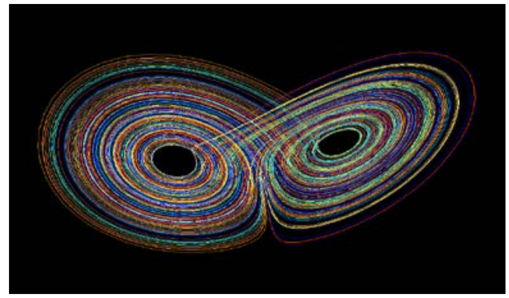
What's Going On? Understanding Systems



Objective

Students will be able to explain the general principles of living systems. Students will be able to identify the relationships between interacting components in a system.

Materials

- Lesson Plan with game instructions
- Open space

Appropriate Grade Level: 3rd - 8th

Time Required: 30min – 1 hr

Curriculum Benchmarks: 3.2P.1, 4.2L.1, 5.1L.1, 5.2L.1, 6.2L.2, 7.1

Background Information

Nature is full of systems! A forest is an example of a type of natural system! The purpose of this activity is to expose learners to the concept of systems and how they function. By understanding systems, learners will have a better understanding of how different things interact to form sensitive complex interactions which give rise to new qualities and characteristics. Systems thinking is applicable to all fields of study!

The Earth is an open system because it is constantly receiving inputs from outside of itself like the sun, meteorites, and space radiation. Open systems use feedback to adapt and evolve. Living systems exhibit “positive” feedback when an event increases the likelihood the event will happen again. This leads to incredible adaptations and evolution of the components of the system and eventually evolution of the system itself. An example of “positive” feedback would be the reduction of ice of a glaciated region. If a glaciated region loses ice, it reflects less solar energy, thus absorbing more solar energy and perpetuating the loss of ice. “Negative” feedback is just the opposite and discourages an event from occurring. An example of negative feedback can be found in a common air conditioning thermostat. The air will keep running until it reaches a certain temperature, at which point negative feedback occurs and the air stops running. “Negative” feedback creates dynamic balance in a system but with insufficient stimulation can lead to stagnation and death. A healthy system has a dynamic balance of “positive” and “negative” feedback – evolving, diversifying, but not to the point of prolonged stress.

Life is an interdependent network of relationships. The behavior of every member of any system depends on the behavior of many others. The unique interactions between the parts make each whole distinctive. How a person's cells interact determines how an organ will function, which will determine how the person will function. The success of a system depends on the success of the members and the success of the member depends on the success of the system. When relationships between members develop, new possibilities arise!

Life stays in balance by self-organizing. Natural systems are constantly fluctuating and adapting to compensate for changing conditions in the environment (e.g. temperature). Simple linear chains of cause and effect probably do not exist in nature. Healthy resilient systems are sustainable because of their complex webs of relationships, the diversity of their parts, and their ability to recycle everything they consume – what is waste for one is food for another. A pollutant is simply an out of place resource! This is the web of life.

No system is an island! Every system in the universe, from an atom to a galaxy, is simultaneously part of a whole and a whole of parts. This is called a “holon.” A “holon” cannot be reduced to its parts without altering or destroying the whole. Each part interacts with other parts to create synergy, and a new whole emerges with properties beyond the capacity of the parts (cells to organs, organs to person, person to family, family to community, etc). This is called “emergence.” Order tends to emerge from the bottom up, and with order comes complexity and diversity. Parts become diverse as they coordinate their roles and develop complex new ways of interacting together. A diverse system is resilient because it contains many different parts with overlapping functions that both duplicate and complement each other. The more complex a system, the denser are its patterns of interconnection. This complexity creates many new possibilities for "emergence" and evolution.

Dynamic systems are systems that change over time. This is opposed to static systems which remain constant. All natural systems are dynamic. Dynamic open systems are very sensitive to change. Very small changes can, over time, change the entire state of the system. This is sometimes referred to as the "Butterfly Effect." (See Additional Information below)

Activity

1. Introduce the "Systems Game" and explain learning outcomes.
2. Tell participants to silently pick two other participants without letting them know that they have been picked.
3. Tell participants to move so as at all times to keep an equal distance between you and each of the two people you have chosen.
4. Have the participants begin circulating, each movement triggering many others in an active, interdependent fashion.
5. Occasionally tell participants to speed up or slow down.
6. Continue game for approximately 5 minutes.
7. After the game is over, ask students what they experienced and what they noticed.
8. After discussion, the game will start again, with a twist. About two minutes into the game, tap a student (or assign this role to another student). The participant who is tapped waits 5 seconds and then sits down. Then anyone who chose that player must wait 5 seconds and sit down. And so on, and so on until everyone sits down.
9. After the game is over, point out that what was witnessed was an ecosystem and the person that was originally tapped was an example of a keystone species.
10. Proceed with a discussion about the interconnectedness of biotic and abiotic factors in ecosystems and how ecosystems can change when a component is removed or changed. This can be followed up with a discussion about the impacts that human activities can have on natural system and the need for

sensitivity in our actions because everything is connected and everything affects everything else.

11. Optional reflective essay questions:
    - "Based on what you have learned about systems, why do humans need to act sensitively toward their environment?"
        - Appropriate answers will include something about how a system depends on the relationships of its components, systems are very sensitive to change, and we cannot accurately predict how systems will respond to change.
    - "Imagine a forest ecosystem. Pick a component of a forest and remove it. Explain how the forest would change in response to the absence of the component you chose."

Extensions

α. This game can be extended to talk about trophism (how energy moves through a natural system) by employing the activity "Let's Eat!" which is also included in this kit. A good segue from this activity to the "Let's Eat!" activity is to tell the learners that it is time to model a real natural system, after going through the "Understanding Systems" game.

Glossary

Butterfly Effect: the sensitive dependency on initial conditions in which a small change at one place in a deterministic nonlinear system can result in large differences in a later state

Chaos Theory: a field of study in mathematics with applications in several disciplines including meteorology, physics, engineering, economics, biology and philosophy which studies the behavior of dynamical systems that are highly sensitive to initial conditions.

Emergence: process by which a new whole emerges with properties beyond the capacity of the parts

Feedback: a process in which information about the past or the present influences the same phenomenon in the present or future

Feedback Loop: the complete causal path that leads from the initial deterction of the gap to the subsequent modification of the gap

Holon: a system that is both a whole and a part

Keystone Species: a species that has a disproportionately large effect on its environment relative to its abundance

System: a set of interacting or interdependent components forming an integrated whole

Additional Information

When studying systems, it is important to gain a bit of understanding of chaos theory and how it relates to natural systems. Chaos theory is the science of sensitive dynamic systems and is often employed to present the Butterfly Effect which illustrates the fact that dynamic systems are extremely sensitive to initial conditions and small changes in initial conditions can cause great changes in the future states of the system. The example was made originally be Edward Lorenz when he postulated that a hurricane's formation might be dependent on whether or not a butterfly far far away had flapped its wings some time in the past. Did you know that the reason computers were invented was to try to predict the weather? Chaos theory was born out of this pursuit to try to accurately predict the weather, but steadily scientists learned that even the smallest change to initial conditions led to very different weather scenarios the longer time went by, and so, weather prediction can only be somewhat accurate for a short amount of time into the future.

Chaos theory can be a segue into discussing human influences of natural systems and the need for an understanding of our own ignorance when it comes to how systems will change and evolve in response to our actions. The *slightest* change to a system can ripple through time and push the system into a totally different state. And let us not forget that all systems are connected.

This activity was adapted from Bobbi Allan's “System Game” from Stillness in Action, 2008.