevant information about how major advancements have helped to enhance safety or performance. For interesting thought-starters, visit: <http://scienceofeverydaylife.com/innovation/>
3. Finally, come up with one way that you would like to further improve either safety or performance related to your equipment. List your goal below. Then create a sketch of the new design that includes a scientific justification for your change.

Scoring Key for “Good Sports” Evaluation:

Information in the paragraphs will vary but students should include how the design can help:

- Make the equipment lighter.
- Make more durable equipment that can withstand force.
- Help to improve performance based on forces of energy.
- Reduce injury through safer equipment.
- Help to reduce friction.