Grade Level Expectation: 6-8
The Bicycle as a System
Content Area: Science; Reading, Writing and Communicating

Lesson Time:
1-2 class periods

Materials:
1.Internet access. Cycle of Heroes article on the Franklin Institute website http://www.fi.edu/learn/sci-tech/bicycle-heroes/bicycle-heroes.php?cts=recreation

2. *The Science of Cycling* http://www.exploratorium.edu/cycling/index.html

3..The Bicycle as a System - student sheet (at end of lesson)

4. A Bicycle (or picure of a bicycle) - so students can point to the various subsystems and parts when describing its properties

Objective:
To explore the nature of systems by examining the systems that make a bicycle work. Students will begin to understand how the different systems of a bicycle relate to each other and be able to identify the properties of each part or subsystem. This lesson is adapted from "The Bicycle as a System" from the American Association for the Advancement of Science.

7th Grade Standards:
Content Area:Reading, Writing and Communicating
1. Oral Expression and Listening
    1. Small and large group discussions rely on actuve listening and the effective contributions of all participants.

Background:
This lesson gives students an opportunity to examine the nature of systems in the context of an object with which they are very familiar - the bicycle. While this lesson is intended for grades 6-8, it presents concepts that are more appropriate for 7th and 8th grade students.

The main goal of having students learn about systems is not to have them talk about systems in abstract terms, but to enhance their ability (and inclination) to identify the various aspects of systems in attempting to understand the whole system. Examining systems is really a way of thinking that will supplement thinking about theories or making discoveries.

Students will identify the properties of the various subsystems of a bicycle and examine how they relate to the whole. According to research: "Children tend to think of the properties of a system as belonging to individual parts of it rather than as arising from the interaction of the parts. A system property that arises from interaction of parts is therefore a difficult idea." (Benchmarks for Science Literacy, p. 26211.)

Students should already know that if something consists of many parts, the parts usually influence one another. Also they should be aware that something may not work as well (or at all) if a part of it is missing, broken, worn out, mismatched, or misconnected. It is important to establish the boundary of the system to include enough parts so that their relationship to one another makes sense. Drawing the boundary of a system well can make the difference between understanding and not understanding what is going on. Thinking of everything within some boundary as being a system suggests the need to look for certain kinds of influence and behavior. For example, students should consider a system's inputs and outputs - the outputs of some parts being inputs for others.

Systems are not mutually exclusive. Systems may be so closely related that there is no way to draw boundaries that separate all parts of one from all parts of the other. Any part of a system may itself be considered

as a system-a subsystem - with its own internal parts and interactions. Any system is likely to be part of a larger system that it influences and that influences it. The idea of a system should be expanded to include connections among systems.
Students will also learn about the choices and constraints that go into the design of a bicycle system. Depending on whether the bicycle is intended for racing, mountain roads, or touring, influences its design and such choices as the type of tires, frame and materials, and drives and gears. In addition, accommodating one constraint can often lead to conflict with others. For example, the lightest material may not be the strongest, or the most efficient shape may not be the safest or the most aesthetically pleasing. Therefore, every design problem lends itself to many alternative solutions, depending on what values people place on the various constraints.

Procedure:
Before reading the article Cycle of Heroes, on the Franklin Institute website, discuss with students their personal experience and knowledge of bicycles.

Ask students:
- Describe the qualities of your own bicycle.
- What do you like about your bicycle?
- Describe how a bicycle works.
- Has your bicycle ever broken? What part broke? Were you able to repair it?

Distribute the article *Bicycle Heroes* or have students read it online.
URL: http://www.fi.edu/learn/sci-tech/bicycle-heroes/bicycle-heroes.php?cts=recreation

The article describes one of the earliest bicycles, how it worked, and the design changes that improved its use. It also discusses the early bicycle clubs, as well as the first bicycle racers who became stars and who helped to popularize the sport. In addition, the article has several photographs of these early bicycles.

After reviewing the article, ask students:
- How do the early bicycles differ from bicycles made today?
- What accounted for the popularity of bicycles when they were first invented in the late 1800s?
- What accounts for the popularity of bicycles today?
- Identify the various parts of the bicycle.
- What does each part do? Describe some of the properties of these parts.

What is the purpose of a bicycle system?

Finally, ask students:

- In your opinion, list in order of importance the following bicycle characteristics: speed, safety, comfort, durability. Explain your choice.
- How might a bicycle's design differ depending on which characteristic is more important?
- Is it possible to accommodate all four characteristics in designing a bicycle?

Procedure:

Divide students into six groups. Explain to the groups that they will conduct an Internet exploration to understand more about the parts of a bicycle and how bicycle systems work. Have students review *Science of Cycling* on The Exploratorium website (http://www.exploratorium.edu/cycling/index.html). Ask each group to select one subsystem to explore. The groups of students should review their section and describe the subsystem and the parts that make a bicycle work.

The subsystems are:

- The Wheel
- Drivers & Gears
- Frames & Materials
- Brakes & Steering
- Aerodynamics
- Human Power

Note: The Introduction section discusses the people who were interviewed and provided information for the website. It is not necessary for students to read the Introduction to understand the lesson.

Distribute the student sheet entitled The Bicycle as a System13. As students read about each subsystem, they should use their worksheet to list the parts of the subsystem, define the properties it has on its own, and how it works with the whole system. To answer the questions, students may need to use their knowledge about the other bicycle subsystems that are described on the site. Ask the students to present their findings to the class. At appropriate times during the presentations, lead the discussion to help the rest of the class process the information.

Ask such questions as:
What is the boundary of the bicycle system? (For the purpose of this lesson, it includes all the bicycle's subsystems, as well as the person riding the bicycle.)

How is the bicycle system related to other larger systems? (It can be related to road, air currents, and weather systems.)

The seat is one part of the bicycle. Use three different words or phrases that describe the seat.

Do any of these words or phrases also describe the whole bicycle? (Possible answers include: soft, hard, smooth, narrow, uncomfortable. These could also describe the bicycle as a whole.)

What parts of the bicycle must work together if you want to ride around a corner? (Wheels, frame, steering, and human power all work together to ride the bicycle around a corner.)

How would the functioning of the bicycle change if one part or subsystem wears out? (The bicycle would be more difficult or impossible to ride.)

What about riding the bicycle- How are you part of the system?

Assessment

Assess students' understanding based on how well they have answered the questions about the bicycle as a system. Students should demonstrate an understanding that all the subsystems need to work together for the bicycle to function.

Students should be able to identify approximately six parts for each subsystem they explored, including each part's function, as well as the input and output for the subsystem. Students should acknowledge that all bicycles have similar subsystems and it is possible to place the same part from one bicycle in another bicycle. Variations to the bicycle, in terms of materials or the arrangement of parts, may affect the bicycle's speed, safety, comfort, or durability. It is even possible that the variations would cause the bicycle not to function.

The Bicycle as a System
Student Sheet

Name:_____ Date:_____

Review the information from the **The Science of Cycling** http://www.exploratorium.edu/cycling/, on The Exploratorium website. Apply your knowledge of systems to answer the questions below and then be prepared to present your answers to the class.

Also, use this worksheet to take notes as the other groups present their answers.

1. Describe the subsystem that your group researched. What is its function within the bicycle system?

2. Complete the table to indicate how the subsystem affects the bicycle's speed, safety, comfort, and durability.

	Speed	Safety	Comfort	Durability
The Wheel				
Drivers and Gears				
Frames & Materials				
Brakes & Steering				
Aerodynamics				
Human Power				

3. Complete the table below to identify the following:
    - Name the parts of the bicycle's subsystem. If you don't know the name of a part, make up a name.
    - Tell what function each part has and how it contributes to the subsystem.
    - For the bicycle subsystem to work, what input must it receive?
    - What, if any output does the subsystem produce?

	Parts	Function	Input	Output
The Wheel				
Drivers and Gears				
Frames & Materials				
Brakes & Steering				
Aerodynamics				
Human Power				

4. Could any part of this bicycle be made of a different material and still help the bicycle carry out its function?

5. Can any one part of the bicycle carry out the job of the whole bicycle? Explain your answer.

6. Can you take a part from another bicycle and use it to replace a part in this bicycle and still have the bicycle carry out its function?

7. Could some parts of the bicycle be arranged differently so that the system will still carry out its function? Explain your answer.

8. Does the bicycle require symmetry among any of its parts? If so, describe the symmetry.

9. What will happen to the bicycle if one part, such as a spoke, breaks? What if all the spokes on a wheel break?

10. Is it useful to think of a bicycle as a system? Justify your answer.

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