Session 10

Bicycle Breakdown: Systems, Components and Parts

Making, Modeling, and Materializing

In This Session:

A) Systems and Synergy (50 minutes)
- Student Handout
- Student Reading

B) Sum of the Parts (100 Minutes)
- Student Handout

This session uses the mechanisms of a bicycle to help students think about the systems in a product that must be designed. It offers student engineers a strategy for tackling a complex solution that they might have in mind. It provides practice with breaking big ideas into manageable, designable parts by identifying systems and/or components that need design and engineering. This session requires either a field trip to a bike shop or assistance from adult bicycle enthusiasts among the leaders, parents, mentors, or other volunteers. If a field trip is not possible, then you will need to have students bring in bicycles for demonstration and study.

In the first activity, *10A: Systems and Synergy*, students learn the difference between systems, components, and parts as they identify them on a bicycle. The second activity, *10B: Sum of the Parts*, involves a field trip to a bike store or a demonstration on a bicycle's systems, components, and parts.

Supplies

- 8-10 bicycles and tricycles of different kinds, shapes, and sizes (brought by the students and mentors)
- Additional specialty bicycles (recumbent, folding or collapsible, track and racing bikes, BMX freestyle, fat tire coaster bikes)
- Bike repair stands (to raise and support bikes off the floor for study)
- Bicycle parts, 1 or 2 examples of each system or a few parts in each system:
    1. Drive systems: pedals, cranksets (crank and chainwheel), chains, axles, wheels
    2. Steering system: handlebars, front wheel, headset bearings
    3. Brake systems: brake levers, cables, and calipers (attached as a system)

Session 10, Bicycle Breakdown: Systems, Components, and Parts (continued)

4. Structural system parts:
    - Frames: without any components attached—any size, style
    - Wheels: different sizes and designs (some missing spokes or out of true is fine)
    - Handlebars: downswept and straight
    - Seats (or saddles): different shapes and designs

- Markers (highlighters) of different colors
- Old rags or paper towels for wiping grease and dirt off hands and bikes
- Optional: Erector* set (toy construction set)

Bicycle Breakdown: Systems Components and Parts

Key Concepts: Session 10

Students begin planning the development of their design solutions by first looking at how designed objects can be broken down into **systems**, **components**, and **parts**. In Session 10, students look at a familiar object—the bicycle—in order to understand how this process happens. Students get hands-on experience with bicycle systems either by visiting a bike shop or by bringing experts in to demonstrate the systems.

Key Concepts
Designed things can be deceiving. At first glance, they can appear functional and seem so simple to use. But being simple to use does not necessarily mean something is easy to engineer. An important skill is the ability to analyze, to break a design solution into the smaller systems, subsystems, components, and parts that work together to make a functioning product. A valuable design step is having students look at devices as systems and start asking and answering questions—What are the subsystems that make up the my design? What kinds of components and parts will I need to design to build the system as a whole?

Systems are important to engineering and design. They make the design and production processes much easier. Imagine if you had to design a Boeing 777 airplane, a huge and complex task. However, the task becomes more manageable if the Boeing 777 system is divided into subsystems and then further into components and parts. One team might be assigned to design the wing system, another team of engineers designs the landing gear system, another team designs the fuselage system, and so on.

A mechanical system is made up of subsystems, components, and parts that connect to perform a function. Help your students understand these terms:

> **System:** A group of related subsystems or components that form a whole functioning device.
> **Subsystem:** A system of components and parts that is part of a larger system.
> **Component:** A group of parts that work together that perform a specific function in a system or subsystem.
> **Part:** The smallest piece of a design.

In the case of mechanical systems, the boundaries between a system, subsystem, component, and part are relative and are determined by the complexity of the starting system. Think about using the brakes on a bike—the braking *subsystem* of the bicycle *system*. There are several components (each with *parts*) that make up the brake subsystem. On most bikes today, you stop by grasping brake levers. The lever is a component that has parts to attach to the frame and other parts that connect to cables that move as you pull. As cables are pulled, the brake arm component has parts that squeeze together on brake shoe parts that grip on the wheel and slow it down.

In the case of a simpler device, a flip-top toothpaste cap, the system could be the toothpaste dispenser. A subsystem is the cap. There is no real separation between the final part or component, the hinged cap.

Key Concepts: Session 10 (continued)

More About Systems
The American Association of the Advancement of Science states the following science literacy benchmarks in its Project 2061 (www.project2061.org/tools/benchol/ch11/ch11.htm*): "By the end of the 8th grade, eighth grade, students should know that

- "A system can include processes as well as things.
- "Thinking about things as systems means looking for how every part relates to others.
- "Any system is usually connected to other systems, both internally and externally. Thus a system may be thought of as containing subsystems and as being a subsystem of a larger system."

Exploratorium Science of Cycling, www.exploratorium.edu/cycling/index.html*
At this site, explore the wheel, drivers and gears, frames and materials, braking and steering, aerodynamics, and human power.

Session 10, Activity A

Systems and Synergy

Goal
Learn about analyzing a complex product for its designed systems and components.

Outcome
Students understand the difference between systems, components, parts, and connections that make up designed products.

Description
Following a warm-up activity about what the students already know about bicycles, students discuss a short reading about bicycles and compare the systems, components, and parts of a bicycle to other "wholes."

Supplies
Markers (highlighters) of different colors

Preparation

1. In advance, send home information or announce that students should bring or ride bicycles to this session—one bike for every two to four students will work. Let them know that you are interested in a variety of bikes: all sizes, types, state of repair, etc. Ask for or send home information requesting help to locate bike enthusiasts to help out with this session. Ask for any parts on the materials list.

2. Get familiar with bicycles, the history of their development, and how they work:

    - The Exploratorium: www.exploratorium.edu/cycling/index.html*
    - HowStuffWorks: www.howstuffworks.com/bicycle.htm*
    - The Pedaling History Museum: www.pedalinghistory.com*

Procedures
Debrief Home Improvement

1. Check in with student's progress on the Home Improvement for Session 9, *Project Analysis*.

2. Discuss how students will test their projects. Have them share their ideas with the group.

10A: Systems and Synergy (continued)

Bicycle Brainstorm

1. Warm up with a 15-minute discussion to collect what the group knows about bicycles in two areas. Write questions on flip chart paper or the board and add responses:

    - What do we know about what bicycles do?
    - What do we know about bicycle parts?
    - What do we know about what makes bicycles work?

2. Conduct this as a brainstorm—anything that anyone knows is fair game. The goal is to get students thinking about bicycles. Save the responses for the wrap up to the next activity, *10B: Sum Of the Parts*.

Systems, Components, and Parts

1. Introduce the purpose of the activity: To analyze a designed product and separate it into systems and components, and practice with a strategy for breaking complex solutions into manageable, designable parts by identifying systems and/or components that need design and engineering.

2. Have students read *10A Reading: What's a System?* Take turns reading aloud. Discuss and share understanding about the difference between systems, components, and parts in other contexts:

    - Analyze systems in another means of transportation such as a car or boat.
    - Analyze systems in a different context: For example, a house and the systems it has, such as plumbing or heating. Try analyzing a non-mechanical context such the body and its systems (skeletal, circulatory, and digestive systems).

Bicycle Systems, Components, and Parts

1. Using the chart on the handout and any bicycle systems, components, and parts that you have, explain the chart.

2. Once they have an understanding for systems, components, and parts, students should color code the systems of the bicycle on their handout.

Wrap Up
Call students' attention to the definition of synergy at the top of the reading. Ask them: What does this mean in relation to a bicycle? In relation to a design team?

Follow With
The activity *10B: Sum Of the Parts* gives students a hands-on exploration and study of four bicycle systems.

Systems and Synergy

Handout: Session 10, Activity A

Sample Title
The bicycle can be organized into four major systems (see table below). Sometimes a bigger system is made up of smaller systems, or subsystems. Systems can also share the same components. For example, every system listed below makes use of the wheels.

A bicycle has four major systems:

Major System	Purpose	Example Components
1. Drive System	Power you along efficiently under your own steam	Pedals, chain, gears, wheels, transmission subsystem
a. Transmission Subsystem	Shift gears and allow you to adjust for changes in terrain	Gear shifter, cables, derailleur, derailleur gears, hub gears
2. Braking System	Make the bicycle stop reliably at a moment's notice	Wheels, caliper brake subsystem, or coaster brake subsystem
a. Caliper Brake Subsystem	Apply pressure to rim of tire	Brake lever, cables, caliper arms, brake pads
3. Steering System	Turn the bicycle	Handlebars, stem, wheels, frame system
4. Structural System	Support and connect you and the other systems together during operation	Frame, handlebars, wheels, suspension subsystem
a. Suspension Subsystem	Allow wheels to move up and down to absorb bumps in a road	Shock absorber with spring and damper parts

Using the diagram below, highlight the different systems. Each system should be one color—include a color key.

What's a System?

Reading: Session 10, Activity A

System: A group of related subsystems or components that form a whole functioning device.

Synergy: The combined power of a group of things when they are working together which is greater than the total power achieved by each working separately.

Important problems often have very simple solutions. But what is simple? A solution may be very elegant and seem obvious until you start to examine how to make it. Designed things can be deceiving. At first glance, they are so functional and seem so simple to use. But being simple to use does not necessarily mean it is easy to engineer. A very important skill is the ability to analyze, to break down your design solution into the smaller systems and components that work together to make a functioning product. It will help you to think about systems within your product as you design and create a prototype.

Systems are very important to engineering and design. They make the design process much easier. Imagine if you had to design a Boeing 777 airplane, a huge and complex task. However, the task becomes more manageable if you were on a team to design the wing system, another team of engineers designs the landing gear system, another team designs the fuselage system, etc.

Are Bicycles Simple?
Bicycles are everywhere; they are so familiar you almost take them for granted, right? Most of us have ridden bicycles or tricycles. It's pretty easy to think about different things you expect a bicycle to do. Take a minute to analyze how you use a bicycle: You sit on it comfortably, make it go, you make it stop, you make it go fast on flat places, and you make it go up steep hills. In many ways bikes seem so simple. Yet each of these things that you expect a bicycle to do requires a different system. Each system has essential components, and each component may be made of several parts.

What Makes a System?
A mechanical system is made up of components and parts that connect to perform a function. Think about using the brakes on a bike. There are several components (each with parts) that make up the brake system. On most bikes today, you stop by grasping brake levers that have parts to attach the levers to the frame and other parts that connect them to cables that move as you pull. As cables are pulled, brake arms squeeze together on brake shoes that grip on the wheel and slow it down.

Session 10, Activity B

Sum of the Parts

Goal
Learn about the mechanisms of four bicycle systems: Study the components, the parts, and connections for each.

Outcome
Students identify and distinguish systems (drive, braking, steering, and structural) and components (frame, wheels, and seats) in a bike.

Description
During a field trip to a bike shop or on-site with students' own bikes and loaned parts, students study four systems on a bicycle: power, braking, steering, and structural. They isolate and observe the operation of each system. They also study examples of individual components and parts removed from the bicycle in a rotation through "study stations" organized around the four systems.

Supplies

- 8-10 bicycles and tricycles of different kinds, shapes, and sizes (brought by the students and mentors)
- Additional specialty bicycles (recumbent, folding or collapsible, track and racing bikes, BMX freestyle, fat tire coaster bikes)
- Bike repair stands (to raise and support bikes off the floor for study)
- Bicycle parts, 1 or 2 examples of each system or a few parts in each system:

    1. Drive systems: pedals, cranksets (crank and chainwheel), chains, axles, wheels
    2. Steering system: handlebars, front wheel, headset bearings
    3. Brake systems: brake levers, cables, and calipers (attached as a system)
    4. Structural system parts:
        - Frames: without any components attached—any size, style
        - Wheels: different sizes and designs (some missing spokes or out of true is fine)
        - Handlebars: downswept and straight
        - Seats (or saddles): different shapes and designs

- Old rags or paper towels for wiping grease and dirt off hands and bikes
- Optional: Erector* set (toy construction set)

10B: Sum of the Parts (continued)

Preparation

1. Set up an outside location where the bike study will take place.

2. Gather all bike materials. Arrange for four facilitators to lead bicycle systems "study stations" among the bicycle enthusiasts who are willing to help (parents, mentors, leaders).

3. Send guest facilitators copies of the session materials. Have them be prepared to facilitate a short hands-on demonstration/experience of the components and parts for the system at their "study station" of a system: drive, braking, steering, and structural systems.

4. Organize placement of bikes and parts for hands-on study of systems, components, and parts. Set up workspace for:

    - Bike systems study: teams of two to three students to study four systems on one bike
    - Components and parts study: "study stations" of components and parts grouped by each of the four systems
    - Specialty bicycle study: recumbent, racing or track, folding, coaster, BMX, and unicycle

Optional: Bike Shop Field Trip
As an option to having students bring bicycles, it may be easier to arrange a field trip to a bicycle shop where students can study bike systems, components, and parts as outlined in the procedures. If this is possible, be sure to familiarize the bike shop manager with the purpose of the field trip. Meet together and plan the experience ahead of time together.

Procedures
Examining Bicycles

1. Have students read the handout and get organized for studying the bicycles.

2. Divide students into teams to examine and observe the mechanisms (components, parts, and connections) for four systems on the available bicycles. If bicycle stands are not available, demonstrate how to turn the bike over and with one person supporting it so that the wheels turn freely during the observations. Or, with smaller bikes demonstrate how to be a human bike stand: Hold the rear tire off the ground by straddling the rear tire and raising the bike with the seat. Hold on firmly.

3. Rotate teams to each study station to examine and operate components and parts. Have students jot down notes about how parts connect and work together in each system. Their notes may be sketches.

10B: Sum of the Parts (continued)

4. In a whole group, have a rider demonstrate each specialty bike. Have students identify each of the systems.

Optional: Erector Set Vehicles
In the classroom, students can use Erector sets for hands-on construction and application of systems. Ask students to build model vehicles (cars, scooter, bicycles, and so forth) to demonstrate their understanding of systems

Wrap Up
Return to the classroom and revisit the three lists that were generated during the *10A: Systems and Synergy* activity. Ask, what do we know about what bicycles do? What do we know about bicycle parts? What do we know about what makes bicycles work?

Ask students to share or write about new understanding of bicycles as a result of studying its systems, components, and parts.

Discuss what do you know about bicycles now?

Take a bike ride!

Follow With
In Session 11, *Design Requirements and Drawings*, students develop design requirements and technical drawings for their design and engineering project.

Sum of the Parts

Handout: Session 10, Activity B

Chances are you have had some experience with bicycle mechanisms. Perhaps you've had to fix or adjust something on a bicycle or have watched while someone else did quick maintenance during a ride. Have you ever really looked at a bike and studied how it works? A bicycle has a set of mechanical systems that are familiar and easy to observe.

Directions
Study four systems on your bicycle. You'll also be able to observe and operate the components and parts of each system that are removed from a bike. This will give you another way to observe how things connect and work together.

Systems Study

1. Drive system: Support the bike with the rear wheel off the ground (turn the bike on its side, use a stand, or have a partner hold the bike up.) Slowly power the bike using the pedals and study how the energy you add transfers through the drive system to the wheels. Switch partners.

2. Braking system: Study how the brakes work as you press and release the brake lever. Trace the operation of the brakes through components and their parts. Notice the connections.

3. Steering system: Study how you steer a bike. Trace the steering through the handlebar to the wheels. Notice the connections.

4. Structural system: Study the frame and how all the systems connect to it.

Components and Parts Study
Observe and take notes about how parts connect and work together in each of the systems. Which systems seem simple and require few parts? Which systems seem complex and require more parts and complicated connections? Which systems seem easy to break down? Which systems seem easy to repair? Your notes may consist of words or sketches.

Drive system:

Braking system:

Steering system:

Structural system:

Specialty bikes: Identify and study the four systems in each of the specialty bikes. Compare them to the systems in the more traditional bicycle. What did you observe?

Optional: Using an Erector* set for parts, make your own model vehicle. Try to incorporate the four systems you studied: structural, drive, steering, and braking.