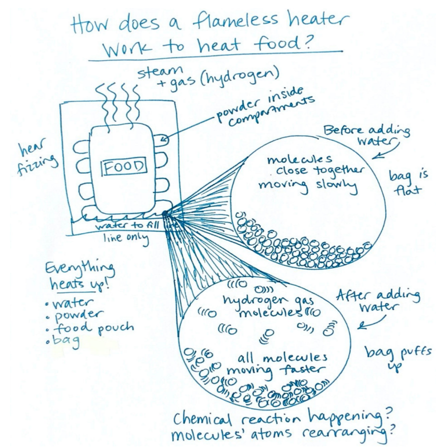
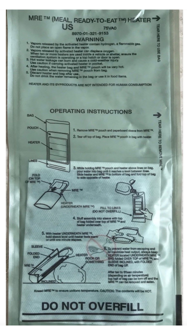
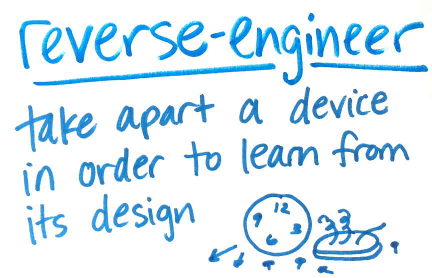
UNIT STORYLINE

How can we help people design a flameless heater?

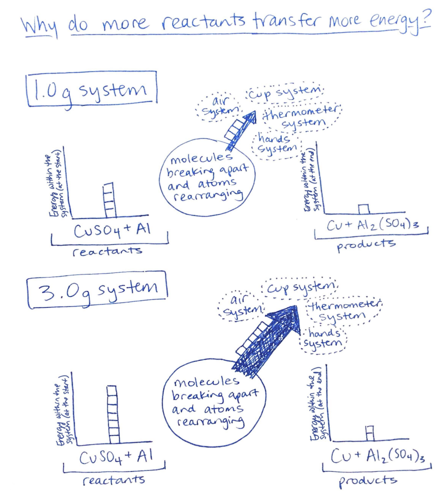
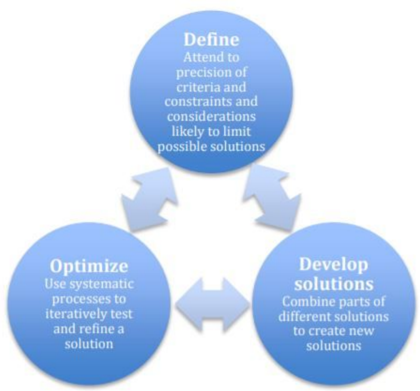
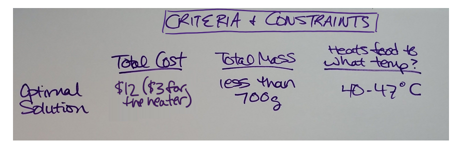
How students will engage with each of the phenomena

HANDS-ON/ LAB ACTIVITIES | VIDEOS OR IMAGES | DATA SETS | READINGS | COMPUTER INTERACTIVES

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 1 3 days **How can we heat up food when we don't have our typical methods available?** Anchoring Phenomenon	 *The flameless heater in a Meal, Ready-to-Eat significantly increases in temperature and is able to heat food when the user simply adds water to the pouch and waits a few minutes.*	We develop an initial model to consider how the flameless heater in an MRE works, but we also notice some problems with prepackaged MREs. After brainstorming criteria and constraints for a homemade flameless heater, we attempt to create designs. We build a Design Questions Board and gather ideas for investigations. We figure out: • Prepackaged MREs are useful, but they are expensive, possibly confusing to use, and can be difficult to get to people. • We want to design an effective, inexpensive, easy-to-use flameless heater that people can make at home to heat food when typical methods are not available. • We cannot design for all our criteria and constraints at once—we need a systematic way to test parts of designs and share ideas. • We have a lot of questions and ideas for investigations to drive our design work.	
LESSON 2 1 day **What's inside the MRE flameless heater that's making it warm?** Investigation	 *When magnesium and water are combined in the MRE heater, the temperature increases.*	We look at images of an MRE heater that has been cut open and see a list of ingredients inside. Then we do an experiment during which we combine ingredients one at a time with water to see which substance is really responsible for heating up. We figure out: • We reverse engineered an MRE heater and found out that magnesium and water make the temperature of the heater increase. • Magnesium and water are not good substances for our homemade flameless heater design. We need to find another chemical process.	

⇓ **Navigation to Next Lesson:** We have some initial design ideas, but many of us are wondering what's inside a flameless heater that makes it heat up when we just add water? We want to cut open an MRE heater pack and see what ingredients are in it.

⇓ **Navigation to Next Lesson:** Since magnesium and water are not good substances to use for our homemade flameless heater design, we are wondering if there is another chemical process that heats up and that we could use in our designs.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 3 2 days **What other chemical processes could we use to heat up food?** Investigation	 *Different chemical processes cause an increase, decrease, or no change in temperature.*	We measure temperature changes of various amounts of chemical processes to determine a candidate for our homemade flameless heater. We create LOL energy models to identify how energy transfers between systems, including when chemical processes occur. We figure out: • Root killer and aluminum foil mixed together in saltwater caused a large increase in temperature. • Exothermic processes can release energy; these processes feel warm. Endothermic processes absorb energy; these feel cold. • Chemical processes can transfer energy to other systems. • The more reactants we use in a chemical process, the greater the temperature change, which corresponds to more energy being transferred into or out of the system.	
⇓ Navigation to Next Lesson: We figured out a chemical process that we can use in our designs and how energy can be transferred to heat up food. We're excited to think about how we might apply our ideas to our homemade heater designs.			
LESSON 4 1 day **How can we refine our criteria and constraints?** Putting Pieces Together, Investigation	 *The class seems to be repeating some of the work they are doing as engineers.*	We define our stakeholders and their needs, which allows us to refine what our design solutions need to do. We revise our criteria and specify constraints based on patterns within data and information we read and analyze. We figure out: • We are starting to see steps of this process repeating and decide to organize our "What We Do as Engineers" board. • It will be important to have a way to organize how our designs perform so we create a Design Matrix to keep track of how our designs will align with our revised criteria and constraints.	
⇓ Navigation to Next Lesson: Now that we know more specific criteria and constraints that our designs should be targeting, we need to figure out what we can do to get our heaters to those temperatures/weights without just guessing how much food versus reactants we should use.			

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

LESSON 5

2 days

How much food and reactants should we include in our homemade flameless heater?

Investigation

The same amount of energy does not heat up more food to the same temperature. Also, adjusting the proportion of reactants causes different temperature outcomes.

We analyze provided data to determine how much food we can heat up with a given amount of reactants. Then we conduct an investigation to determine which proportion of each reactant will work best to heat up our food.

We figure out:

- The more food we have, the more energy we need to heat it up.
- The best combination of reactants is 8% Al and 92% $CuSO_4$ when using 60 g of saltwater.

Group	Grams of Aluminum	Grams of CuSO4	Max Temp Change(°C)
A	0.1 g	5.9 g	26.0
B	0.1 g	5.9 g	25.7
C	0.5 g	5.5 g	45.6
D	0.5 g	5.5 g	45.9
Lesson 3	3 g	3 g	35
E	4.5 g	1.5 g	29.1
F	4.5 g	1.5 g	28.7

* 8% Aluminum
92% $CuSO_4$

⇓ **Navigation to Next Lesson:** We figured out the optimal amount of each reactant and what that means for how much food we can heat up. Now we're ready to apply these ideas to our designs!

LESSON 6

3 days

How can we redesign our homemade flameless heater?

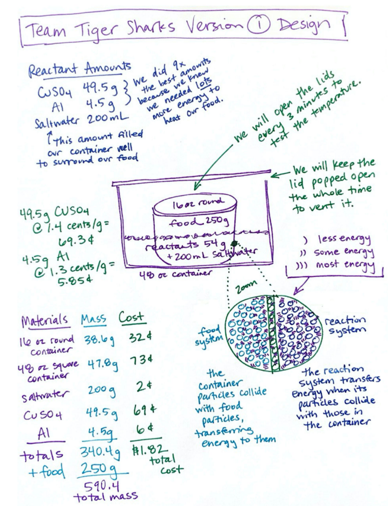
Investigation

Copper sulfate and aluminum in saltwater can be used in a homemade device to heat up food.

We work in teams to draw models of our homemade flameless heaters. Our teacher checks our plans for safety before we build prototypes and test them using a Design Testing Matrix based on our criteria and constraints. After testing, we complete a self-assessment of how well our team works as engineers and how well we individually meet expectations as teammates.

We figure out:

- Designs need to be tested to inform modifications that will lead to a better solution.
- Different kinds of models are helpful for testing design solutions.



⇓ **Navigation to Next Lesson:** We want to share our designs and test results with other teams so that we can see different ideas that worked, and then we can combine those parts to create an even better solution.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

LESSON 7

1 day

How did our design compare to others in the class?

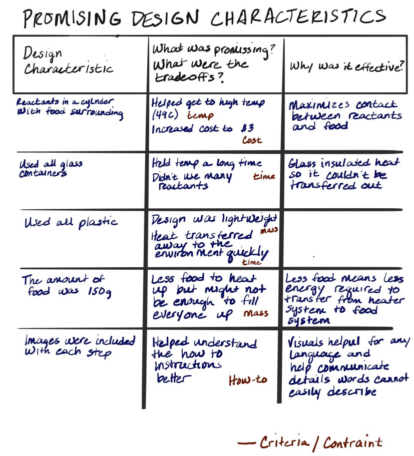
Problematizing

Sharing designs among teams helps to determine which flameless heater design characteristics are more promising than others with respect to the identified criteria and constraints.

We provide and receive critique about our flameless heater designs with other teams and work as a class to identify the most promising design characteristics.

We figure out:

- We have some ideas about which *characteristics* lead to the best performance outcomes in our flameless heater designs.
- We want to optimize our flameless heater designs by incorporating different combinations of *characteristics* to improve performance.



PROMISING DESIGN CHARACTERISTICS

Design Characteristic	What was promising? What were the tradeoffs?	Why was it effective?
Reactants in a cylnder with food surrounding	Helped get to high temp (49c) temp Increased cost to $3 Cost	Maximizes contact between reactants and food
Used all glass containers	Held temp a long time Didn't use many reactants time	Glass insulated heat so it couldn't be transferred out
Used all plastic	Design was lightweight mass Heat transferred away to the environment quickly time	
The amount of food was 150g	Less food to heat up but might not be enough to fill everyone up mass	Less food means less energy required to transfer from heater system to food system
Images were included with each step	Helped understand the how to instructions better How-to	Visuals helpul for any Language and help communicate details words cannot easily describe

— Criteria / Contraint

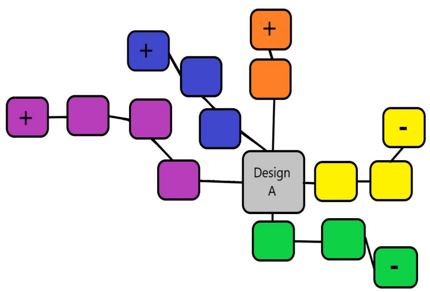
⇓ **Navigation to Next Lesson:** We are wondering how changes to our designs might affect other parts of our design, the solution as a whole, or the people who will use it. As we make decisions about how to revise and optimize our designs, what other possible effects do we need to consider?

LESSON 8

2 days

What are the effects of changes we might make in our designs?

Investigation, Putting Pieces Together

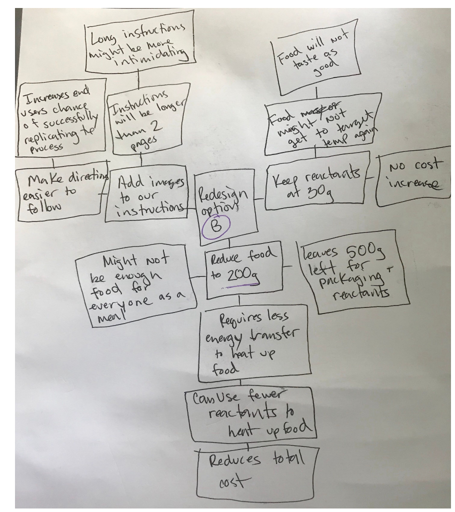


When a change is made to a design, there are downstream consequences of varying degrees that may have different effects on stakeholders.

We consider possible changes to implement in our design and chart the effects on the other characteristics of our homemade heater

We figure out:

- There may be negative consequences for some of our changes.
- We think about the effect on stakeholders to make decisions on which design changes will have the most positive impact overall.
- We use that information to decide which 2-3 changes we will implement in our final design.



⇓ **Navigation to Next Lesson:** We have identified changes that we think are important to make and are ready to dive into updating our designs.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

LESSON 9

3 days

What is our optimal design for a homemade flameless heater?

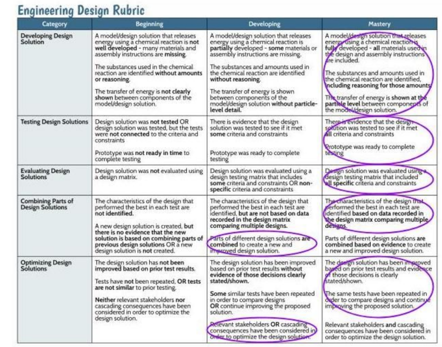
Investigation

We can use test results to redesign our homemade flameless heater.

We work in teams to optimize our homemade flameless heaters, build revised prototypes, and test them using a Design Testing Matrix. We solidify our how-to instructions and a partner team uses our instructions to build and test our homemade heaters. After testing, we complete two self-assessments of how we did as a team in our engineering work. We revisit our Design Questions Board to evaluate and answer any remaining questions.

We figure out:

- Design performance needs to be optimized by revising and retesting.
- Parts of different solutions can be combined to create a solution that is better than any of its predecessors.
- Designs and instructions need to be peer tested to inform modifications that will lead to a better solution.



Engineering Design Rubric

Category	Beginning	Developing	Mastery
Developing Design Solution	A model/design solution that releases energy using a chemical reaction is **not well developed** - many materials and assembly instructions are **missing**. The substances used in the chemical reaction are identified **without amounts or reasoning**. The transfer of energy is **not clearly shown** between components of the model/design solution.	A model/design solution that releases energy using a chemical reaction is **partially** developed - **some** materials or assembly instructions are missing. The substances and amounts used in the chemical reaction are identified **without reasoning**. The transfer of energy is shown between components of the model/design solution **without particle-level detail.**	A model/design solution that releases energy using a chemical reaction is **fully** developed - **all** materials used in the design and assembly instructions are included. The substances and amounts used in the chemical reaction are identified, **including reasoning for those amounts.** The transfer of energy is **shown at the particle level** between components of the model/design solution.
Testing Design Solutions	Design solution was **not tested** OR design solution was tested, but the tests were **not connected** to the criteria and constraints Prototype was **not ready in time** to complete testing	There is evidence that the design solution was tested to see if it met **some** criteria and constraints Prototype was ready to complete testing	There is evidence that the design solution was tested to see if it met **all** criteria and constraints Prototype was ready to complete testing
Evaluating Design Solutions	Design solution was **not** evaluated using a design matrix.	Design solution was evaluated using a design testing matrix that includes **some** criteria and constraints OR **non-specific** criteria and constraints	Design solution was evaluated using a design testing matrix that included **all specific** criteria and constraints
Combining Parts of Design Solutions	The characteristics of the design that performed the best in each test are **not identified.** A new design solution is created, **but there is no evidence that the new solution is based on combining parts of previous design solutions** OR a new design solution is **not** created.	The characteristics of the design that performed the best in each test are identified, **but are not based on data recorded in the design matrix comparing multiple designs.** Parts of different design solutions **are combined** to create a new and improved design solution.	The characteristics of the design that performed the best in each test are identified **based on data recorded in the design matrix comparing multiple designs.** Parts of different design solutions **are combined based on evidence** to create a new and improved design solution.
Optimizing Design Solutions	The design solution has **not been improved based on prior test results.** Tests have **not** been repeated, **OR tests are not similar** to prior testing. **Neither** relevant stakeholders **nor** cascading consequences have been considered in order to optimize the design solution.	The design solution has been improved based on prior test results **without evidence of those decisions clearly stated/shown.** **Some** similar tests have been repeated in order to compare designs **OR** continue improving the proposed solution. Relevant stakeholders **OR** cascading consequences have been considered in order to optimize the design solution.	The design solution has been improved based on prior test results and evidence of those decisions is clearly stated/shown. The same tests have been repeated in order to compare designs and continue improving the proposed solution. Relevant stakeholders **and** cascading consequences have been considered in order to optimize the design solution.

⇓ **Navigation to Next Lesson:** In this lesson, we realize we can answer most of the questions on the DQB. We've learned a lot, and we're ready to apply it to addressing other problems.

LESSON 10

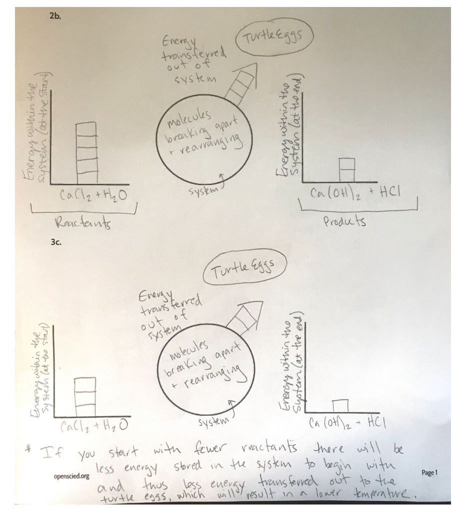
1 day

How can we decide between competing designs?

Putting Pieces Together

Transfer task article states that sea turtle populations in Australia are now over 99% female.

We demonstrate understanding on a summative assessment transfer task involving sea turtle incubators. In this assessment we evaluate different designs and develop an argument for which sea turtle incubator design or combination of design features would work best based on relevant criteria and constraints. Then we celebrate our designs by thinking of other applications for our homemade heaters.



LESSONS 1-10

19 days total