# Teachable Agents -- Planetary Rescue
# Teacher's Guide

## Overview of the Game

Teachable Agents builds on the wisdom that people "really" learn when they have to teach. In Teachable Agents: Planetary Rescue, students teach a computerized agent by creating concept maps showing the causal relationships between key ideas. Through a series of game levels, the agent reasons and solves global warming problems using what it has been taught. The result is that students learn how to use causal reasoning, and they learn about the mechanisms and outcomes of global warming.

The game is divided into three modules, or galaxies. The first considers outcomes of global warming, such as sea level rise and animal migration. The second considers the mechanisms behind global warming and the greenhouse effect. The third galaxy focuses on human causes of increased greenhouse gas emission, as well as some actions to reduce it. Students can play through all three galaxies at their own pace, or they can be instructed to stop at the end of each galaxy.

## Student Learning Objectives

After completing this activity, students will be able to:

- Develop a causal model of the greenhouse effect and global climate change
- Use a model to explain the processes of the greenhouse effect and global climate change
- Use a model to predict the effects of changing input variables within the climate system
- Evaluate the accuracy of a model of the climate system
- Connect human actions (both positive and negative) to effects on the climate system

## Alignment with Next Generation Science Standards

**NGSS Science and Engineering Practices**

- *Developing and Using Models.* Develop a model to predict and/or describe phenomena.
- *Asking Questions and Defining Problems.* Ask questions to identify and clarify evidence of an argument.
- *Constructing Explanations and Designing Solutions.* Construct a scientific explanation based on valid and reliable evidence obtained from sources and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. Apply scientific principles to design an object, tool, process, or system.

**NGSS Disciplinary Core Ideas**

- *ESS2.D. Weather and Climate.* Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary

with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.

- *ESS3.D. Global Climate Change.* Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.
- *ESS3.C. Human Impacts on Earth Systems.* Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.

**NGSS Cross-Cutting Concepts**

- *Cause and Effect.* Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- *Systems and System Models.* Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy, matter, and information flows within systems.
- *Stability and Change.* Stability may be disturbed either by sudden events or gradual changes that accumulate over time.
- *Influence of Science, Engineering and Technology on Society and the Natural World.* All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.

**NGSS Performance Expectations**

- *MS-ESS3-5.* Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

## Why Concept Mapping:

A concept map is a diagram that depict the relationships between related concepts. Throughout the play of this game, students will be constructing a concept map for the causes and effects of global climate change. They will also be evaluating their concept map for accuracy by participating in terraforming challenges and content quizzes. In this game, the concept map serves as a model – an abstract representation – of Earth's climate system. Concept maps are a tool in which students organize their subject matter knowledge. Educational research suggests that creating causal concept maps can increase an individual's conceptual understanding and improve causal reasoning, even when learning new topics. Collaborative concept mapping - constructing concept maps in small groups - has been found to increase the amount of scientific discourse between students. In creating a single concept

map, student groups must engage in scientific co-constructed reasoning. In addition, concept maps are a tool used to make thinking visible to others. As a teacher, it can be used to assess student understanding of a topic.

## Teaching Notes

The following section on instructional notes includes:

- Suggested classroom implementation models for different lengths of instruction.
- Common student challenges that sometimes occur early in the gameplay.

Additionally, separate documents outline the concepts the students will be learning for each galaxy, the "answer key" concept map, common areas where students may have confusion or misconceptions, and extension activity ideas. Finally, there is a printable pdf of the "handbook" (content guide) included within the game that can be given to students before or during gameplay.

**Classroom Implementation Suggestions: *Play in Pairs***

It is suggested that the teacher create the student pairings in which the students will work to complete the game. We have found that working in pairs enables students to progress through challenges and increases discussion and reflection about the content. To increase the success of the group's work: 1) pair students in heterogeneous groups, 2) review the classroom expectations for groupwork before the activity, and 3) monitor student work throughout the activity. More on successful group work can be found at: https://complexinstruction.stanford.edu/

### *2-3 Day Model*

This shorter timeframe model works better if students have already learned something about global warming and climate change in advance of playing. The handbook document can be printed in advance for students to refresh their knowledge before coming into the game.

**Days 1 & 2:**

- Have students begin the game with the tutorial. This will help students to understand how the game is structured.
- Students can then progress through galaxies at their own pace. For pairs of middle school students who already have learned something about global warming, we have found that it can take between one and a half and three hours to complete the game. Teachers can support students or student groups who may be struggling more than others with the content and causal reasoning skills. If students do not finish the game, it can be continued at home or as a free choice activity during gaps when students have extra time.

**Day 3 (optional):**

- We would not recommend having students play three days in a row to the fatigue factor. We would recommend a culminating discussion activity based on the content of the game. To support causal reasoning skills, teachers can have the students take on the role of agent. Print out or project one of the concept maps at the front of the class. Ask students to use it to reason about effects. For example, from the full expert map students can be asked to reason about what would happen to polar ice if there was an increase in gas powered cars. Students can talk through their answers in small groups.
- As an additional or alternate activity, students can explore local effects of climate change by visiting http://www.globalchange.gov/explore . Have students compare and contrast the effects from their concept maps with the local effects they will see in their communities.

### *5-6 Day Model*

**Day 1 - Galaxy 1: Climate Change**

- Have students begin the game with the tutorial. This will help students to understand how the game is structured.
- Have students continue through Galaxy 1. At the end of the first galaxy, have students stop play for the day. Not all students may complete Galaxy 1 by the end of this day, but most should be close. They can finish on day three.

**Day 2 - Galaxy 1: Climate Change**

- Teachers can project the expert concept map for Galaxy 1 and have students discuss some of the key relationships (see Galaxy 1 document for particular concepts that students may struggling with). Students can take on the role of agent, and be asked to reason using the concept map. (For example, "If global warming increased, what would happen to wildfires?") They can discuss their reasoning in small groups. If desired, teachers can take this opportunity to include additional information not covered in the game, such as expanding ocean water or the difference in effects of melting polar ice between the north and south poles (see Galaxy 1 document).
- To link the game play with a classroom activity, there are several possibilities (additional extension ideas included in the Galaxy 1 document):
    - Explore your local effects of climate change by visiting http://www.globalchange.gov/explore Have students compare and contrast the effects from their concept maps with the local effects they will see in their communities.
    - Have students conduct an experiment called the Sea Level Lab. Detailed directions at https://pmm.nasa.gov/education/lesson-plans/climate-change-inquiry-lab

**Day 3 - Galaxy 2: Greenhouse Effect**

- This 2-minute video from the National Resource Council describing the greenhouse effect can be used as an introduction to the day's play. https://youtu.be/3JX-ioSmNW8
- Have students continue through Galaxy 2. At the end of the galaxy, have students stop play for the day.

**Day 4 - Galaxy 2: Greenhouse Effect**

There are again several options for classroom activities that would follow this module well.

- Tying into light and dark surfaces, students can explore the effect of different colors on absorbed heat energy. Detailed directions for an experiment activity can be found at: https://www.teachengineering.org/activities/view/colors_absorb_heat_better
- Have students work together in groups to create a skit to act out or explain the greenhouse effect.
- Several lesson plans can be found online for creating a "greenhouse in a bottle" experiment, such as found in the Carbon Dioxide lab here: https://pmm.nasa.gov/education/lesson-plans/climate-change-inquiry-lab . After, students can discuss ways in which the plastic wrap does/does not

**Day 5 - Galaxy 3: Greenhouse Gases & Human Causes**

- Have students continue playing through the end of the game.

**Day 6 - Galaxy 3: Greenhouse Gases & Human Causes**

- To link the game play with a classroom activity, have students can research ways in which humans can reduce greenhouse emissions, such as new energy technologies, or they can brainstorm actions they can take.
- If time permits, students could create a poster indicating what they have learned about global warming.

## More Flexible Models:

- Each module of the game (each galaxy) can be played during a different unit of instruction, spread out over the course of a few weeks or months. Currently the galaxies must go in order. It is not possible to skip ahead to the human impacts galaxy, for example. If being able to choose any ordering of content is important to you, please email us that feedback at kpilner@stanford.edu.

- If you are sure of technology access at home, students could play the game over the course of three to five nights as a homework assignment, either in preparation for, or in addition to classroom-based instruction on global warming.

## Common Student Challenges Early in Gameplay

- Link direction matters. Some students initially may not realize that a link going from 'habitat temperature changes' to 'animal migration' is different than a link going in the opposite direction (from 'animal migration' to 'habitat temperature changes'). The direction of the link matters for causality. Habitat temperature changes are causing an increase in animal migration, not the other way around.
- "+/-" refers to increases and decreases. Students sometimes think it refers to things that are good and bad initially.
- When determining which concepts should be linked, students should consider each possible pair of concepts independently and only create a link if the concepts are *directly* and *causally* related. For example, as part of the first map, three concepts could be connected: drought, wildfires, and human homes. When creating the concept map, the link between drought and wildfires should be considered in its own right (drought increases wildfires) and the link between wildfires and human homes should be considered in its own right (wildfires decrease human homes). The agent could then reason through the chain that droughts cause an increase in wildfires and that wildfires will decrease human homes. Sometimes students will create a "shortcut" link between drought and human homes, because they are looking down the chain and reasoning that more drought should lead to fewer human homes. However, drought and human homes are not directly connected.

### Notes on Terraforming

Terraforming refers to changing the conditions of another planet so they more closely resemble Earth for humans to be able to live there. It is the premise of the gameplay (that agents are making distant planets habitable to humans), but it is not the main content covered. The game could lead into a unit focused more specifically on terraforming. (See for example: https://www.nasa.gov/pdf/546136main_ESS5_EarthvsMars_C3.pdf

### Additional Resources

Environmental Protection Agency; climate change programs for kids - https://www.epa.gov/students

NASA; climate change program for kids - http://climatekids.nasa.gov/greenhouse-effect/

Climate Literacy & Energy Awareness Network (CLEAN); vetted lessons for teachers - http://cleanet.org/index.html

### References

Basque, J., & Lavoie, M. C. (2006). Collaborative concept mapping in education: Major research trends.

Biswas, G., Leelawong, K., Schwartz, D., Vye, N., & The Teachable Agents Group at Vanderbilt. (2005). Learning by teaching: A new agent paradigm for educational software. *Applied Artificial Intelligence*, *19*(3-4), 363-392.

Carnot, M. J., Feltovich, P., Hoffman, R. R., Feltovich, J., & Novak, J. D. (2003). A summary of literature pertaining to the use of concept mapping techniques and technologies for education and performance support. *Pensacola, FL*.

Chin, D. B., Dohmen, I. M., Cheng, B. H., Oppezzo, M. A., Chase, C. C., & Schwartz, D. L. (2010). Preparing students for future learning with teachable agents. *Educational Technology Research and Development*, *58*(6), 649-669.

Novak, J. D. (1990). Concept mapping: A useful tool for science education. *Journal of research in science teaching*, *27*(10), 937-949.