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.	Students record what they wonder when they carefully observe a flameless heater heating food in their classroom and on a video. Students also generate questions to clarify their thinking and seek additional information about how they could design a similar device that will heat food without electricity or flame based on their observations of the flameless heater.
1	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 collaboratively list problems they identify with prepackaged Meals, Ready-to-Eat, including that they are expensive, possibly confusing to use, and hard to transport to people who need them. Based on these problems, students propose the solution of a homemade flameless heater, and they work with partners to develop the criteria that it functions well (able to heat food to an appropriate temperature without using typical heating methods) and is easy to construct and use (have clear directions), and the constraints that it does not take too long to construct or heat up the food, does not cost as much as prepackaged MREs, and uses materials that are easy to get. After discussing these problems, solution ideas, criteria, and constraints, students record what they've figured out in their Progress Trackers.
1	Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system.	Students begin to apply scientific ideas about chemical reactions and systems to independently design an effective, inexpensive, easy-to-use flameless heater that people can make themselves. Students also begin to collaborate with small groups to compare and discuss these designs. These initial designs will be significantly revised and improved throughout the rest of the unit, as students construct and test prototypes and apply scientific ideas to their designs more intentionally.
2	Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.	Students work in small groups and as a class to conduct an investigation to produce temperature data when water is combined with table salt, iron, and magnesium. This data serves as evidence to meet the goal of the investigation: to determine which substance from the MRE heater is causing it to heat up.
3	Use and/or develop a model of simple systems with uncertain and less predictable factors.	Students use the LOL energy model to show how energy is transferred from the chemical process system investigated on day 1 that caused the greatest temperature increase to other systems (e.g., the thermometer, the cup, the air). This model is used to account for the relative energy that is stored within the system, transferred to other systems, such as food or the environment, and left in the products at the end of the chemical process. Students develop their own LOL energy model with an increase in the amount of reactants.
3	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.	Students work in small groups to conduct an investigation to identify other chemical processes that cause an increase in temperature (release energy). The data produced serves as evidence to identify a chemical process to use in their homemade flameless heater.

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4	Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.	Students work in small groups to share information they have obtained from multiple sources to answer their questions about how the temperature of food is related to taste and safety. They use this shared information to develop a target temperature range to which our homemade heater needs to warm our food, which helps us refine the criteria and constraints of the design solution.
5	Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.	Students conduct an investigation to produce data to help determine the proportion of reactants that causes the biggest temperature change. This data serves as evidence for which proportion of reactants should be used in the homemade flameless heater designs in order to achieve the greatest temperature increase.
5	Evaluate the accuracy of various methods for collecting data.	Students review the experimental design and evaluate methods of data collection to help get accurate data to answer our question and identify ways to make it more accurate. They identify ways to make the temperature data collection and the qualitative observations of the products more accurate.
5	Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.	Students analyze two sets of data to determine an optimal range of the amount of food that can be heated up and the proportion of reactants that causes the biggest temperature change in order to meet the criteria and constraints of their design solutions.
6	Collect data about the performance of a proposed object, tool, process or system under a range of conditions	In this lesson, students work in their design teams to collect data about the performance of their redesigned homemade flameless heater. After using a model on paper to propose their design to their teacher (who checks it against safety constraints), teams construct a prototype to test how well it is able to meet the criteria and constraints of the optimal solution.
6	Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.	In this lesson, students work in teams to continue engaging in the design cycle around the project of constructing a homemade flameless heater that will meet specific design criteria (e.g., heat food 40-47 °C) and constraints (e.g., heater costs under $3).
7	Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.	Students will engage in feedback rounds with other teams to provide and receive critiques and pose and respond to questions about their flameless heater designs. These discussions will elicit details about the most promising design characteristics and will inform team decisions about revisions to optimize designs in a later lesson.
8	Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.	Students will evaluate competing design solutions based on jointly developed and agreed-upon design criteria as they create their Consequences Chart and consider impacts on other design characteristics and on stakeholders.

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9	Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.	In this lesson, students work in teams to optimize the designs of their homemade flameless heater that will meet specific design criteria (e.g., heat food 40-47°C) and constraints (e.g., costs under $3). They consider the criteria they want to choose based on prior tests and make trade-offs using the Consequences Chart.
9	Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or	In this lesson, students work in teams to revise the how-to instructions for their homemade flameless heater so that another team can build and test their design. Regardless of the medium they have chosen, teams must effectively communicate the technical details of their design as evidenced by the results generated by their partner team.
10	Make an oral or written argument that supports or refutes the advertised performance of a device, process, or system based on empirical evidence concerning whether or not the technology meets relevant criteria and constraints.	Students evaluate the advertised performance of different sea turtle incubator designs and develop an argument for which design or combination of design features would work best based on relevant criteria and constraints in an assessment task.

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.	Students consider possible causes for how a flameless heater heats food, including making connections to the work they did with chemical reactions in the [material: ca.n] to make predictions and ask questions about what is causing the food to heat up.
1	Models can be used to represent systems and their interactions—such as inputs, processes andoutputs—and energy, matter, and information flows within systems.	Students consider how the flameless heater system in a Meal, Ready-to-Eat is able to interact with the food system in order to heat the food, and they develop an initial model to begin to describe this interaction. Students also develop models for how a non-typical heater system could heat up a food system in their own designs for a homemade flameless heater.
2	Patterns can be used to identify cause and effect relationships.	Students use patterns in the temperature data that they gather from combining salt, iron, and magnesium with water to identify that magnesium and water is the combination that causes the MRE heater to heat up.
3	Patterns can be used to identify cause and effect relationships.	Students use patterns in the data they collect to identify cause-and-effect relationships. As small groups investigate temperature changes caused by different chemical processes, they realize that some processes absorb energy, some release energy, and some show very little energy change. Students look for patterns between the amount of substances used and the observed temperature changes. For chemical processes that cause measurable temperature changes, students identify that the magnitude of the temperature change is directly proportional to the amount of substances involved in the process.

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3	The transfer of energy can be tracked as energy flows through a designed or natural system.	The LOL energy model tracks the energy flow during a chemical process. As the molecules in a system of reactants break apart and rearrange during a chemical process, energy that is stored within the system is released. This energy is transferred to the environment (or food), and the energy in the system of products is decreased by that amount.
4	Graphs, charts, and images can be used to identify patterns in data.	Students examine survey data and identify patterns in the results to inform the acceptable upper and lower temperature range to which our food should be heated.
5	Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.	Students collect and analyze data to determine the optimal proportion of reactants that cause the biggest temperature change.
5	Unknown practice identifier: 1.2.	Students identify patterns in the relationship between the total amount of food we can heat and the amount of thermal energy that is transferred to it.
6	Patterns can be used to identify cause and effect relationships.	As they collect data about how quickly their prototype design is able to change the temperature of “food,” students look for patterns in that data to identify cause-and-effect relationships. They consider what specific characteristics of their design are affecting the change in the food’s temperature.
6	Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.	Student teams use a model to show how the transfer of energy changes the motion of particles in different systems (the substances used, the heater packaging, the food being heated, the outside air) in their design for a homemade flameless heater.
7	Patterns can be used to identify cause and effect relationships.	Students work as a class to identify the most promising design characteristics by considering patterns across multiple teams’ designs for which design characteristics resulted in more effective performance outcomes.
8	Small changes in one part of a system might cause large changes in another part.	Students notice that even small changes in one design characteristic might cause unexpected changes in other design characteristics, which may be large enough to make that change lead to a much more or less optimal design.
9	The transfer of energy can be tracked as energy flows through a designed or natural system.	Student teams use a model to show how the transfer of energy is tracked through the changes in the motion of particles in different systems (the substances used, the heater packaging, the food being heated, the outside air) in their design for a homemade flameless heater.
10	Graphs, charts, and images can be used to identify patterns in data.	Students use and add to a table with data about how various incubator designs perform against the criteria and constraints for the optimal turtle egg incubator design. Students use this data to look for patterns to inform their arguments for which incubator design best fits the needs for moving the sea turtles.

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10	The transfer of energy can be tracked as energy flows through a designed or natural system.	Students track the energy flow from the hot packs used in Incubator B to the turtle eggs using LOL energy models. Then, they can adjust the amounts of reactants used in the hot packs to transfer more, less, or the same amount of energy to the turtle eggs and update their energy models to reflect their design decisions.