10 Developing a Prototype

DESIGN

Someone who uses science and tools to build a product that solves a practical problem is called an **engineer**. In the "Chemical Batteries" activity when you designed and tested prototypes of batteries, you were doing the work of an engineer. In the following activities, you and your classmates are going to be engineers who design, build, test, and refine a product to keep your hands warm when it is cold outside. You will use the exothermic iron reaction you have been investigating as part of your design.

GUIDING QUESTION

How do engineers design and test a prototype hand warmer?

What kinds of products would help you keep warm on a cold day?

MATERIALS

For each group of four students

- 1 container of iron filings
- 1 container of calcium chloride
- 1 container of pre-swelled absorbent beads
- 1 sealable plastic bag
- 1 graduated cup (30-mL)
- 1 scoop (30-cc)
- 3 scoops (5-cc)
- water
- 1 thermometer
- timer or clock
- 1 tray
- paper towels

For each student

- 1 pair of chemical splash goggles
- 1 Student Sheet 10.1, "Hand Warmer Designs"

SAFETY

Wear chemical splash goggles at all times during this lab. Do not allow the solutions to touch your skin or clothing. Clean up any spills immediately. If accidental contact occurs, inform your teacher and rinse exposed areas. Keep all materials on the tray to catch any accidental spills. Wash your hands thoroughly with soap and water after you finish the activity.

PROCEDURE

Part A: Define the Problem

1. Watch your teacher's demonstration of a hand warmer prototype.
2. Read the following criteria and constraints for the hand warmer. As a class, clarify or add any relevant criteria or constraints to the design challenge.

   Design Criteria

   The design must

   - be contained within a sealable bag.
   - use an exothermic reaction containing iron.
   - reach and maintain a temperature of 35–45°C for at least 5 min.

Design Constraints

The design is limited by

- using only the materials provided.
- using no more than 15 cc of iron filings and 15 cc of calcium chloride.
- using equal amounts of iron filings and calcium chloride or less calcium chloride than iron filings.
- using the absorbent beads as is. Do not smash or squish the beads.

Part B: Brainstorm Designs

3. Review all of the available materials with your partner.
4. Discuss different ways that you can use the available materials to design an improved prototype that could meet the criteria and constraints. Come up with as many ideas as possible. Remember to only modify one variable at a time.
5. On Student Sheet 10.1, "Hand Warmer Designs," draw and label diagrams of your designs. At this point, you should indicate how much of each material you will use to build the prototype. You should also indicate the specific modification of the original design shown by your teacher.

Part C: Build and Test Your Design

6. With the other pair in your group, discuss all of your design ideas. Choose the one design that you would like to build that you think will best meet the criteria within the given constraints.
7. As a group, build and test a prototype of your chosen design. Be sure to make and record your observations on your Student Sheet. Don't forget to measure the temperature change using the thermometer. Keep the thermometer on the outside of the hand warmer—do not put it inside the sealable bag! Remember, the hand warmer is supposed to maintain a temperature of 35–45°C for at least 5 min.

Part D: Evaluate Your Design

8. Compare and contrast your initial design and test results of your prototype with another group of students in your class.
9. Discuss which of your prototypes best meets the design criteria and constraints. As a larger group, determine if a better design could be made from combining parts of your designs.
10. As a class, identify characteristics of everyone's designs that contributed to the function of your hand warmers. Also, identify characteristics of the designs that might have decreased the function of your hand warmers.

ANALYSIS

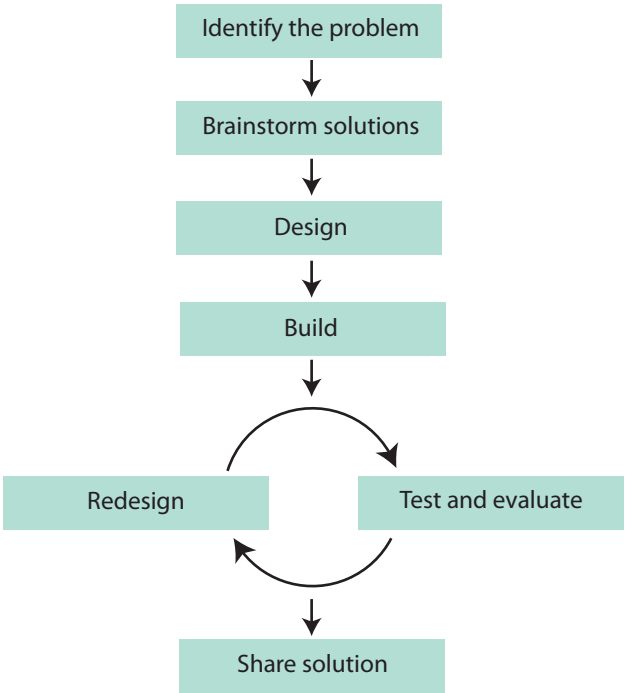
1. Did your prototype meet the criteria for the hand warmer? If not, what criteria did your design fail to meet?
2. How could you improve your design? Is there a feature of another design or a material that you did not use that you would like to include? Why or why not?
3. When you combine the reactants provided in this activity, the reaction begins almost instantly. How do you think you could make the reaction start when you want it to?
4. The reaction in your hand warmer releases thermal energy, which increases the temperature of the warmer.
   a. Why does the warmer not stay warm forever?
   b. Where does the released energy from the reaction in the hand warmer go?

11 Refining the Design

DESIGN

WHEN DEVELOPING SOLUTIONS to problems, engineers engage in the **engineering design process—**a series of steps that engineers follow to come up with a solution to a problem. In this process, many steps are repeated and sometimes in various orders because prototypes often need to be tested, redesigned, and retested many times until the engineers find the best solution. A diagram of a common design process is shown below. In the "Developing a Prototype" activity, you and your partner designed, built, tested, evaluated, and redesigned a hand warmer. In this activity, you will continue to redesign, build, test, and evaluate your hand warmer.

Engineering Design Process



GUIDING QUESTION

How can the hand warmer design prototypes be redesigned and improved?

MATERIALS

For each group of four students

- 1 container of iron filings
- 1 container of calcium chloride
- 1 container of pre-swelled absorbent beads
- sealable plastic bags (small, medium, and large)
- 1 graduated cup (30-mL)
- 1 scoop (30-cc)
- 3 scoops (5-cc)
- water
- 1 thermometer
- timer or clock
- 1 tray
- paper towels

For each student

- pair of chemical splash goggles
- 1 Student Sheet 11.1, "Evaluation of Hand Warmer Design"

SAFETY

Wear chemical splash goggles at all times during this lab. Do not allow the solutions to touch your skin or clothing. Clean up any spills immediately. If accidental contact occurs, inform your teacher and rinse exposed areas. Keep all materials on the tray to catch any accidental spills. Wash your hands thoroughly with soap and water after you finish the activity.

PROCEDURE

Part A: Redefine the Problem and Brainstorm Designs

1. Read the following criteria and constraints for the hand warmer. As a class, clarify or add any relevant criteria or constraints to the design challenge.

   Note: There is an additional criterion that your hand warmer needs to meet in this activity.

   Design Criteria

   The design must

   - be contained within a sealable bag.
   - use an exothermic reaction containing iron.

- reach and maintain a temperature of 35–45°C for at least 5 min.
- allow the user to activate the hand warmer when needed.

Design Constraints

The design is limited by

- using only the materials provided.
- using no more than 15 cc of iron filings and 15 cc calcium chloride.

2. Review all of the available materials with your partner.
3. Discuss different ways that you can use the available materials to design an improved prototype that could meet the criteria and constraints. Come up with as many ideas as possible.

   Hint: You do not need to use all of the materials in your design.
4. In your science notebook, draw and label diagrams of your designs. Be sure to include information about how much of each material you will use in each design.

Part B: Build, Test, and Evaluate Your Design

5. With your group, discuss the different designs. Choose the one design you think will best meet the criteria and constraints.
6. Build your chosen prototype. Do not activate your hand warmer.
7. Compare and contrast your designs and built prototype with another group of students in your class. Record your observations, including similarities and differences, in your science notebook.
8. Explain how to activate your hand warmer to the other group of students.
9. Activate their hand warmer while they activate your hand warmer. Use the thermometer to record the temperature change. Remember, the hand warmer is supposed to be 35–45°C for at least 5 min. Record any observations and results on Student Sheet 11.1, "Evaluation of Hand Warmer Design." You and your group will complete this Student Sheet as an evaluation of the other group's hand warmer.
10. Exchange completed Student Sheets with the other group of students after you finish your evaluation of each other's hand warmers.

11. Discuss which of your prototypes best met the design criteria within the given constraints. As a larger group, determine if a better design could be made from combining parts of the prototypes.

ANALYSIS

1. How did you modify your hand warmer design to allow you to control when the reaction started? Why did you make this design choice?
2. Based on the testing of your hand warmer and seeing your classmates' designs, how might you further modify your design?
3. Draw a labeled diagram of your final hand warmer design. Be sure to label all of the materials, the quantities of each, and their sizes. Use your diagram to explain
   - the design criteria and constraints.
   - the chemical process used to solve the problem.
   - the movement of thermal energy when your hand warmer is activated.
   - how and why your design changed throughout the engineering design process.
   - how your design choices helped you meet the criteria and constraints.
4. **Reflection**: For what purpose might you design a product that uses an endothermic reaction?

Name_____ Date_____

STUDENT SHEET 10.1

HAND WARMER DESIGNS

1. Draw and label your preliminary designs.
2. Circle the design you and your group choose to build a prototype for and test.
3. Record your observations.

Design 1 Variable changed from the original design: Testing result(s):	Design 2 Variable changed from the original design: Testing result(s):
Design 3 Variable changed from the original design: Testing result(s):	Design 4 Variable changed from the original design: Testing result(s):

Name_____ Date_____

STUDENT SHEET 11.1

EVALUATION OF HAND WARMER DESIGN

Hand warmer engineers: _____

Criteria and constraints	Does the design meet the criterion or constraint?	Evidence for or against
Is contained within a sealable bag		
Uses an exothermic reaction containing iron		
Reaches and maintains a temperature of 35–45°C for at least 5 min		
Allows the user to activate the warmer		
Uses only the materials provided		
Uses no more than 15 cc iron filings and 15 cc calcium chloride		