

MIT BLOSSOMS Teachers Guide

The Surprising World of Complex Systems

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Lesson Overview and Objectives:

This lesson introduces students to complex systems, and particularly complex, adaptive systems (CAS). Complex systems are all around us in everyday life and are an integral part of many subjects we study in the school setting (biology, social studies, economics, etc.), yet often students are not exposed to the analytical tools needed to observe, understand, and analyze systems in their entirety. Rather, complex systems are often studied reductively, by breaking them into their constituent parts for analysis.

This lesson introduces some basic concepts that are needed in order to analyze systems holistically, and to some foundational concepts in the study of system dynamics, such as stocks and flows, feedback loops, and unintended consequences. This lesson introduces these topics through an immersion in (and a role-play simulation of) the dynamics of urban recycling systems, many of which are in crisis following the implementation of China's National Sword policy in December 2017, which effectively banned imports of most recycled paper and plastic scrap to China.

Focusing on this current-affairs example of a complex system in crisis, we discover how well-intentioned action can cause negative unintended consequences when we try to intervene in a complex system without understanding how it operates.

Learning Objectives:

By the end of this lesson, students will:

1. Be able to identify what makes a system a system (elements, relationships between those elements, and a function, or purpose) and be able to state, through observation, some key attributes of how complex systems behave (e.g. elements are interrelated, system behavior arises from the interaction between parts and can be unpredictable, etc.)
2. Be able to articulate the difference between "stocks" and "flows" in a system and identify examples of feedback loops in their lives;
3. Be able to read very basic system diagrams, including stock and flow diagrams and feedback loop diagrams; and
4. Have an awareness that intervening in a complex system without first understanding that system's structure and dynamics can result in unintended consequences.

Structure of the Lesson:

This lesson is focused around one primary activity (the **Recycling Role Play**: Activity #2) that provides students with an opportunity to discover and experience some of the behaviors and

properties of complex systems themselves. In this activity, 10 students arrange themselves in the room in a pattern that they think illustrates how the actors in a recycling system are connected, and then they pass three balls of yarn between themselves to illustrate how they think that materials (recyclables and money) flow through their system. This activity will take a minimum of 15 minutes and can take up to 25 minutes, if there is time for some discussion and reflection involving the whole class following the activity's completion (highly recommended!)

The remaining activities in the lesson (Activities #1, #3, and #4) each consist of 5-minute discussions with peers. Including video segments, the lesson runs between 47 and 57 minutes, depending on how much time is devoted to discussion following the Recycling Role Play.

Guide to the Lesson Activities:

PREP (BEFORE THE LESSON DAY)

Materials:

The Recycling Role Play requires the following materials, which should be gathered ahead of time:

1. **Three balls of yarn/string**
 - Note: something that is in a ball and not tangled, so it can be unwound and passed easily between students;
2. **Safety pins, string, or tape**
 - Note: for students to attach their name tags/Role Cards to themselves);
3. **Name tags with descriptions on the back**
 - Note: these are available as a PDF download on the Blossoms site, but need to be printed and cut. They are designed to be printed double-sided, with the name of an Actor on one side and that Actor's role on the back. There is also a 1-sided version available; if this is used, the descriptions should be attached to their respective Actor names ahead of class.

Room set-up:

The tables should be either moved to the center of the classroom to create space around the perimeter, or moved off to one side so that students can arrange themselves in the room with some space in between them to pass the ball. Ideally, this room set up can take place **prior to class**, which will allow more time for group discussion immediately following the completion of the Role Play Activity.

ACTIVITY FACILITATION GUIDE

Here, we provide brief instructions for facilitating each of the activities in this Blossoms lesson.

Activity #1: Unintended Consequences of Complex Systems (Peer Discussion)- 5 minutes

Instruct students to turn to form small groups of 2-4 (depending on class size) with other students near to them and discuss: what unintended consequences or results their

transportation system is producing, and if they have any initial thoughts about what is causing those results?

They do not need to share out their discussion with the full room-- this is simply to get them thinking about systems on a general level and realizing that the lesson is about complex systems in general, even though we'll be focusing on recycling systems as an example.

Activity #2: RECYCLING ROLE PLAY--- 15-25 minutes

This is an interactive activity in which students pass several balls of yarn between each other to simulate how the actors in a recycling system are connected and how materials flow through the system.

Players (students):

The activity requires 10 players, so if a class has 20 or 30 students, 2 or 3 groups of 10 can form simultaneously and all students can play (if there is enough room or space outside for more than one group). If space is limited, or the class does not have enough students for a full second or third round, some students can watch as observers and be given instructions to pay close attention to what is going on in the activity. These students will then also participate in the brief discussion following the activity.

Timing: We anticipate it will take the students a minimum of 3 min to get their roles and read them, another 5 or so to get organized in the room, and about 7 minutes to pass the ball through the system. 15 min is the minimum run time without discussion, but if the teacher wants to add 5-7 minutes of discussion/reflection following the activity (which is highly recommended to draw out the learning objectives), then the activity can extend to 20-25 minutes.

Optional discussion/reflection prompts are provided at the end of this handout.

INSTRUCTIONS FOR THE TEACHER

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| <ol style="list-style-type: none">1) Hand out Name Tags (with descriptions on the back) to the students playing the game2) Give a ball of yarn to Household 1, Household 2, and the City Waste Department (pass out all 3 balls of yarn) |
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INSTRUCTIONS TO GIVE TO THE STUDENTS:

(These are the directions that the teacher should provide to the students when facilitating the activity):

1. Read your name tag (front and back) and put it on with your name facing out so others can see it.
2. Position yourself near to players who you think you will be interacting with in the activity, based on the description of your Role.
3. Now, we're going to use the ball of yarn to simulate how we think materials move through this system, including where they start and where they end up. We'll use the balls of yarn to symbolize both recyclables AND money.

4. **Pass your ball of yarn to the player to whom you give either money or materials.** As you pass the ball, tell your classmates why you're giving it to the player you're giving it to.

Teacher: wait until the ball has made it through the system (either back to the Households or back to the City, or until the time for this segment runs out). Then instruct the rest of the members of the class, who have been watching the roll play, to share their observations:

QUESTION 1: What did you notice about this system we modeled?

(possible observations students might make include):

- a. All the players ended up connected to each other;
- b. The actions of some players depended on the actions of others (the players were inter-dependent, and had to wait for some to take action before they could);
- c. There were delays in the system- some people wanted to take action but couldn't because they didn't have the ball yet;
- d. The system had different people operating with different motivations;
- e. It was hard to predict how the ball would flow through the system;
- f. It got confusing at some point!
- g. Etc... *(depending on how much time you have, see if you can continue to probe students for reflections on what they experienced and/or observed- much of the richest learning in this Blossoms lesson takes place in this discussion, not the lecture).*

OPTIONAL DISCUSSION/REFLECTION QUESTIONS:

QUESTION 2: Based on this example, what do we think makes a system a system? (what differentiates a system from a non-system?)

(possible answers/observations):

- There are parts which are connected to each other
- The parts have been put together to serve a purpose (or evolved to serve a purpose); they are not randomly assembled;
- They work as a coherent entity, and produce behavior which results from the interaction of the parts, not the separate action of the parts (e.g. we can't understand how the system will behave just by understanding how each of its individual parts is behaving).
- Etc...

Activity #3: Feedback Loops (Small group and the full-class discussion) 5-8 min.

- 1) First, have the students turn to their neighbors as in the first activity to discuss briefly (2-3 min) what they think about the question on the screen: "Does the reinforcing loop of reputation work in both directions? What happens if the team is losing?"

- 2) Then, ask for a show of hands: who thinks that the reinforcing dynamic of this loop can create a downward spiral in addition to an upward spiral? Ask someone who has raised their hand to explain their reasoning to the rest of the class (2 min)
- 3) Then, for the remaining time, ask the whole class if they can think of other examples of feedback loops in their life that work in the same way (e.g. that produce better and better or worse and worse results) and note any examples they identify on the board. (2-3 minutes)

Activity #4: Opportunities to Influence System Behavior (small-group peer Discussion)- 5 min.

Ask the students to form small groups again (2-4 students) and to brainstorm together for 5 minutes to see if they can identify any actions that could be taken to change how the “typical urban recycling system” is operating.

About half-way through (minute 2 or 3) ask for a show of hands: “how many of you have identified at least one action that could be taken that might help to improve the recycling system we’ve been looking at?” If not many hands go up, give some hints/prompts for the remaining time: “You might think about the components of systems we’ve learned about today, for example, making changes to the elements in this system, to the relationships between the elements, to the purpose of the system, to the rules structuring how players interact, etc...” and give them a few more minutes to keep thinking.