TEACHER GUIDE
ENGAGE LESSON 21

Food and Agriculture Center for Science Education

Module Question: *How can we improve on the costs and risks of the dairy system?*

What We Figure Out:

We figured out that the dairy production system can have both benefits and associated costs and risks. We set out to improve the system to improve on its costs and risks while maintaining its benefits. We identify several problems present within the dairy system and describe the mechanisms by which these problems impact the environment.

3D Learning Objective:	**Time estimate:**	**Materials:**
Students identify the benefits, costs, and risks of the dairy system, which they use to define a problem in the system that can be improved upon to manage natural resources more responsibly.	50 minutes	Lesson 21 Student Guide

Targeted Elements

SEP:

AQDP-H8:
Define a design problem that involves the development of a process or **system with interacting components** and criteria and constraints that may include social, technical and/or environmental considerations.

DCI:

ESS3.A-H2:
All forms of energy production and other **resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits.** New technologies and social regulations can change the balance of these factors.

ESS3.C-H1:

CCC:

PAT-H3:
Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system.

	The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.	

Directions

Part 1: Our Motivation

USE OF PHENOMENA

Students ended the previous module by concluding that the dairy system has benefits and costs. Students reviewed their questions on the Driving Question Board and saw that there were still questions remaining about how the dairy system can improve on some of its environmental impacts. Therefore, in this module, students will use the engineering design process to generate solutions to the environmental impact problems with the dairy system.

To start the lesson, return to the Driving Question Board. Remind students that in the last lesson we saw that the class still had a number of questions remaining about how the dairy system can improve on its impacts on the environment. Share with students that they will set out to use an engineering approach to help solve some of these problems. Students can record these questions in Lesson 21 Student Guide Part 1: Our Motivation. This will help students understand how this lesson connects to what they were trying to figure out about the Anchor Phenomena.

Example student questions or ideas could include:

- How can we decrease the impacts of the dairy system on the environment?
- What is the dairy industry trying to do to reduce its harm on the environment?
- What are some ways to improve the dairy system?
- How can the dairy system be redesigned to have less impacts on the environment?

Part 2: Stages of Engineering Design

Ask students to recall and record what they already know about the engineering design process in the space provided in Lesson 21 Student Guide Part 2.

Example student responses or ideas could include:

- The engineering process is about finding a solution to a problem.
- It is basically like a cycle where we define a problem, define criteria and constraints for solutions, think of possible solutions, test the solutions, measure their performance relative to the criteria and constraints, and iterate on the designs to improve them.
- The engineering design process includes many different stages

STUDENT SUPPORT

If students have difficulty recalling the steps of the engineering design process, consider:

- Asking students to describe how they solved a recent problem in their lives, then building off of what the student shared and labeling each of those steps as steps in the engineering design process.
- Giving students a familiar example, such as deciding what to have for lunch, and having students describe the steps in this process. Then, label the steps students described with the steps in the engineering design process.

Build off of what students share to confirm the steps in the engineering design process.

The steps of the engineering design process include:

- Defining and Delimiting an Engineering Problem: state the problem to be solved as clearly as possible and stating the criteria for success and the constraints or limits on the design.
- Developing Solutions: generate several different possible solutions and then evaluate the potential solutions to see which ones best meet the criteria and constraints.
- Optimizing the Design Solution: Systematically test and refine a design via testing, redesigning, and retesting. In this process, tradeoffs are made for between various components of the design.
- Communicating the Design: Share the design solution with a relevant audience.

It is important to point out that these component ideas do not always follow in order, any more than do the “steps” of scientific inquiry. At any stage, an engineer can redefine the problem or generate new solutions to replace an idea that isn’t working.

Ask students, “If you were to redesign components of the dairy food system using engineering, what new tasks would you want the dairy system to accomplish?” Give students a few moments to share their responses with one another. Use a Think-Pair-Share for students to

share their responses with each other and with the class. Build off student responses to confirm that the system should produce dairy products while improving its environmental impact in areas such as climate, biodiversity, and pollution.

Next, students will consider how they think engineering can help them improve the dairy system and how to use engineering to help us improve the dairy system to provide dairy products more sustainably for people. Use a think-pair-share to ask students to respond to these two prompts, they will record their thoughts in their Lesson 21 Student Guide Part 2.

Example student responses or ideas could include:

- We can use engineering to improve the dairy system. We can identify a problem that exists in the way the system operates to produce dairy products and then design a solution to this problem using the engineering design process.
- The solution should improve on the existing problem to help improve the system.
- The solution should not decrease the benefits we already get from the system, so they should not produce less products for consumers.

The purpose of this conversation is for the students to understand how engineering can be used to solve problems. Confirm with students that the engineering design process can help us find solutions to specific problems in the dairy system. Share that before we start figuring out the solutions that exist, we must start at the beginning of the engineering process - defining the problem.

Part 3: Defining the Problem by Analyzing Costs and Benefits of the Dairy System

Ask students to review their artifacts from previous lessons in the unit and use them to determine the benefits, costs, and risks present in the dairy system as a whole. Allow students time to find these costs, benefits, and risks. As students find them, they can add what they find to their Lesson 21 Student Guide.

CCSS SUPPORT

SL 9-10.1(d): Respond thoughtfully to diverse perspectives, summarize points of agreement and disagreement, and, when warranted, qualify or justify their own views and understanding and make new connections in light of the evidence and reasoning presented.
The goal of this standard is to challenge students to respond to diverse perspectives. At this point in the lesson, students should have an understanding of the various problems associated with the dairy system but likely do not have enough evidence of solutions to potentially solve those problems. They will explore these solutions to fully develop their perspective throughout the module.

After a short period of time, invite students to add what they have recorded in their Lesson 21 Student Guide Part 3: Costs and Benefits of the Dairy System to a class list of costs, benefits, and risks. After all students have had a chance to add their ideas, with the class, refine the list to eliminate redundant items. Ask students which items they think should be combined or removed. Questions to ask may include:

- Which of these is similar to another? Can we combine them?
- Are there any of these items that we can combine?

Develop a class list with the following problems:

- Air pollution from manure
- Fertilizers and other pollution in waterways
- Biodiversity loss from infrastructure or monocultured crops
- Transit greenhouse gas emissions
- Processing and packaging
- Greenhouse gas emissions from cattle
- Greenhouse gas emissions from manure
- Air pollution from the dairy system

TEACHER SUPPORT

In Lesson 23, students will read a series of texts with possible solutions to these problems in the list above. Accordingly, ensure that you facilitate the discussion to have this same list of problems emerge. If students come up with additional problems they want to solve, you can honor their choice, and that will mean you will have to research and prepare three custom solution options to present to students in Lesson 23.

With the class list developed, provide students some time to record the consensus list on their Lesson 21 Student Guide Part 3: Defining the Problem by Analyzing Costs and Benefits of the Dairy System. Then, allow students time to label each item as economic, social, ethical, environmental, or geopolitical.

CCC SUPPORT

PAT-H3: Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system.

Here, students are engaging in this element by analyzing the costs and benefits of the dairy system as patterns of performance to help them define a problem to reengineer and improve the system.

DCI SUPPORT

ESS3.C-H1: The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.

In middle school, students learned that changes in biodiversity can influence humans' resources and ecosystem services. This unit builds on this knowledge in that students figure out that human activity has adverse consequences on biodiversity and that sustaining biodiversity requires responsible management of natural resources. Students figured out the impacts of human activity on biodiversity in Module 3, and in this module, students will figure out strategies by which the dairy system is undertaking to more responsibly manage natural resources, including climate and biodiveristy.

As students work on these labels, circulate the room to support students in identifying an appropriate label for each item on the list. Hold a whole-class discussion for students to reach a consensus on their labels. Here is one example of how to label the problems identified:

- Air pollution from manure – environmental, social, ethical
- Fertilizers and other pollution in waterways – environmental, social, ethical
- Biodiversity loss from infrastructure or monocultured crops – environmental, economic, ethical
- Transit greenhouse gas emissions – environmental, social, ethical
- Processing and packaging - environmental
- Greenhouse gas emissions from cattle - environmental, social, ethical
- Greenhouse gas emissions from manure - environmental, social, ethical
- Air pollution from the dairy system - environmental, social, ethical

STUDENT SUPPORT

If students need additional support, consider:

- Asking students to share the meaning of the terms in their own words.
- Creating a graphic organizer for students to add their own definitions of these terms.
- Asking students to refer to their resources from Module 1 to find the definitions of these terms.
- Asking students to think of examples from their day-to-day lives that might fit into these categories.

Share with students that now that we have listed possible costs and risks from the dairy system, we can use this list to choose a specific problem to focus on. Remind students that, when engineers design solutions, the goal is to focus on increasing the benefits we get from the system while decreasing the costs. Therefore, we will focus our solutions on improving the system's costs and risks.

Ask students to identify one cost or risk of the dairy system from their list to serve as the problem they will set out to develop a solution for. Students should record this in the space provided in their Lesson 21 Student Guide Part 3. To allow for student choice, have the list of problems on the board and allow students to sign up for a problem to focus on.

TEACHER SUPPORT

To ensure all options have students signed up, limit the number of students that can sign up for each option. Alternatively, have any number of students sign up for each option, knowing that the solutions they choose, and their reasoning will likely differ.

SEP SUPPORT BOX

AQDP-H8: Define a design problem that involves the development of a process or **system with interacting components** and criteria and constraints that may include social, technical and/or environmental considerations.

In this lesson, students focus on defining the problem that they want to develop a solution for. In the next lesson, students will generate a list of criteria and constraints for a successful solution. As a result, students fully use this element across both Lessons 21 and 22.

Part 4: Selecting and Defining Problems

When students have chosen their problem, they will assemble into groups based on the problem selected. These will be called their Problem Groups, and students remain with these groups throughout this module (Lessons 21-25). There should be no more than three students per group. Explain that to better design a solution, it helps to fully understand the problem students identified. Accordingly, students together will now complete a Problem, Mechanism, and Impact Analysis for the problem they chose.

Direct students to use the Student Guide to complete the Problem, Mechanism, and Impact Analysis for their group's chosen problem.

Allow students time to work. As students work, circulate the room and ask pressing questions to get students to explain their thinking:

- What is the problem you chose? How does that problem impact the environment?
- What steps are there in how this problem impacts the environment?
- Can you say more about this problem? Why did you choose it? Why do you think it is important to solve? What impact does that problem possibly have on your home or community?

FORMATIVE ASSESSMENT OPPORTUNITY

Students identify the benefits, costs, and risks of the dairy system, which they use to define a problem in the system that can be improved upon to manage natural resources more responsibly.

Assessment Artifacts:

- Students' identification of the costs, risks, and benefits of the design of the dairy system (Lesson 21 Student Guide Part 3 Defining the Problem by Analyzing Costs and Benefits of the Dairy System).
- Students' selection and analysis of a problem identified in the dairy system (Lesson 21 Student Guide Part 3 Defining the Problem by Analyzing Costs and Benefits of the Dairy System).

Look Fors:

- Students generate a list of costs, benefits, and risks of the design of the dairy system and name these as economic, social, environmental, or geopolitical costs and risks. (ESS3.A-H2)
- Students identify a problem in the design of the current dairy system, which they can re-engineer. (PAT-H3)
- Students identify the design problem they want to solve and describe the components of the system that interact in this problem. (AQDP-H8)

Assessment Rubric:

	Emerging	Developing	Proficient
Sample Student Response	Identification of Costs, Risks, and Benefits: • Pollution • Pesticides • Produces food Problem, Mechanism, Impact Analysis: Reducing the amount of greenhouse gases	Identification of Costs, Risks, and Benefits: • Air pollution from manure - social/environmental • Use of pesticides and herbicides in raising crops - environmental • Greenhouse gasses emissions from cattle, transit, Waste in packaging and processing – environmental • Food production and food	Identification of Costs, Risks, and Benefits: • Air pollution from manure - social/environmental • Use of pesticides and herbicides in raising crops - environmental • Greenhouse gasses emissions from cattle, transit, Waste in packaging and processing – environmental • Food production and food security - social • Low-cost products – social/economic • Readily available dairy products-social • Improving rural livelihood-social/economic

	from cattle could help climate change.	security - social • Low-cost products – social/economic • Readily available dairy products-social • Improving rural livelihood-social/economic Problem, Mechanism, Impact Analysis: Dairy cattle contribute methane to the atmosphere, which is a greenhouse gas. If we reduce the greenhouse gas emissions from the cow burps, we could help prevent climate change.	Problem, Mechanism, Impact Analysis: Dairy cattle contribute methane to the atmosphere. When dairy cattle eat grass or feed, they digest the food and produce greenhouse gases from their digestion. These gases go into the atmosphere from their burps. In the atmosphere, they contribute to the greenhouse effect, raising the average surface temperature of the Earth. If we reduce the greenhouse gas emissions from the cow burps, we could reduce the total amount of greenhouse gas emissions from the agricultural and dairy industries, which could lead to less temperature rise due to the greenhouse effect in the future.
How to Achieve This Level	Student completes 0 out of 3 Look Fors	Student completes 1-2 out of 3 Look Fors	Student completes 3 out of 3 Look Fors

To Provide Additional Support for Students:

If students need additional support in finding costs, risks, or benefits, or in defining the problem they want to solve, consider:

- Focusing students' attention on particular aspects of one of the artifacts from the unit. For example, on the Dairy System Model from the Dairy Food System Module, ask students what they notice about what moves outside of the boundaries of the dairy system and what impacts this might have. Similarly, you could ask students to review their arguments they have developed throughout the module in which they may have identified costs and benefits of the dairy system.
- Provide an analogy to a common situation in which they can identify benefits, costs, and risks. For example, ask students about driving a car. Driving a car provides benefits in time saved compared to walking, but it provides costs in fuel and vehicle expenses and risks such as a car crash.

If students need additional support to complete the Problem, Mechanism, and Impact Analysis, consider providing students with an everyday example: The Use of Plastic Straws in a City.

- Problem: The excessive use of plastic straws in a city is contributing to environmental pollution and harming wildlife. Plastic straws are non-biodegradable and often end up in bodies of water, where they can be ingested by marine animals and cause injury or death.
- Mechanism: The mechanism behind the environmental impact of plastic straws lies in their widespread consumption and improper disposal. Many restaurants, cafes, and fast-food chains use plastic straws as a default option, leading to an enormous volume of single-use plastic waste generated daily. These plastic straws are lightweight and easily carried by wind and water, leading to littering in public spaces, rivers, and oceans.
- Impact: There are at least three different impacts from solving the problem.

Pollution: Plastic straws pollute land, water bodies, and coastal areas, affecting ecosystems and natural habitats. This pollution could be decreased if the problem is solved.	**Marine Life:** Marine animals, such as turtles, fish, and seabirds, can ingest or become entangled in plastic straws, leading to injury, suffocation, or death. These animal injuries can be decreased if the problem is solved.	**Microplastics:** Over time, plastic straws degrade into microplastics, entering the food chain and potentially causing harm to wildlife and also to humans through the consumption of contaminated seafood. This pollution could be decreased if the problem is solved.

Part 5: Navigation to the Next Lesson

Ask students to return to the start of the lesson to review the list of steps of the engineering design process. Ask students which step they think they can now take to move forward in designing solutions to the environmental effects of the dairy industry now that they have defined the problem they want to focus on. Build off of student responses to confirm that, next, students will define the criteria and constraints for successful solutions to the problem.