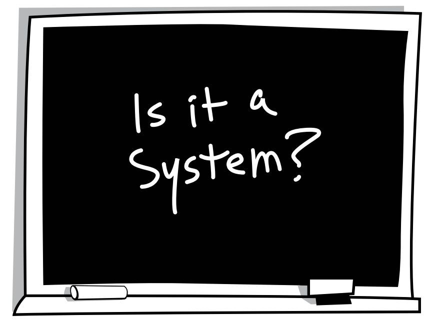
Is It a System?



Various things are listed below. Put an X in front of the things that can be thought of as a system.

___ aquarium	___ digestion	___ cell phone
___ pile of sand	___ food web	___ A + B = C
___ Earth	___ hurricane	___ electrical circuit
___ grasshopper	___ graph	___ water cycle
___ volcano	___ seed	___ human body
___ soil	___ bicycle	___ Density = Mass ÷ Volume
___ ocean	___ Earth and its Moon	___ box of nails

Explain your thinking. How did you decide whether something is considered to be a system?

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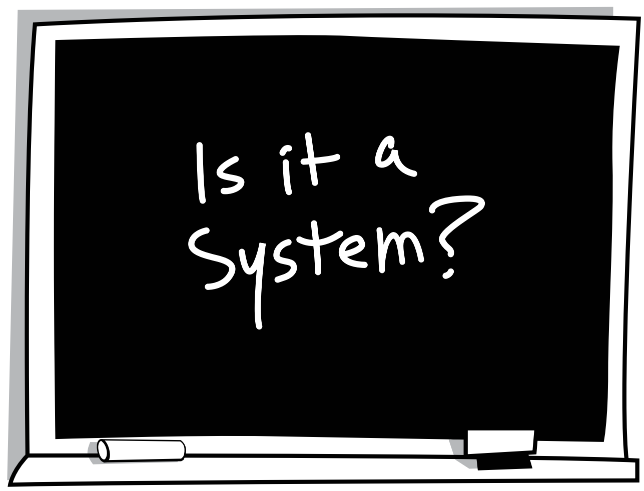
Is It a System?

Teacher Notes



Purpose
The purpose of this assessment probe is to elicit students' ideas about systems. The probe is designed to find out whether students can recognize that things with parts that interact or influence each other are systems.

Related Concept
system

Explanation
The best answer is that everything except for the pile of sand and box of nails can be considered to be a system. If you remove some of the sand, it is still a pile of sand. Removing a sand grain, a cup of sand, or a bucket of sand does not influence whether the sand is still a sandpile, nor do the parts of the sand interact with one another. The nails in the box do not interact with or influence each other. They may be part of a larger system but by themselves they are not a system. You can remove some of the nails and you still have a box of nails. However, there are ways one could stretch this to justify that the sandpile or box of nails is a system. For example, the atoms that make up the sand or nails interact with one another.

Systems range from the simple to the complex. A system is a collection of things (including processes) that have some influence on one another and the whole (AAAS 1989). Systems can be manufactured objects (thermometer, bicycle, cell phone, electrical circuit), life-forms (grasshopper, human body, seed, cell), combinations of living and nonliving things (food web, aquarium, ocean, soil, Earth), physical bodies (volcano, Earth and its Moon), processes (water cycle, hurricane, digestion), or quantitative relationships (Density = Mass/Volume, A + B = C, graph). To be considered a system, the components must interact with or influence each other in some way. Systems are often connected to other systems, may have subsystems, and may be part of larger systems (e.g., human body systems). Their inputs and outputs can include matter, energy, or information.

Curricular and Instructional Considerations

Elementary Students

In the elementary grades, systems begin with parts-and-wholes relationships. Students begin to identify parts of objects such as toy vehicles, animals, dolls, and houses and observe how one part connects to and affects another. This sets the stage for taking apart and reassembling more complicated mechanical systems, emphasizing the importance of the arrangement of parts, and recognizing interactions.

Middle School Students

In the middle grades, students begin thinking from a systems approach, analyzing parts and interactions and identifying subsystems. Disassembly of more complex objects such as clocks or bicycles provides opportunities to describe the interaction of parts, not simply label collections as systems. Projects in which students design, assemble, analyze, and troubleshoot manufactured systems (e.g., battery-powered electrical circuit) and examine biological systems (e.g., organisms in an aquarium) are common at this grade span. Experiences are provided in which inputs to a system that affect the output are changed (e.g., adding another battery to a circuit, adding more fish to an aquarium). Emphasis is placed on the connections among systems; a battery can be thought of as a system that is also part of a larger system in a circuit, and a fish itself can be considered to be a system that is part of a larger system in an aquarium.

High School Students

Students at the high school level have opportunities to reflect on the value of thinking in terms of systems and to apply the concept in a variety of contexts. Through projects, readings, experiments, and discussion, students analyze the boundaries and components of systems and distinguish the properties of the system from the properties of the parts. Students begin to use the concept of feedback mechanisms (e.g., homeostasis) to explain why things happen and predict changes that may occur.

Administering the Probe

This probe is best used at the upper-elementary, middle, and high school levels. It can be used as a paper and pencil assessment to gather students' ideas for later analysis as well as a stimulus for provoking discussion about systems. It can also be administered as a card sort with small groups sorting examples into two groups—"Is a System" or "Is Not a System"—justifying their reasons as they place each card into a category. Remove items that students may be unfamiliar with and/or add items that connect to systems ideas in your curriculum.

Related Ideas in *National Science Education Standards* (NRC 1996)

K–12 Unifying Concepts and Processes—Systems

- The natural and designed world is too large and complex to comprehend all at once. Scientists define small portions for the convenience of investigation. These portions are referred to as *systems*.
- ★ A system is an organized group of related objects or components that form a whole. Systems have boundaries, components, resources flow (input and output), and feedback.
- Within systems, interactions between components occur.
- Systems at different levels of organization can manifest different properties and functions.
- Thinking in terms of systems helps keep track of mass, energy, objects, organisms, and events referred to in the other content standards.
- The idea of simple systems encompasses subsystems as well as identifying the structure and function of systems, feedback and equilibrium, and identifying the distinction between open and closed systems.
- Understanding the regularities in systems can develop understanding of basic laws, theories, and models that explain the world.

Related Ideas in *Benchmarks for Science Literacy* (AAAS 1993 and 2008)

Note: Benchmarks revised in 2008 are indicated by (R). New benchmarks added in 2008 are indicated by (N).

K–2 Systems

- Most things are made of parts.
- Something may not work if some of its parts are missing.
- When parts are put together, they can do things that they couldn't do by themselves.

3–5 Systems

- In something that consists of many parts, the parts usually influence one another.

6–8 Systems

- ★ A system can include processes as well as things.
- Thinking about things as systems means looking for how every part relates to others. The output from one part of a system (which can include material, energy, or information) can become the input to other parts. Such feedback can serve to control what goes on in the system as a whole.
- 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.
- Some portion of the output of a system may be fed back to that system's input. (N)

★ Indicates a strong match between the ideas elicited by the probe and a national standard's learning goal.

- Systems are defined by placing boundaries around collections of interrelated things to make them easier to study. Regardless of where the boundaries are placed, a system still interacts with its surrounding environment. Therefore, when studying a system, it is important to keep track of what enters or leaves the system. (N)

9–12 Systems

- A system usually has some properties that are different from those of its parts but appear because of the interaction of those parts.
- Understanding how things work and designing solutions to problems of almost any kind can be facilitated by systems analysis. In defining a system, it is important to specify its boundaries and subsystems, indicate its relation to other systems, and identify what its input and its output are expected to be.
- Even in some very simple systems, it may not always be possible to predict accurately the result of changing some part or connection.
- The successful operation of a designed system often involves feedback. Such feedback can be used to encourage what is going on in a system, discourage it, or reduce its discrepancy from some desired value. The stability of a system can be greater when it includes appropriate feedback mechanisms. (R)
- 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. (N)

Related Research

- Elementary students may believe that a system of objects must be doing something in order to be a system or that a system that loses a part of itself is still the same system (AAAS 1993).
- Students of all ages tend to interpret phenomena by noting the qualities of separate objects rather than by seeing the interactions between the parts of a system (e.g., force is considered as a property of bodies rather than as an interaction between bodies; AAAS 1993).
- Students explain changes as a directional chain of cause and effect rather than as two systems interacting (AAAS 1993).

Suggestions for Instruction and Assessment

- Provide students with opportunities to examine a variety of examples of familiar manufactured systems (bicycle, can opener, pencil sharpener, flashlight). Ask questions about what this example of a system does; what the boundaries, inputs, and outputs are; and how the components interact and contribute to the system as a whole. Then ask the same questions about a natural system (e.g., a familiar ecosystem, a cell, the solar system). Emphasize the interactions and influences, not simply the names of the components. A list of questions about systems accompanies the American Association for the Advancement of Science Project 2061 lesson "Seeing the Cell as a System," included in *Resources for Science*

Literacy (AAAS 1997). This lesson can also be accessed online at *www.project2061.org/publications/rsl/online/guide/ch2/hlpsys0.pdf* and *www.project2061.org/publications/rsl/online/guide/ch2/hqsystem.pdf.*

- Challenge students to come up with examples of systems that have the word *system* in them (e.g., solar system, school system, human body systems, ecosystem). Ask them what all of these things have in common that make them systems. Then challenge them to come up with examples of systems that do not include the word *system*.
- Use a FACT (formative assessment classroom technique) such as the Frayer Model, Scientist's Idea strategy, or First Word–Last Word to determine students' ideas about systems before and after instruction (Keeley 2008).
- Integrate the unifying theme of systems into content domains in a variety of contexts. Make explicit connections between systems-thinking and life science (the human body, cells, photosynthesis), Earth/environmental science (ecosystems, climate and weather, Earth system interactions), and physical science (force and motion, energy transfer and transformation) ideas.
- Develop the ideas of input, output, and interactions among components during engineering design exploration and analysis.
- Connect ideas about systems to the idea of models, data collection, and graphing. The purpose of studying systems is to develop the ability to think and analyze in terms of systems. Such thinking can strengthen the skill of identifying regularities and patterns, which supports an understanding of models that explain the world. Prediction from a systems perspective involves using knowledge about the world and an understanding of trends in data to identify and explain observations or changes in advance.
- Challenge students to come up with ideas of things that are not systems. Ask them to apply their lists of characteristics of a system to decide whether the item is a system or not.

Related NSTA Science Store Publications, NSTA Journal Articles, NSTA SciGuides, NSTA SciPacks, and NSTA Science Objects

American Association for the Advancement of Science (AAAS). 2001. *Atlas of science literacy.* Vol. 1. (See "Systems," pp. 132–133.) Washington, DC: AAAS.

Breene, A., and D. Gilewski. 2008. Investigating ecosystems in a biobottle. *Science Scope* (Feb.): 12–15.

Hmelo-Silver, C. E., R. Jordan, L. Liu, S. Gray, M. Demeter, S. Rugaber, S. Vattam, and A. Goel. 2008. Focusing on function: Thinking below the surface of complex natural systems. *Science Scope* (July): 27–35.

Leager, C. R. 2007. Ecosystem in a jar. *Science & Children* (Apr./May): 56–58.

Llewellyn, D., and S. Johnson. 2008. Teaching science through a systems approach. *Science Scope* (July): 21–26.

Ludwig, C., and N. S. Baliga. 2008. Systems concepts effectively taught: Using systems practices. *Science Scope* (July): 16–20.

National Science Teachers Association (NSTA). 2006. Coral ecosystems. NSTA SciGuide. Online at *http://learningcenter.nsta.org/search.aspx?action=quicksearch&text=Coral%20Reef%20Ecosystems*

Related Curriculum Topic Study Guide

(Keeley 2005)

"Systems"

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Keeley, P. 2008. *Science formative assessment: 75 practical strategies for linking assessment, instruction, and learning.* Thousand Oaks, CA: Corwin Press.

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