Activity 9: Feedback Loops Introduction
Instructor Guide

Summary:

Students are introduced to feedback loop vocabulary and experiment with different relationships between reservoirs in simple feedback loops using LOOPY, a free, online modeling program.

This activity is the 9th activity in a Systems Thinking module designed for middle school science courses. These activities are designed to provide middle school students with the tools to assess complex issues of sustainability holistically. The series begins with activities that introduce systems thinking vocabulary and systems diagrams, then moves to activities addressing how rates, equilibrium, and feedback loops contribute to changes in systems over time. The module concludes with several activities that require students to assess an issue of sustainability through a variety of interconnected human and natural systems. The activities begin using simple water system examples such as the classroom sink and the school water supply system. Then the activities progress to more complex system examples with a greater focus on the interconnectedness between systems, ultimately assessing the issue of water scarcity in the United States through many connected human and natural systems like agriculture, energy, and the water cycle.

Context:

This activity is intended for a middle school science course but fits within any skills, history or english course. Materials presented here are designed to be implemented in a remote learning environment, either as part of an entirely online or hybrid course.

Students need background information on systems thinking vocabulary (reservoir, flow, equilibrium/nonequilibrium or stable/unstable).

This activity is best taught after the Systems Thinking vocabulary Activity 1 and the equilibrium experiment Activity 8 (the instructor can pick and choose the vocabulary elements from these activities). This activity is also best followed by Activity 10 which applies feedback loops to earth science topics.

Goals of Activity:

1. Students will define feedback loop vocabulary.
2. Students will identify feedback loops.
3. Students will apply equilibrium and nonequilibrium vocabulary to feedback loops.
4. Students will experiment with the relationships between reservoirs in feedback loop models using LOOPY.

Activity Description and Materials:

Materials:

- Zoom meeting or other online platform (with breakout groups enabled)
- Activity 9 Google Drive Folder:
    - Instructor Guide Activity 9
        - Make a single copy for Instructor use
    - Activity 9 Powerpoint Presentation
        - Make a single copy for Instructor use
    - Student Handout Activity 9
        - Give students access to their own copies to fill out individually
    - Answer Key Student Handout Activity 9
        - Make a single copy for Instructor use
    - LOOPY diagrams (linked throughout the Powerpoint and Instructor Guide)
    - Instructor Resource: LOOPY instructional Video

Activity Description (total time: 45 - 55 min)

Part 1(Optional) - Introduction to Feedback Loops (15 min)
The instructor opens the Activity 9 Powerpoint Presentation powerpoint and shares their screen with the class.

Slide 1: The instructor introduces the goals for the activity: Build a feedback loop from a problem and learn feedback loop vocabulary. Part 1 addresses this first goal: build a feedback loop from a problem.

Slide 2: The instructor asks the class to think about problems that they face in their day to day lives that apply to other people in the class and are solvable.
The instructor might say something like this: *"Think for a minute about some problems in your day-to-day life that also apply to other people in our class. Problems that you wish you could fix - they could be school related, friend related, hobby related, etcetera."*

Slide 3: The instructor tells students this should be a problem that has causes and effects that impact each other. The instructor then provides a minute for students to brainstorm before asking students to call out or type in the chat some of the problems that they thought of. From these student solicited responses, the instructor selects one problem that can be broken down into 4 simple system elements (2 reservoirs, 2 flows) that are related by a circular cause and effect feedback loop.
Student ideas of problems could be:

- Too much HW, Bullying, Late for the bus, Not enough time between classes to get to class on time, Tired throughout the school day, Hungry before lunch period, Bored in class, Not enough likes on media posts, Not enough time to practice (sports, instruments, other hobbies)

The instructor might say this while on slide 3: *"Once you think of a few problems we'll choose one that can easily represent today's topic, and we'll dive into these questions: what causes this problem, what are the effects of this problem, and are the causes and effects connected, meaning do they impact each other? So as you think about your problem keep these questions in mind. Now I'll let everyone think for a minute, and then when I say time's up, anyone can call out what they brainstormed or type their idea in the chat."*

Slide 4 - Creating the LOOPY:

The instructor clicks on the LOOPY link and shares their screen with the LOOPY diagram. As a class, the instructor solicits explanations of the causes and effects of the selected issue, typing them out on LOOPY. From the students' list of causes and effects, the instructor fills in the reservoir and flow names on the diagram to create one of the many possible feedback loops with two reservoirs and two flows. The provided pre-fabricated LOOPY can be easily adjusted to include more flows and reservoirs and different + or - relationships as needed. Here is an example of a Hunger (Metabolism) LOOPY. If the instructor would like students to feel more involved, the students can draw the LOOPY diagram on a piece of paper as the instructor creates the LOOPY online.

- Loopy Hunger/Metabolism Example (Balancing feedback loop - in equilibrium)
- Loopy Bullying Examples (Reinforcing Feedback Loop - in nonequilibrium)
- Loopy Instructional Video - How to create this LOOPY in class.

Then, the instructor plays the Loopy diagram illustrating how one reservoir in the feedback loop changes and then subsequently causes the other reservoir to change. If the students have learned the terms equilibrium and nonequilibrium the instructor can ask the students which term they would use to describe the loop they created.

Here's how an instructor might talk through creating a LOOPY about Being Hungry:

"Thanks for sharing why don't we dive into the hungry issue." *The instructor clicks on the LOOPY link in slide 3.* "W*hat causes us to be hungry? And what do we do to stop being hungry?"*

Student Ideas could be: Cause - Waited too long to eat since breakfast, didn't eat enough breakfast, digested all the food they had in their stomachs, not enough food available. Effect - Ate food to feel less hungry.

"There are many different ways that you could make this circular diagram, but why don't we make the first reservoir the stomach and the second reservoir the stomach. We'll have eating be the flow connecting your hunger level and your stomach and we'll have digestion being the flow that connects your stomach back to your hunger level. I'll put a + sign here because it's a same relationship: the more you eat the more food there is in your stomach. And

I'll put a negative sign here because it's an opposite relationship: the more food in your stomach the less hungry you are. We'll go back over these terms later.

"Now let's play this loop! If you are hungry you eat, that fills up your stomach. You start to digest your food and you feel less hungry. So, you eat less, your stomach becomes less full, but you continue to digest so you become more hungry. Then you eat again! Do you think this system keeps your hunger levels in equilibrium or nonequilibrium (ie. balanced or unbalanced)?"

The instructor asks the students to open Student Handout Activity 9 and complete Part 1: On a blank sheet of paper, **draw** the feedback loop your teacher created on LOOPY.

Slide 5: The instructor provides students with the definition of a feedback loop and applies it to the example the class just built. If applicable, the instructor can also use this slide to explain how a prior class concept demonstrates a feedback loop.

Part 2 - Relationship Vocabulary and LOOPY (10 min)

The instructor asks students to open their Student Handout Activity 9. The instructor uses Activity 9 Powerpoint slides 6-14 to explain the same (+) and opposite (-) relationships between reservoirs that are the building blocks of feedback loops.

Slide 6 introduces the two types of relationships between reservoirs: same and opposite relationships. The instructor might say: *"Flows connect reservoirs in two ways: same relationships and opposite relationships. Same relationships are indicated by a plus sign, opposite relationships are indicated by a minus sign."*

Slide 7 defines same relationships and slide 8 shows how one reservoir increasing causes the reservoir related by a same relationship to also increase.

Slide 9: The instructor prompts students to answer questions A-C on same relationships in their student handout. The instructor also explains that questions B and C require the students to click on the link provided and experiment with same relationships on LOOPY. After providing these instructions, the instructor stops sharing their screen and provides students with 3 minutes to complete questions 1) A-C.

Slide 10: After 3 minutes, the instructor begins sharing their screen again and asks students to think of their own examples of same relationships. The instructor should prompt students to think about specific past course material or provide a specific example to get students thinking. Students comment their ideas in the class chat and then answer question 1) D on their student handouts.

Slide 11 defines opposite relationships and slide 10 shows how one reservoir increasing causes the reservoir related by an opposite relationship to decrease.

Slide 13: The instructor prompts students to answer questions A-C on opposite relationships in their student handout. The instructor also explains that questions B and C, again, require the students to click on the link provided and experiment with opposite relationships on LOOPY. After providing these instructions, the instructor stops sharing their screen and provides students with 3 minutes to complete questions 2) A-C.

Slide 14: After 3 minutes, the instructor begins sharing their screen again and asks students to think of their own examples of opposite relationships (in their day to day lives or in course related topics). Students comment their ideas in the class chat and then answer question 1) D on their student handouts.

Part 3 - Feedback Loop Vocabulary and LOOPY Examples (20 min)

The instructor uses slides 15-35 to teach students about balancing and reinforcing feedback loops.

Slide 15 introduces Part 3 of the activity and presents a modified definition of feedback loops to include same and opposite relationships.

Slide 16: The instructor introduces the two types of feedback loops: balancing and reinforcing, providing students with LOOPY examples of balancing (body temperature regulation) and reinforcing (sugar craving) feedback loops students experience in day to day life. Watch this link for a recorded example of how to use these LOOPY links to introduce balancing and reinforcing feedback loops.

- When clicking on external links, instructors should remember to either share their entire desktop screen or start a new screen share for students to see the LOOPY webpage when it is opened.

Better to have video and/or text?

The instructor might explain this slide like this:

"There are two types of feedback loops: balancing and reinforcing. Balancing feedback loops keep systems in equilibrium."

[The instructor clicks on the balancing link and makes a new screen share of the LOOPY webpage]

"This feedback loop of our body's ability to regulate our temperature is an example of a balancing feedback loop."

[The instructor hits play, slows the simulation speed with the sliding scale at the bottom, and clicks the up button (^) on either exercise or temperature. As the arrow moves through the feedback loop the instructor explains what is happening in the system.]

"When it's hot outside or we exercise, we can cause our body's temperature to increase, so we sweat. As the sweat evaporates our bodies cool, so we stop sweating. When we stop sweating our bodies may get hot again, so we start sweating again."

[The instructor speeds up the simulation speed for students to see the feedback loop balancing the size of the reservoirs]

"This balancing act keeps the system in equilibrium over time. See how the sizes of the reservoirs fluctuate a little but always stay within certain sizes? This is showing a balancing loop keeping a system in equilibrium."

[The instructor exits the loopy example and screen shares the powerpoint slide 16 again.]

"The other type of feedback loop is a reinforcing feedback loop. These loops make systems fall out of equilibrium. [The instructor clicks on the reinforcing link and makes a new screen share of the LOOPY webpage]. This feedback loop of our sugar cravings is an example of a reinforcing feedback loop. [The instructor presses play…. I'll keep writing if this feels helpful in addition to the video

Slide 17: The instructor defines a balancing feedback loop.

Slide 18: The instructor tells students that an event causes the left side reservoir to increase.

Slides 19-24 demonstrate the balancing act of reservoirs in a balancing feedback loop.

Slide 19 shows that because the other reservoir is related to the left reservoir with an opposite flow, the other reservoir will decrease. The instructor asks students what they expect will happen to the left hand reservoir, which is related to the right reservoir with a same relationship, when the right side reservoir decreases. Students are asked to post their predictions in the class chat.

Once students have posted prediction, the instructor proceeds to walk through slides 20-24, prompting students to predict what will happen as the reservoirs change (after slide 19 students can call out or think to themselves).

On slide 25, the instructor reminds students that this balancing feedback loop causes the reservoirs and system to stay in equilibrium.

Optional: The instructor can use slide 26 to replay the initial body temperature regulation feedback loop linked on slide 16 to reinforce the idea of a balancing feedback loop staying in equilibrium over time by running the simulation on high speed again.

Slide 27: The instructor provides students with 2 minutes to answer question 1) A. on part 3 of their handout: Describe a real world example of a **balancing** feedback loop.

Slide 28: The instructor defines a reinforcing feedback loop.

Slide 29: The instructor tells students that an event causes the left side reservoir to increase.

Slides 29-32 demonstrate the magnification of changes to reservoirs in a reinforcing feedback loop.

Slides 30-31 The instructor asks students what they expect will happen to the other reservoir when one reservoir changes. Students can think to themselves, call out, or chat their predictions.

On slide 32, the instructor reminds students that this reinforcing feedback loop causes the reservoirs and system to fall out of equilibrium.

Optional: The instructor can use slide 33 to replay the initial body temperature regulation feedback loop linked on slide 16 to reinforce the idea of a reinforcing feedback loop falling out of equilibrium over time by running the simulation on high speed again.

Slide 34 reminds students that other combinations of same and opposite relationships can make feedback loops reinforcing (not just two same relationships), and slide 35 asks students to think about what other combinations of relationships could make a two-reservoir feedback loop reinforcing. Students should comment their ideas in the chat. The instructor can click on the link at the bottom of slide 35 to show that feedback loops with two opposite relationships will also cause the feedback loop to be reinforcing but one reservoir will continually increase and the other will continually decrease. The example LOOPY shows population continually increasing and resources to support the population continually decreasing (when the LOOPY begins by increasing (^) the population reservoir).

Slide 36: The instructor provides students with 2 minutes to answer question 2) A. on part 3 of their handout: Describe a real world example of a **reinforcing** feedback loop.

(Optional) Part 4 - Challenge Questions, 3-reservoir feedback loops

Part 4 is intended to introduce students to more complex feedback loops and show students that different arrangements of relationships can work together to form reinforcing and balancing feedback loops. This activity is also a good introduction to LOOPY for classes that intend to complete activities 8, 10, 11, or 12 of the systems thinking activities. Part 4 can be completed by students outside of class as homework or omitted from the activity.

Slide 37 of the Activity 9 Powerpoint introduces the challenge question part of the activity.

Slides 38 and 39 explain and prompt students to complete question 1 of part 4 and question 2 part 4, respectively, on the student handout: what combination of same/opposite relationships make 3-reservoir feedback loops balancing? Reinforcing? Students will need to follow the link provided in the student handout in order to experiment with different relationships between 3-reservoir feedback loops.

Teaching Notes

The loopy examples linked in the powerpoints can be substituted for a variety of examples that are better fitted for the instructor's course and the student's prior knowledge. Ideally the feedback loop examples are related to prior class topics or universal student experiences (body cooling mechanisms, digestion mechanisms, etc) so that new information is not added in addition to the systems thinking feedback loop information. Here are some alternative feedback loop examples to those linked in the Feedback Loop Introduction Powerpoint:
Balancing Feedback Loop:

- Mice and Birds of Prey Populations mini ecosystem - More mice, more birds of prey; fewer mice, fewer birds of prey
- Other ideas: Homeostasis, Sustainable Farming

Reinforcing Feedback Loops:

- Social Media Algorithms - Newsfeed shows you what you react to, hides what you don't.
- Ice Cover and Climate Change (Albedo) - The more ice the cooler the earth gets, the cooler the earth gets the more ice; the less ice the warmer the earth gets - the warmer the earth gets the less ice there is.
- Other ideas: Impacts of Systemic Racism, Farming and Soil Degradation, Addiction

Also, Part 4 of the activity, the challenge questions, can be assigned to students as homework to be completed outside of class. This section helps students realize that simply seeing more **+** signs (same relationships) than **-** signs (opposite relationships) does not necessarily indicate a reinforcing feedback loop. This part of the activity can also help familiarize the students with LOOPY, which could be helpful if they go on to complete activities 8, 10, 11, or 12.

Assessment:
Answer Key Student Handout Activity 9

References and Resources:

This systems thinking module is based on the undergraduate Systems Thinking module on InTeGrate, created by Lisa A. Gilbert, Deborah S. Gross & Karl J. Kreutz. This feedback loop activity relates to Unit 4: Feedbacks in a System.

Inspiration for Part 1: Q Design Pack Systems Thinking. Institute of Play. http://educators.brainpop.com/wp-content/uploads/2014/07/IOP_QDesignPack_SystemsThinking_1.0.pdf

Online Feedback Loop Diagramming Tool: Loopy by Nicky Case: https://ncase.me/loopy/

Systems Thinking Vocabulary Glossary

Why teach systems thinking in Middle School?

“Appendix G - Crosscutting Concepts.” 2013. Next Generation Science Standards. https://www.nextgenscience.org/sites/default/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf
NGSS?

Learn about why we should teach Systems Thinking in Earth Science:

- Lisa A. Gilbert, Deborah S. Gross & Karl J. Kreutz (2019): Developing undergraduate students’ systems thinking skills with an InTeGrate module, *Journal of Geoscience Education,* https://doi.org/10.1080/10899995.2018.1529469

- SERC’s page on Complex Earth Systems: An explanation of the different types of systems thinking involved in Earth’s systems

Learn more about teaching systems thinking:

Mambrey, Sophia, Justin Timm, Jana Julia Landskron, and Philipp Schmiemann. 2020. “The Impact of System Specifics on Systems Thinking.” *Journal of Research in Science Teaching*, July, tea.21649. https://doi.org/10.1002/tea.21649

Learn more about systems thinking:

- Meadows, Donella H., and Diana Wright. 2008. *Thinking in Systems: A Primer*. White River Junction, Vt: Chelsea Green Pub. https://wtf.tw/ref/meadows.pdf