Climate Engineering Teaching Module

Lesson 1: Collaborative Design Thinking

Grade Level: 6-12

Estimated Time for Activity: 60 minutes

Learning Outcomes and NGSS

	Content Knowledge	**Skills**
Expected Learning outcome	Students will learn the evidence of climate change and contributors to global warming; Students will learn the concept of climate engineering as one of the solutions to reduce global warming.	Students will practice their skills of working collaboratively. Students will practice their skills of design thinking. Students will be asked to design solutions to solve problems and revise solutions based on feedback, specific criteria and constraints.
NGSS	**MS-ESS3-5 Earth and Human Activity** Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. **MS-ESS3-3 Earth and Human Activity**. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. **MS-LS2-5 Ecosystems: Interactions, Energy, and Dynamics.** Evaluate competing design solutions for maintaining biodiversity and ecosystem services **MS-ETS1-1 Engineering Design**. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. **HS-ETS1-1 Engineering Design**. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. **HS-LS2-7 Ecosystems: Interactions, Energy, and Dynamics.** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. **HS-ESS3-1 Earth and Human Activity** Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. **HS-ESS2-2 Earth's Systems** Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. **HS-ESS3-4 Earth and Human Activity.** Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.	

Materials:

Collaborative Design Thinking worksheet, multiple colors of colored pencils, sticky notes, large sheets of paper or poster board, access to ChatGPT

Key Terms:

Climate engineering, climate change, collaborative design thinking, activity-before-content learning

Background:

This lesson invokes a collaborative design thinking activity that guides students towards creating a climate engineering solution to reduce global warming (or reduce the amount of solar radiation reaching Earth's surface). While secondary school students have a basic understanding of climate change as well as some strategies to mitigate against them, most students do not have any knowledge of climate engineering (also known as geoengineering). Climate engineering is the deliberate modification of an environmental system that impacts Earth's climate in order to reduce the negative impacts of global warming. Though scientists and engineers are currently researching technologies to reduce solar radiation reaching the Earth and technologies to remove carbon dioxide removal technology, this lesson purposely avoids introducing these specific ideas to the students. Therefore, this activity enables students to innovate new technology, free from design fixation with respect to what is already considered as climate engineering. While teachers should support their students' creativity, this lesson establishes some basic criteria and constraints to scaffold the designs as well as a structured lesson plan that guides the students from idea generation to concept design. This lesson is a good "low floor, high ceiling" in which all students can actively participate and generate exceptional ideas.

Collaborative design thinking is a process in which students think and brainstorm as a team towards a shared design goal. A framework (Van Mechelen et al., 2019) for collaborative design thinking includes

1) Introduction about the theme.
2) Sensitizing. This step is for each student to have a sense of the design theme through hands-on activities and allowing time for some idea incubation.
3) Scaffolding collaboration. Students will be facilitated to collaborate with their team members.
4) Defining a design goal. In this step, each team defines their design goal and the expected outcome.
5) Reflection on collaboration. Students reflect on how they could improve their collaboration.
6) Ideation. Students brainstorm to generate ideas as many as possible.
7) Grouping and selection. Each team chooses 2-3 ideas that can best solve the problem.
8) Elaboration through making. Students can use materials to make a prototype of their design and tell the story.
9) Presentation and peer jury.
10) Iteration and/or wrap up.

Depending on the grade level and available time, space and resources, teachers can adopt the steps in the frameworks above as needed.

Design Criteria and Constraints

This lesson intentionally limits criteria and constraints in favor of creativity (the designs will be refined in Lesson 3 to meet more specific criteria and constraints). The main criteria for the initial engineering designs are that

1) each design must modify or work with an existing environmental system and

2) each design's intent is to slow global warming.

Introduction about the theme

The accompanying PowerPoint introduces evidence of global warming and climate change in the U.S. as well as various climate "tipping points" that may be reached given some amount of global warming. A climate tipping point represents a temperature threshold that when passed, will result in abrupt and dramatic changes to the climate system. The PowerPoint also includes a graphic showing many environmental systems that the students may choose from for their technology to alter to reduce global warming/climate change impacts. The teacher should provide a brief overview of several of the environmental systems before proceeding.

Example questions that could be asked prior to students' brainstorming:

- What are some of the causes of global warming?
- Can you think of a way to stop or slow it down?

Activity 1-Brainstorming and Idea Generation (using sticky notes)

This activity uses brainstorming to generate ideas. Group students (3, 4, to 5 students per group). Using sticky notes, each student writes down as many ideas that meet both criteria in three minutes (one idea per sticky note). Teachers should encourage students to write down all ideas, and wild ideas are especially encouraged.

Rules for Brainstorming:

- Defer judgment - there is no bad idea. Sometimes the wild ideas lead to something better
- Build on previous ideas
- Encourage wild ideas - if a reasonable idea worked, we would have already solved this problem
- Go for quantity
- Make it a fun game - who develops the wildest idea?

Scaffolding: Teachers can deliberately seed a wild idea at each group's table by writing an idea on a sticky note and placing it at each table. The students will see teachers as giving them permission to think outside the box. Some ideas include:

- Sunglasses for the Earth
- Super tall smokestacks to vent CO_2 to space
- Paint all roofs white
- Bugs that eat CO_2
- Move all power plants to the moon
- Check out this wild geoengineering idea

Then students talk with others in the group and write down ideas for three minutes. **Encourage students to think big and to build on previous ideas**, reminding students to think like an engineer and of the goal to design new technology to slow down global warming by altering one or more environmental systems. Optional - Ask AI to create wild ideas for geoengineering. Using ChatGPT, enter the prompt "Create 10 wild ideas that fit the category of geoengineering to stop global warming". This will get some unique ideas, but ask again by entering the prompt "but, more wild" and ChatGPT will have a list of 10 wild ideas which students may have thought of too!

Teacher Note: There is a good chance that the common misconception of the ozone hole being a result of global warming - this is an opportunity to discuss how the ozone hole developed and the actions (Montreal Protocol) taken to help resolve this issue.

Each group then collects and organizes the sticky notes into a Mind Map (e.g., Wandersee, 1990; Hyerle, 1996; on a large sheet of paper or on the board. The ideas can be categorized into 3-4+ main groups. Categories may include carbon uptake (afforestation, carbon capture), emission reduction, sunlight reduction (reflection or shading), and miscellaneous. Feel free to supply the students with these categories.

It may also be beneficial to group the categories as a class with the teacher providing structure and commentary. Idea Generation and Mind Map should take **12-15 minutes**.

Activity 2-Concept Sketching - embody your big ideas (using working sheet)

After Idea Generation, the next step in the engineering design process (see PowerPoint) is for Concept Sketching. **Concept sketches** are quick and simple freehand drawings that show designers' initial ideas about the designs. In this part, students are asked to illustrate some of the big ideas they have generated in Activity 1. For example, students might say they can prevent solar energy from entering the earth's surface. Next, they will need to conceptualize how they can realize the goal of preventing solar energy from entering the earth's surface. What device can be invented? How will it look and what technologies need to be developed?

For this activity, students remain in their groups but complete the following first task of the next activity by themselves. The first task is to draw 3 different technology designs on the back of their worksheet (the paper can be separated into 3 equal spaces by drawing a big "Y"). Each student in the group should have a different colored pencil (e.g., 4- 5 different colors for each group). Each student draws their three rough technology concepts in "their color" – allow for 10 minutes. Then, the paper is passed to the next group member to their right. Each student then adds to the three designs in front of them by drawing with "their color". Each rotation should allow for 4-5 minutes, until each paper has input from everyone in the group (or at least input from two other students). The PowerPoint demonstrates Concept Sketching for a prompt to make a better computer mouse. The total time for this part of the activity is **25 or 30 minutes** for groups of 4 or 5.

Example questions and comments for teachers to pose to their students:

- What ideas/details/technologies can be added to improve the design?
- Teachers should again encourage wild ideas and help students avoid funneling their designs to a common theme (e.g., solar powered cars).
- "What idea did you come up with that's different from anyone else's?"

Activity 3-Presentation, elaboration and gathering feedback

If teachers would like to spend more than one class period on this lesson, consider a lengthier feedback time period wherein students can help one another:

Gear-up: Elaboration through making**.** Students can work as groups using materials to make prototypes of one of their ideas that can best solve the problem. Then, each group can set up a station to show their technology sketches and prototypes. Students work as a community by providing and receiving feedback. One way for students to share their feedback on other designs is for each student to place one sticky note at each station that includes a "glow" remark (compliment), "grow" remark (suggestion), and "question" remark (to clarify the design or its use). This activity may be beneficial to use after Lesson 3 as well.

Gear-down: Students share their ideas in the class with the technology concepts involved for each group. Other students are encouraged to ask questions or make comments.

References

Hyerle, D. (1996). Visual tools for constructing knowledge. Alexandria, VA: Association for Supervision and Curriculum Development.

Van Mechelen, M., Laenen, A., Zaman, B., Willems, B., & Abeele, V. V. (2019). Collaborative Design Thinking (CoDeT): A co-design approach for high child-to-adult ratios. *International Journal of Human-Computer Studies*, *130*, 179-195.

Wandersee, J. H. (1990). Concept mapping and the cartography of cognition. *Journal of Research in Science Teaching, 27* (10), 923-936.