GRADE 11 SYSTEMS THINKING AND SUSTAINABILITY: BEHAVIOR OVER TIME GRAPHS

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LEARNING PLAN OVERVIEW

Subject(s)	• Social Sciences • Environmental Education • Global Citizenship Education • Sustainable Development Project
Grade Level (s)	• High School (ages 14-18) • Higher Education • Adult Education
Systems Tool(s)	Behavior Over Time Graphs
Purpose of Using Tool	• Critical Thinking • Discussion
Summary	The learning plan introduces Behavior Over Time Graphs using the human population through time as a concrete example.

Learning Objectives

- Create and use Behavior Over Time Graphs (BoTG) to widen and deepen understanding of a system.
- Describe 4 population models (exponential growth, system oscillation, s-shaped growth, and overshoot and collapse) using concrete examples.
- Key terms: Behavior Over Time Graphs (BoTG), population, population model, exponential growth, oscillation, S-shaped growth, overshoot & collapse, carrying capacity, rule of 70.

Material and Settings

- Internet access.
- Projector/smart board to present slides and shared docs.
- Small pieces of paper.

Learning Context

This lesson is part of a Grade 11 course on systems thinking and sustainability.

This lesson is part of a unit that introduces the most common systems thinking tools and applies them to topics related to sustainability.

This lesson discusses Behavior Over Time Graphs (BoTG) in the context of the human population. Connections are made to Causal Loop Diagrams, introduced in a previous lesson.

Purpose of Using the Systems Thinking Tools

This lesson is part of a grade 11 course on systems thinking and sustainability.

This lesson is part of a unit that introduces the most common systems thinking tools (Systems Map, Systems Iceberg, Causal Loop Diagram, Behavior Over Time Graphs (BoTG), and stocks-and-flows diagram) and applies them to topics related to sustainability.

Learning Plan Step-by-step Description

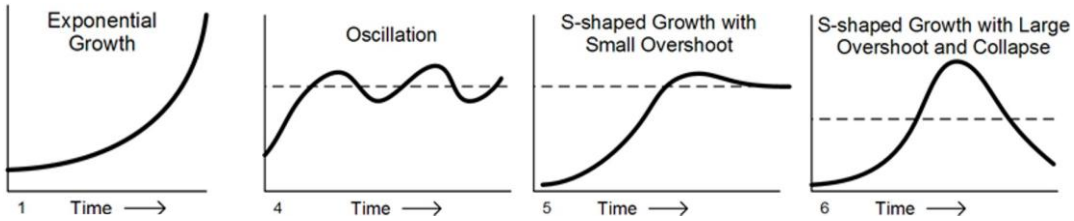
Lesson 1: BOTG

1. Opening hook: Paper fold activity: Take a small piece of paper. How many times can you fold it in half?
2. First example of a BOTG: YouTube video Human Population Through Time (American Museum of Natural History).
3. Mini-lecture:
   a. Behavior Over Time Graphs (BoTG) show time on the horizontal axis and a quantity or behavior on the vertical axis.
   b. Time scales can range from seconds to hours to years to millennia.
   c. The vertical axis can be numbers (e.g., population) or descriptors (e.g., bad → good)
   d. BOTG can help us widen and deepen our understanding of how a system behaves over time.
4. Practice:
   a. On a padlet/shared doc, each student adds 1 BOTG from another class/course + 1 BoTG from another source. Sources must be credited.
   b. Evaluate the submissions: are all graphs BOTGs?
   c. Note: A common mistake is graphs that do not show time (e.g. price elasticity and other graphs from economics).
5. Introduce summative assignment: for one week, collect personal behavior data, graph the data, and create a short Flip video describing and evaluating the BoTG. Key questions: Did the data surprise you or confirm what you already knew? What did you learn? Will the data lead you to change your behavior/habits?

Lesson 2-3: Population Models

1. Opening hook: A lily pad grows so that each day it doubles its size. On the 20th day of its life, it completely covers the pond. On what day of its life was the pond half covered?

2. Four-part Lecture: 4 population models:



(If you have already introduced Causal Loop Diagrams, show examples of basic CLDs for each model.

   a. Exponential growth
      i. Key ideas:
         1. One of the most common behaviors over time, exponential growth can occur when a system has no balancing feedback loops, when growth rates are independent of population size, and when the system is far from biophysical limits/carrying capacity.
         2. Rule of 70: if the growth rate is x% then it takes 70/x to double. E.g., bank accounts, human population growth, and fossil fuel use. (Advanced math students can be asked to prove where this rule comes from.)
         3. The quantity added in the latest period is equal to ALL the quantity that came before!! (E.g., we used more fossil fuels in the last x decades than in all of history before that.)
         4. "It occurs first very slowly, then all at once".
         5. E.g., bank accounts, economies when far from limits, and populations when far from carrying capacity.
      ii. Practice: Graph paper folds vs. thickness. After about 35 folds, the graph explodes all the way to the moon!
      iii. Practice: applications of the Rule of 70: savings account, GDP, human population…
   b. System oscillation
      i. Key ideas:
         1. System oscillation is the characteristic symptom of systems with a balancing feedback loop with a delay.
         2. E.g., basic predator-prey model.
      ii. Practice: Think–pair–share: draw a simple two-node causal loop diagram for a common predator-prey pair (e.g., foxes and rabbits), and explain in words what happens.
   c. S-shaped growth (logistic function, sigmoid)
      i. Key ideas:

1. S-shaped growth is the characteristic behavior over time of a system in which a positive and negative feedback structure fight for dominance but result in long-run equilibrium.
2. Occurs when growth does not damage carrying capacity.
3. It is possible that the system oscillates around carrying capacity.
4. E.g., economies when reaching limits, populations near carrying capacity.

iii. Practice: Think–pair–share: brainstorm examples of S-shaped growth in nature, the economy, society, and wellbeing.

d. Overshoot and collapse:

i. Key ideas:

1. Overshoot and collapse occur when growth does permanent damage to its environment, lowering the carrying capacity.
2. E.g., brewing yeast, overgrazing leading to desertification, excessive irrigation leading to aquifer depletion and drought, end of empires?

ii. Practice: Think–pair–share: Think of yeast in a petri dish: what happens to the yeast when the petri dish is full?

3. Class discussion: Which population model(s) best represents human population through time? How will the human population behave in the future?
   a. Review class norms first. (I like this approach and use the rubric discussed there.)
4. (Optional homework reading assignment on exponential growth: One Grain of Rice, a mathematical folktale, or similar story. Gist of these stories: on a chessboard, put 1 grain of rice on the first square, 2 on the second, 4 on the third, etc. Students can use math to check if the numbers in the story are mathematically sound.)

Lesson 4 (can be partly or wholly done outside of class):

1. Make BoTG Flip video (see lesson 1).
2. Peer review BoTG videos: did the student show what they learned about themselves from this BoTG exercise?

REFLECTION

Plusses

The first part of the lesson was more or less successful: all students who submitted work created a meaningful BoTG. Most students collected meaningful data related to personal challenges: daily hours spent on homework/sleep/video games/social media. They did well describe their graph but did not always evaluate the graph and draw lessons from them. A subsequent unit test showed the vast majority of students could identify BoTG from a range of graphs.

The second part of the lesson contains a lot of information. Many students were able to draw from their mathematics, psychology, economics, biology, environmental science, and other

classes. A subsequent unit test showed most students were able to identify the correct population model described in the reading on overfishing.

I do not expect all students to get everything all at once. The course is spiralled, and the tools introduced in this lesson and unit are revisited in the next unit on systems archetypes.

Feedback from students:

"The class taught a lot of diagrams to help us think, which helped me sort out my thoughts."

"I like the skills that I learned in this class. The skills such as analyzing graphs and creating different kinds of graph help me see things in a system."

"The technics we learnt which technically can be applied to life and help."

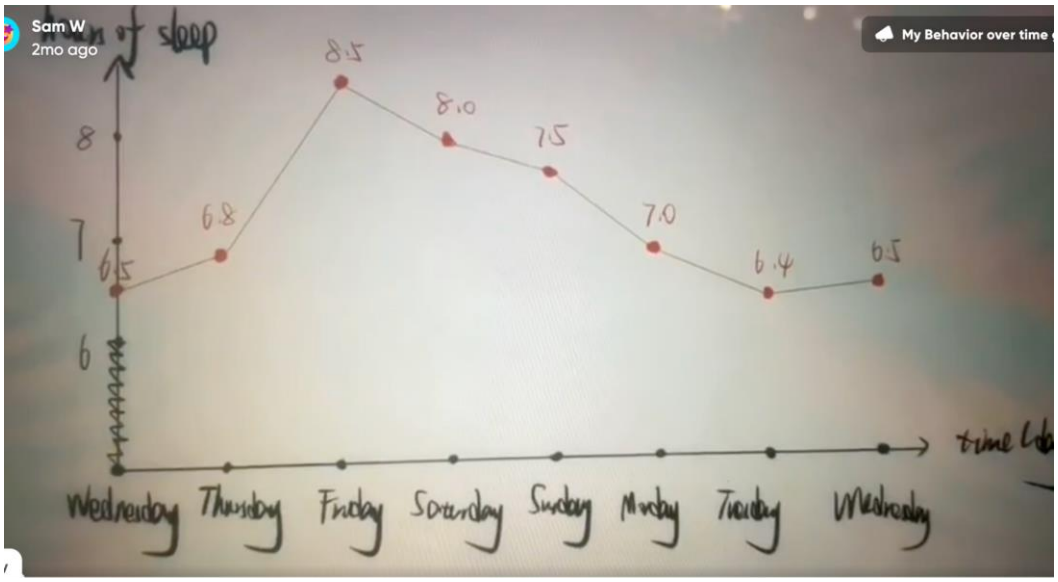
Areas for Improvement

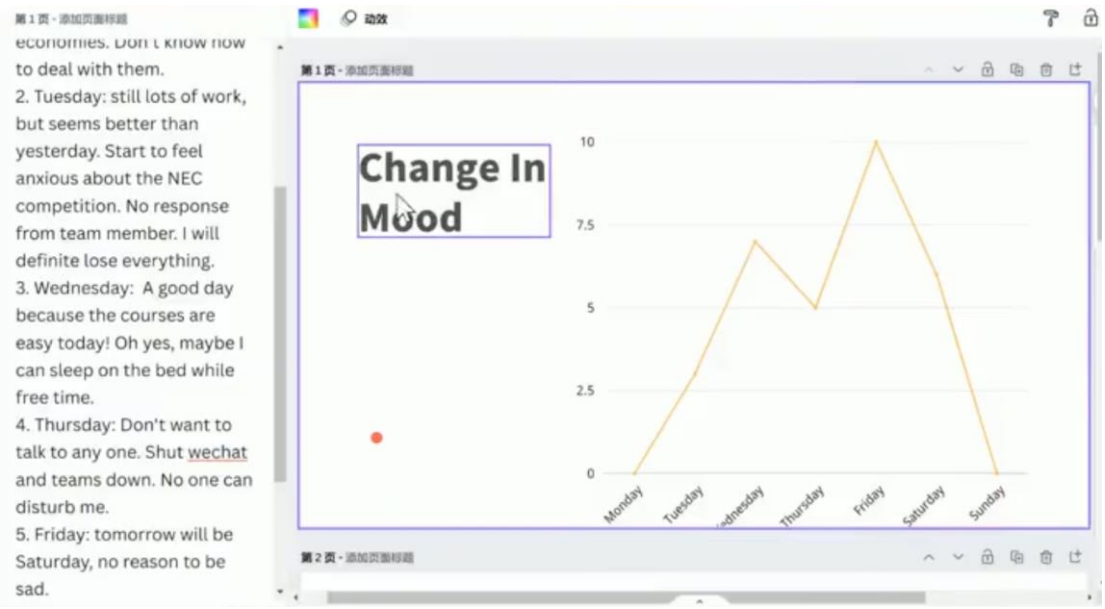
Some students may have faked their data and/or BoTG. Most students did well describing their graph but did not always evaluate the graph and draw lessons from them.

In the future, I will model and explain the need to look for meaning in the graph: Did the data surprise you or confirm what you already knew? What did you learn? Will the data lead you to change your behavior/habits?

The second part of the lesson contains a lot of information. Not all students were able to draw from their mathematics, psychology, economics, biology, environmental science, and other classes. In the future, I will use one 40-minute period for each population model, plus one period for the class discussion.

EVIDENCE




economies. Don't know how
to deal with them.
2. Tuesday: still lots of work, but seems better than yesterday. Start to feel anxious about the NEC competition. No response from team member. I will definite lose everything.
3. Wednesday: A good day because the courses are easy today! Oh yes, maybe I can sleep on the bed while free time.
4. Thursday: Don't want to talk to any one. Shut wechat and teams down. No one can disturb me.
5. Friday: tomorrow will be Saturday, no reason to be sad.
Change In Mood
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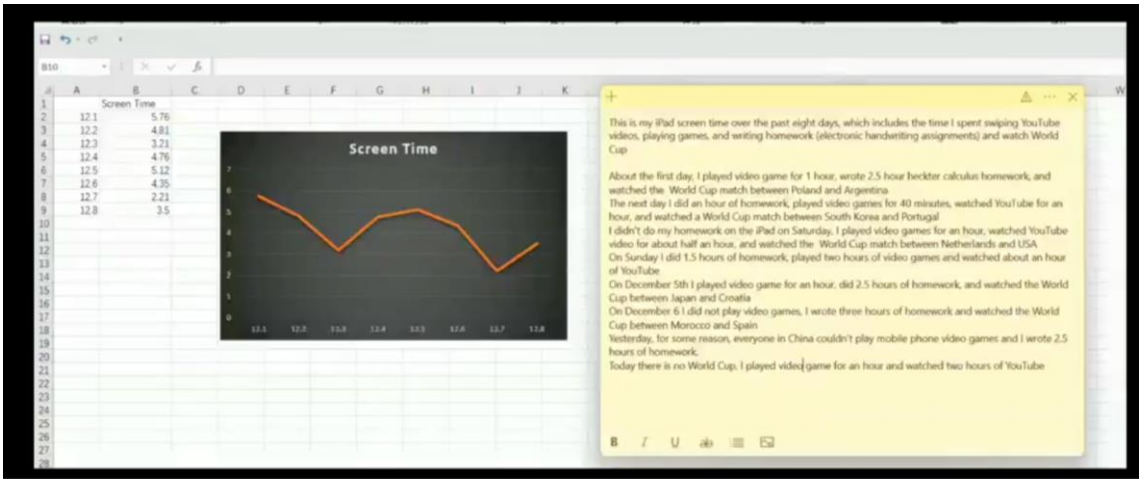
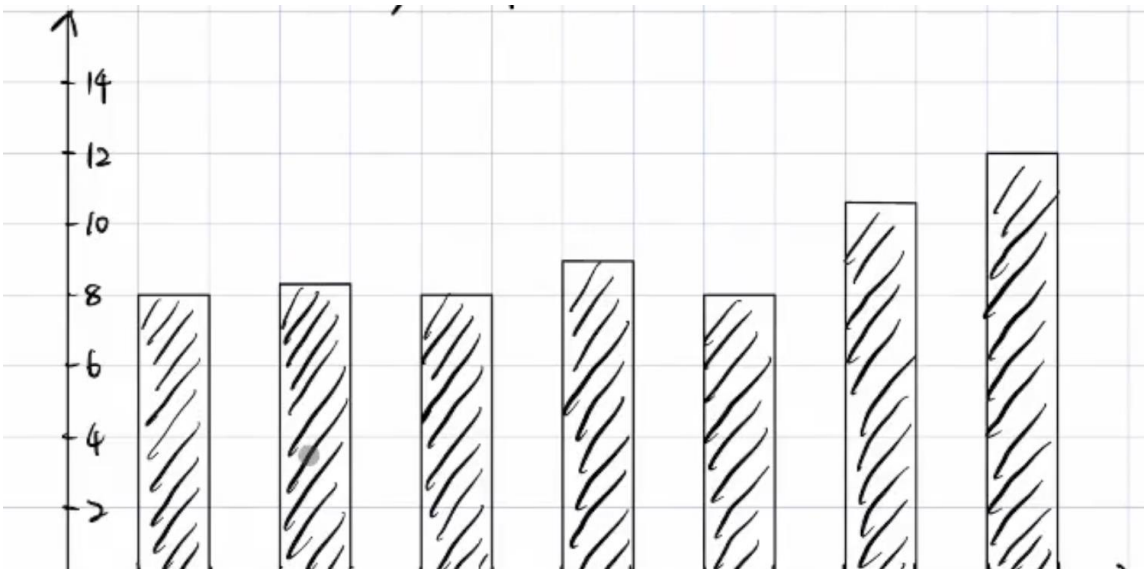
7.5
5
2.5
0
Monday
Tuesday
Thursday
Friday
Saturday
Sunday


Screen Time
This is my iPad screen time over the past eight days, which includes the time I spent swiping YouTube videos, playing games, and writing homework (electronic handwriting assignments) and watch World Cup
About the first day, I played video game for 1 hour, wrote 2.5 hour heckter calculus homework, and watched the World Cup match between Poland and Argentina
The next day I did an hour of homework, played video games for 40 minutes, watched YouTube for an hour, and watched a World Cup match between South Korea and Portugal
I didn't do my homework on the iPad on Saturday, I played video games for an hour, watched YouTube video for about half an hour, and watched the World Cup match between Netherlands and USA
On Sunday I did 1.5 hours of homework, played two hours of video games and watched about an hour of YouTube
On December 5th I played video game for an hour, did 2.5 hours of homework, and watched the World Cup between Japan and Croatia
On December 6 I did not play video games, I wrote three hours of homework and watched the World Cup between Morocco and Spain
Yesterday, for some reason, everyone in China couldn't play mobile phone video games and I wrote 2.5 hours of homework.
Today there is no World Cup, I played video game for an hour and watched two hours of YouTube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