Students learn about systems and systems thinking through creating and observing a system in motion.

What you’ll need:
- A large area inside or outside that will allow enough room for the system's motion.
- Cones, rope, or verbal instructions to define the area in which the activity will occur.
- A minimum of 10 students but ideally 15 to 25.

Directions:
Ensure that students obtain a basic understanding of systems before launching the activity.
Background information and links to additional resources follow in subsequent sections.

1. About systems...
- Present and survey student knowledge about systems and systems thinking through class discussion. (You can use the various biological systems within the human body as an example of a system with its various subsystems: circulatory system, nervous system, endocrine system, skeletal system, etc.). Encourage students to brainstorm examples of other systems and their subsystems.
- Ask the students if they see any defining features across all systems? Are systems always natural in origin or can they be mechanical or human? Allow enough time to foster a basic understanding of systems and their defining features.

2. Introduce the activity and its various steps
- Explain to the students that they are going to be asked to observe or be part of a system.
- Assign one-fourth of the students to be “scientists” or ask for volunteers to play this role. Tell the remaining students that they will collectively comprise the system that will be studied by the scientists.
- Separate the scientists from the remaining students so that they are unable to hear the instructions specifically for the students comprising the parts of the system.
- While the two groups are separated, give each group their instructions and answer any ensuing questions.

3. Instructions for students playing the scientists
- Explain to the students that they will be playing the role of scientists tasked with observing a system and defining the principle or “rule” that governs its motion. Convey to them that while the system appears complex from the outside, it is operating in a manner that can be studied and understood through observation.
- Instruct the scientists that the game will be halted every 2-3 minutes to give them an opportunity to ask “Yes No” questions that can inform their observations and advance their theories.
- Encourage the scientists to work collaboratively and adopt strategies that will increase their collective success such as sharing any patterns they observe and brainstorming questions that they have for the system’s participants.
- Other actions that scientists may find helpful after they have had an opportunity to study the system a few times include:
  - walking through the system while it’s in motion,
  - removing a part or parts of the system and observing what happens,
  - isolating part of the system and watching what happens.

For Teachers:

Student Learning Objectives
- Students will discuss and experience the underlying characteristics of a system
- Students will identify various systems that are natural, mechanical or social in their lives
- Students will be able to explain how understanding a system can help us find solutions to complex problems

Class time
- 2 class periods

Grades
- 5th - 12th grade

National Science Standards
- A: Science as Inquiry
- B: Physical Science
- C: Life Science
- D: Earth & Space Science
- F: Science in Personal & Social Perspectives
- G: History and Nature of Science

National Geography Standards
- 3: How to analyze the spatial organization of people, places, and environments.

Standards for School Mathematics
- Understanding patterns, relations, and functions

Written & Adopted by Teresa Eastburn (Spark, UCAR Science Education)
4. Instructions for students who are part of the system

- Ask the students to randomly choose any two classmates who are also playing parts of the system. It is not necessary for them to share this information with their fellow classmates.
- Explain that they will be a system in motion that will move in a manner that may appear complex or random from an observer's point-of-view. However, this particular system will follow a set “rule” that the scientists will be trying to identify.
- Each student as part of the system will move so that he or she keeps an equal distance at all times from the two classmates that were chosen earlier. (For younger students, a less complex “rule” can be substituted such as choose one person to follow in the system that is in constant motion.)
- Ensure that all students understand that this does not mean that they will remain in a straight line between their chosen subjects, but that the physical shape of their relationship with their chosen parts will fluctuate from linear to triangular in appearance. Use three classmates to demonstrate the various arrangements that are possible when students follow the given “rule.”
- Tell the students that they are to remain in constant motion within the confines of the defined space for the length of the activity, although their motion will randomly accelerate and slow down.
- Lastly, practice the system once or twice before bringing in the scientists to observe.
- If the scientists are allowed to experiment with the system, students who are no longer able to follow the “rule” should stand still. If the experiment does not impact a student, they should continue to follow the “rule” as before.

5. Begin the Activity

- Designate an area for the scientists to observe the system and a separate area near by in which the system can operate.
- Begin the activity with a gentle push of a few of the “parts” within the system in order to set it in motion.
- Approximately every 2-3 minutes, stop the system and allow the scientists to ask “Yes No” questions of their classmates in the system. Listen to ensure that the answers are accurate.
- Allow the scientists to experiment with the system by walking through it, or isolating a part or parts of it, then observing its response.
- After an appropriate amount of time for the scientists to observe and study the system in motion, give the scientists time to make their last predictions of the “rule” under which the system is operating. Stop the exercise regardless if the scientists have been able to explain the system or not. Explain to the scientists that just like real research, many systems can remain a mystery for years to centuries. Complex systems are inherently difficult to understand.

Reflection and Assessment

Ask the students the following questions:
- What was their experience like as part of the system? Their reflections are likely to uncover many of the common components found in a system (i.e. interdependence of the parts, feedbacks, dynamic, self regulating) and lead into rich conversations about observable characteristics of a system.
- What was their experience like as one of the scientists? Their reflections are likely to uncover feelings of frustration and puzzlement when trying to unravel the defining features of a complex system. Many of these emotions are commonly held by researchers in search of answers to scientific questions. In fact many scientists spend many years of their professional life trying to unravel a particular system or a part of a system to advance scientific understanding.
- How did working independently or collaboratively impact the scientists’ work? How might working independently or collaboratively impact the work of actual scientists?
- Where was your attention focused in either role? Did you focus on the system as a whole or on its parts?
• What happens to a system that is altered in some way? Can you think of an example of another system that has been altered (a habitat that is altered through development; a government by a coup; the ocean by an oil spill)?
• Are changes within a system always bad?
• What other systems can you think of at work in the world or universe today?
• What are some of the systems that we do not fully understand?

Science background: Systems and Systems Thinking
A system is an organized group of related objects or components that form a whole. The “whole” can be mechanical, social, temporal, natural, numerical, physical, or even ideological, but it will also have various parts or subsystems that are interrelated and interdependent. In other words, the parts of a system continually influence one another directly or indirectly to carry out the system’s function or goal. Examples include a car engine with its various menchanical parts, a family with its small or large number of members, a subway system with its many routes, or a political system with its various structures and laws of governance. In computational science, these parts are said to be “coupled.” Systems can also be coupled to each other, such as the ocean system impacting the Earth’s climate system. It is only our capacity to comprehend the complexity of an observed entity that limits our understanding of the unending number of systems we see and/or play a part within, and how these systems work.

All systems have certain characteristics, in common. Each has inputs, outputs, and feedback mechanisms; and each maintains an internal steady-state (homeostasis) despite what happens in its external environment. As mentioned prior, a system also has many parts that are interrelated and interdependent. If a part is removed or changed in some capacity, the whole system can be altered, or in extreme cases even destroyed. Despite the fact that systems look quite different from one another on the surface, they in fact have remarkable similarities. Some are closed systems with solid boundaries that exist in a self-sufficient state. Open systems have permeable boundaries with inputs and outputs that allow the system to interact with their external environments.

Analyzing and thinking in terms of systems is an essential component in the study of all science disciplines. As stated in the National Science Standards*, students can develop an understanding of regularities in systems, and by extension, the universe; they then can develop understanding of basic laws, theories, and models that explain the world.


Learn more online!
• Earth System Science, www.cotf.edu/ete/ESS/ESSmain.html
• Pegasus Communications’ website, www.pegasuscom.com/systems-thinking.html
• Mental Model Musings, http://www.systems-thinking.org/index.htm

The Systems Game: System in Motion
Written and adapted by Teresa Eastburn. Variations of this activity have been used in many disciplines for decades to illustrate systems and systems thinking concepts. The creator of the original activity is unknown. (Spark, UCAR Science Education)