Developing and Using Science and Engineering Practices (by Lesson)

Lesson	Elements of Science and Engineering Practice(s)	Rationale
1	Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.	On day 3, students develop questions for the DQB based on their careful observation of the phenomena—the declining orangutan population in Indonesia linked to the buying of candy. Students develop the questions based on their observation of the phenomena, the development of initial models, and the identification of related phenomena. Students will use these questions to guide their investigations throughout the unit.
1	Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.	Starting on day 1, the class develops an initial model to explain the connection between candy buying and declining orangutan populations. On day 1, the model is very simple and only includes the candy and the orangutans. By the end of day 1, students have added palm oil and oil palm trees to their models. On day 2, students included additional components in the ecosystems and hypothesized interactions among those components to revise their initial models.
2	Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.	Students further define the palm oil problem by considering scientific knowledge about (1) the conversion of native plants to space for farming vegetable oil producing plants and (2) the amount of land needed to grow different vegetable oils. This information limits possible solutions of using a substitute for palm oil.
3	Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.	The questions students ask on the DQB in Lesson 1 indicate straightforward solutions to a complicated problem. Students will suggest to just plant the oil palm trees somewhere else, so as not to cut down rainforests. Through this lesson, students make progress on defining the more complicated issues around the problem. They figure out that oil palm requires the same abiotic conditions as tropical forests, which puts the two at odds with one another (competing for space). This lesson has students wrestle with the "scientific knowledge that may limit possible solutions" to this complicated problem.
3	Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.	This lesson has students use graphical displays of data in the form of worldwide solar radiation, temperature, precipitation, and tropical forest location maps to identify spatial relationships between the location of tropical rainforests and the suitable locations to grow oil palm. Students are supported in a very particular skill of data analysis: map overlays and spatial relationships.

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4	Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.	In Lesson 1, students propose and discuss simple solutions to the complex problem of cutting down rainforests, which has caused some local animal populations to decrease. Students will suggest that oil palms should be grown somewhere else so that the rainforests do not need to be cleared. In this lesson, students will hear the perspectives of people living near these rainforests, and they will come to understand that growing oil palms is often one of the only ways for these people to make money and support themselves. This helps the class to define new criteria and constraints for their problem: The solution to this problem has to allow farmers to support themselves and their communities, including those who currently make money from farming oil palms. Adding this criteria late in this lesson encourages students to consider more nuanced solutions and leads them toward investigations into how oil palms could be farmed in a way that is more sustainable for impacted people and animals.
5	Ask questions to clarify and/or refine a model, an explanation, or an engineering problem.	On day 2, students revisit the Driving Question Board to generate a new set of questions that focuses on the engineering design challenge for building a better palm farm.
5	Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.	On day 2, students articulate a bigger problem beyond palm oil around land use change. Students also re-articulate the palm oil problem in the context of the design challenge. Students use new information they have learned in Lessons 2-4 that limits the solutions to the problem, such as oil palm being a more efficient crop than alternatives and oil palm bringing revenue to people who need it. Students generate some initial ideas for criteria and constraints to think about when they design a better palm farm.
6	Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.	On day 1 students apply mathematical concepts of ratios to answer the question of how many orangutans can live in 1 km^2. They calculate a ratio of orangutans per area in four locations at different time points and then, on day 2, analyze these ratios to answer the question.
7	Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.	In this lesson, students carry out a series of investigations to examine what happens to individual orangutans when environmental conditions change. After each investigation, students generate class histograms based on energy levels of individual orangutans. Students use the histograms to answer the question, “Why do orangutans need so much forest space?”
7	Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible.	After conducting each investigation, students record the mean and range of energy levels for the orangutan population using the computer simulation. Students also examine the mean and range of energy levels using class-constructed histograms.
7	Use mathematical representations to describe and/or support scientific conclusions and design solutions.	After each investigation in this lesson, students construct a histogram showing the energy levels of orangutans in the simulation. Using the histograms, students analyze measures of central tendency and range for each condition. Students draw conclusions about how changes in environmental conditions impact individual orangutans based on their analysis of the histograms.

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8	Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.	In this lesson, students carry out three different investigations. In two of the investigations, students plan how to change independent variables. Based on their plans, they run computer simulations and gather data from the simulations over multiple trials. Students use the data from their investigations to make the claim that populations tend to fluctuate and that population sizes can change based on availability of resources.
8	Use mathematical representations to describe and/or support scientific conclusions and design solutions.	In all three investigations, students examine data they collected using a variety of different mathematical representations. First, students examine the average population size for the environmental conditions that they established at the beginning of the investigations. Second, students examine the range in population size (maximum and minimum). Finally, students examine a line graph showing the changes in population size over time. Students use their analyses to make the claim that populations tend to fluctuate and that population sizes can change based on availability of resources.
9	Develop and/or use a model to predict and/or describe phenomena.	On day 1 of this lesson, students build a Gotta-Have-It Checklist and develop models to explain how changes to a rainforest ecosystem, stemming from the expansion of oil palm farming, have caused local orangutan populations to decrease. On day 2, students develop, using the generalizable understandings developed in their first model, new models and explanations for how similar changes to ecosystem factors caused a decrease in monarch butterfly populations in short and tallgrass prairies.
9	Use mathematical representations to describe and/or support scientific conclusions and design solutions.	In addition to explaining, using key science concepts from across the unit, why populations change in response to changes to ecosystem factors, students represent these changes in population mathematically using rate and ratio concepts. For example, on their individual assessments, students have to draw a line on a graph of population over time to represent what they think would be happening in a population that remains stable over time compared to a population that has been unstable. In doing so, students have to translate their content understanding of how stable populations change over time to a grade-appropriate mathematical representation (6th grade Common Core Math standards 6.RP.A3).
9	Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.	In their individual responses on their assessments, students apply grade-appropriate mathematical concepts, namely rate and ratio reasoning (6th grade Common Core Math standards 6.RP.A.1, 2, 3), to describe and explain phenomena. For example, students parse descriptions of quantities that use rate language (like "plants per acre") and understand how relating these two quantities as a ratio helps us to analyze changes to plant populations in specific areas. Students also use rate and ratio reasoning in their constructed responses, like when they use data to compare the ratios of land taken up by colonies to estimate the population size. In each case, the rate and ratio reasoning supports students in making sense of how resource availability changes and how resources are allocated between changing numbers of individuals in populations.

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10	Develop and/or use a model to predict and/or describe phenomena.	Students develop simplified models for the rainforest and oil palm systems that allow them to understand the different interactions between populations under study. These models can be useful for predicting how a change in one population could impact another population.
11	Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s).	Students will critically read a scientific text and a StoryMap, adapted for classroom use, to determine the central ideas and obtain scientific and/or technical information to describe patterns in the amount of plant biodiversity in different types of farms.
12	Develop and/or use a model to predict and/or describe phenomena.	Students use and modify systems models of the monoculture and diversified oil palm farms to predict what will happen within that system if there is disease, drought, or oil palm price drop.
13	Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed.	On day 2, after students co-construct explanations with their group, they engage in a Consensus Discussion. During this Consensus Discussion, the class agrees on how changing a component in the ecosystem impacts different populations and how this creates a ripple effect through the system. Students share a number of ways in which ecosystems change and trace the impacts on other populations using a Basic Ecosystem Model to help them make predictions. On the assessment, students model how interactions between populations in a riparian ecosystem change when there is a change to the system.
13	Construct an explanation using models or representations.	On day 1, students work in groups to construct an explanation, in pictures and words, to answer the unit driving question, “How does changing an ecosystem affect what lives there?” Their explanations focus on one component of an ecosystem (e.g., predator, consumer, plant) and how changing that component impacts other populations. Students are encouraged to use the same Gotta-Have-It Checklist to guide their explanation. Students complete a gallery walk to view each other’s explanations to the same question. On the assessment, students construct explanations using models that show how populations in riparian ecosystems interact before and after disruptions.
14	Use digital tools and/or mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem.	On day 1 students set up Gantt charts to represent their crop selection. They use a spreadsheet calculator to test their crop selection at different ratios to see how their choices impact their income over time. They compare their crop choices and ratio to see which factors seem to stabilize the income over time, as a way of understanding design features to meet criterion 1.
14	Construct an explanation using models or representations.	On day 4, students construct an individual explanation for why their farm design of 3, 4, or 5 crops with strategic utilization of a 20% intact forest corridor supports biodiversity and orangutan populations and is a resilient system for farmers.
14	Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.	The design task in this lesson engages students in outlining criteria and constraints and evaluating progress toward meeting those criteria and constraints at strategic moments in the lesson. Students focus on criteria related to supporting farmers during days 1 and 2 and then transition to designs to meet biodiversity needs on days 3 and 4.

Developing and Using Crosscutting Concepts (by Lesson)

Lesson	Elements of Crosscutting Concept(s)	Rationale
1	Cause and effect relationships may be used to predict phenomena in natural or designed systems.	The overarching claim in this unit is that our candy buying can *cause* the orangutan populations to decline (*effect*). These two components (candy buying and orangutan population decline) seem very distantly related. Throughout the unit, students work to establish a chain of cause and effect to explain the phenomena. In doing so, students should consider the multiple components and interactions involved in addition to immediate and delayed effects.
1	Models can be used to represent systems and their interactions—such as inputs, processes andoutputs—and energy, matter, and information flows within systems.	When developing initial models for the phenomena of our candy buying habits leading to orangutan population decline, students must consider multiple system models—the global system, the ecosystems in Indonesia, oil palm plantations, and rainforest systems. These systems change over time, so students must keep track of the ways in which the systems interact and change.
2	Patterns can be used to identify cause and effect relationships.	Students use patterns across three cases of farming vegetable oils—canola in Canada, soy in the Midwest, and palm in Indonesia—to identify cause-and-effect relationships between demand for food and ingredients in the product causing people to clear land to farm oil plants, which causes the decline of some populations.
3	Graphs, charts, and images can be used to identify patterns in data.	Students use worldwide solar radiation, temperature, precipitation, and tropical forest location maps to identify spatial relationships between the location of tropical rainforests and suitable locations in which to grow oil palm. They then identify a pattern that the tropical plants that make up the rainforests have the same abiotic requirements as the oil palm plants.
4	Models are limited in that they only represent certain aspects of the system under study.	The model that the class created in Lesson 1, which will be developed throughout the unit, includes some factors that are involved in the complex problem that students are trying to solve. There are factors that we can not and do not include in our model, including the people who farm oil palms for money and the downstream economic impact of the palm oil industry in developing countries in which oil palms are often grown. The model the class makes is limited in the aspects of this complicated problem that it represents, and this lesson encourages students to consider factors that fall outside of the model that change our ideas about what constitutes a successful solution to the problem. Considering these factors late in this lesson changes students' ideas about how to solve their problem and causes the class to brainstorm investigations to figure out how they might craft a solution that meets all of the criteria and constraints they have now defined.
5	Patterns can be used to identify cause and effect relationships.	On day 1, students look for patterns across the different cases and recognize that the pattern is a land use change, which relates to populations that lived in the original ecosystem. While students do not get to cause-and-effect relationships in this lesson, patterns across the box-and-line models set students up for wondering about the causes for population decline.

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5	Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function.	On day 2, students articulate this change as a change in the structure of the system by examining images of the structure and composition of the tropical rainforest and oil palm farms. They compare the two systems and brainstorm how the different structures could affect how the system functions for the animals that live there.
5	Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.	On day 2, students use the comparison of structures of the two different systems to brainstorm how to design a better palm farm.
6	Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems.	On day 2, students look for patterns across the ratios of orangutans per area to provide information about the natural rainforest ecosystem, specifically, how many orangutans can live in a 1 km^2 area.
7	Models are limited in that they only represent certain aspects of the system under study.	In this lesson, students are introduced to a computer simulation that they use to investigate how different environmental conditions impact individual orangutans. The simulation is limited in that it includes only four components of the ecosystem (orangutans, fruit trees, rainforest trees, and termites). Through a stop and jot and a whole-class discussion, students consider the advantages and limitations of using a simulation that represents only certain aspects of the ecosystem.
7	Small changes in one part of a system might cause large changes in another part.	Using a computer simulation, students investigate how small changes in environmental conditions (e.g. more fruit trees, fewer fruit trees) might impact individual orangutans. Based on data collected from the simulations, students draw conclusions that small changes to environmental conditions can cause large changes in the energy levels of individual orangutans and in the average orangutan energy levels for the orangutan population.
8	Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms.	In this lesson, students draw important conclusions about the stability of populations. First, students draw the conclusion that stable populations may still fluctuate based on the number of births and deaths. Second, students recognize that some environmental changes may not significantly change population sizes, but that other environmental changes may drastically change population size.

Lesson	Elements of Crosscutting Concept(s)	Rationale
9	Cause and effect relationships may be used to predict phenomena in natural or designed systems.	Throughout the unit, students have used data collected by scientists and gathered through simulations to establish causal relationships between ecosystem factors and the sizes of populations that live in these ecosystems. In doing so, students considered the multiple components and interactions involved in addition to immediate and delayed effects. For example, by this lesson, students have figured out that a decrease in the available resources in an ecosystem causes a decrease in the size of populations that can live there. In the first day of this lesson, students demonstrate this understanding through the links that they add to their consensus model for the orangutan ecosystem. In this lesson, students use these causal relationships in a new context (monarch butterflies living in prairie ecosystems) to explain a decrease in population correlated with changes to ecosystem factors. In their explanations, students not only link these factors to changes in population size, but offer mechanistic explanations for why populations change that demonstrate a shift in understanding from a correlational to a causal relationship between ecosystem factors and population size.
9	Stability might be disturbed either by sudden events or gradual changes that accumulate over time.	In their investigations of the orangutan system, as well as in the new phenomenon they encounter in their assessment, students use the lens of stability and change to develop and explain models for changes to ecosystems, both gradual, like the loss of forest to palm oil production over decades of expansion, and sudden, like a seasonal change in rainfall or the implementation of new farming practices. In their consensus modeling and in their individual responses on their assessment, students leverage this understanding to explain how slow and fast changes to ecosystem factors cause changes to the size of populations living in those ecosystems.
10	Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.	On day 1 students use cause and effect as a lens to brainstorm the different possible causes that lead to population growth or decline. Students notice a pattern across the causes related to food availability and shelter/protection and decide to account for both in their system models. Because ecosystems are so complex, students will recognize that it is difficult to identify any single cause leading to a population's growth or decline.
10	Models are limited in that they only represent certain aspects of the system under study.	On day 2 students discuss the limitations of the models in accounting for all of the components and interactions that occur in these complex ecosystems. Students only account for 15 populations in a system that is composed of millions of different species.
11	Graphs, charts, and images can be used to identify patterns in data.	Students will use images from the texts to identify patterns in the numbers and types of plant biodiversity in diversified and monoculture farms.
12	Cause and effect relationships may be used to predict phenomena in natural or designed systems.	Students use cause-and-effect relationships to make predictions about what will happen to farmers and populations in ecosystems if there is disease, drought, or oil palm price drop.
12	Stability might be disturbed either by sudden events or gradual changes that accumulate over time.	Students consider three sudden events that could disturb stability in the farming ecosystems or for farmers financially: disease, drought, and oil palm price drop.

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13	Cause and effect relationships may be used to predict phenomena in natural or designed systems.	Students reflect on the unit driving question and identify that cause and effect could be a useful lens with which to guide their development of explanations. On day 2, during the students' individual assessment, they use cause and effect as one lens for making sense of disruptions to a riparian ecosystem.
13	Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.	Students use system-model thinking as they develop their explanations and participation in Consensus Discussions. Students use a Basic Ecosystem Model to help them understand how changes in one part of a system impacts populations throughout the systems. This same theme continues on the assessment.
14	Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.	On days 3 and 4 students explore how to utilize their 20% of forest area in conjunction with neighboring rainforest areas to see how coordinating systems at a larger scale can have notable impacts on orangutan populations.
14	Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.	On day 2 students discuss and write an explanation about the factors that affect whether their crop selection helped them to stabilize an income for farmers over time.