Design Thinking Year 2: *The Solve*

Educator's Resource Guide

Prerequisite Lesson: Design Thinking

This is a follow-up lesson to the original from year 1. The topic of Design Thinking is important to review each year, as it sets a solid foundation for scientific thinking throughout the year. If your students have not yet done the original year 1 lesson, begin with that lesson instead.

Note: Any blue text that is not a link is meant to only be read by the educator. Do not read these answers outloud to the students, as they should come to these conclusions on their own.

Objective

In *The Solve*, students will:

1. Observe a phenomenon on the Marco Polo ship, one of the largest vessels to ever dock on the East Coast.
2. Construct a ship capable of floating the greatest amount of "cargo containers" without sinking.
3. Compare ship designs to determine the level of success or failure of the solutions.
4. Reflect on the design process to determine what steps of the Design Thinking process were utilized during this design challenge.
5. Develop their own Design Thinking Reference Guide.

Activity Summary

The students will view a video about the Marco Polo ship to learn about the engineering technology involved in constructing large vessels. They will then create their own model ship and compare/contrast their ship's shape and construction against the ships other teams created. Through this analysis, they will develop and refresh their understanding of the criteria and constraints of Design Thinking.

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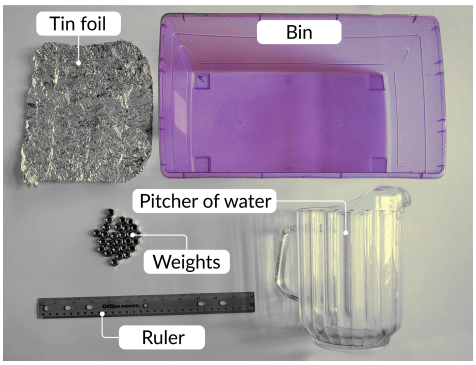
Lesson Prep

Time Required
90-100 minutes
Materials Required
● Ship materials per group or per individual if doing remotely: ○ Aluminum foil: One 15 cm x 15 cm sheet ○ A ruler ○ A sink, tub, bucket, large bowl or dishpan *Note: Recommended tub size is roughly 14'L x 8'W x 4.5'H. Plastic tubs can be issued per student team for ship testing.* ○ Tap water to fill the tub ○ 50 weights per ship to represent cargo containers (suggested weights include washers, bolts, marbles, or pennies) ○ Balance (optional) ○ Paper towels or rags for clean-up ● Appendix: Float Your Ship Class Data Chart *If the students have participated in the Float Your Ship Challenge before, introduce alternative materials for the ship, such as clay and Crayola Model Magic.*
Safety Considerations
None
Science & Engineering Practices
● Asking Questions and Defining Problems ● Developing and Using Models ● Designing Solutions ● Constructing Explanations or Arguments From Evidence



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Inquiry Scale: Leveling Information for In-class Use

Level 1: Teacher-driven

Conduct the Float Your Ship Challenge as a class activity, with the students grouped into teams of 3-4. As a class, ideate/brainstorm possible ship designs. Lead a student brainstorm and document class ideas on a poster or whiteboard, providing support as needed. Assign the student design teams to each of the class ideas. Once the teams start building their prototypes, provide necessary support and guidance when questions or concerns arise. Test each of the designs as a class, and have the students record the results in their student guide. As a class, discuss the possible ways in which the ships can be refined/redesigned. As a class, complete design retesting and record the data together.

Level 2: Student-driven

Conduct the Float Your Ship Challenge as a class activity, with the students grouped into teams of 3-4. The students ideate/brainstorm possible ship designs in their design teams. Provide time for the students to create/build their ships. Test each of the designs as a class and direct students to record results in their Student Guide data table. Instruct individual design teams to discuss possible ways the ships can be refined/redesigned. Provide time for the design teams to redesign and retest. Complete design retesting and record whole-class data as a class.

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Agenda

I. Video Clip of Phenomenon (5-10 minutes)

Differentiation Tip: The video can be viewed as a class, in small groups, or individually.

1. Play the video clip of the phenomenon. As the students watch, instruct them to record their initial observations, reactions, thoughts, and questions in their student guide.

2. Play the video again, and have the students answer the Predict questions in their Student Guide. Then review the answers as a class.

Predict Questions
1. How do you think it is possible for a ship to float while holding so much weight? *Answers may vary.* *Possible answers may include: The ship was made of a special material; the ship was designed specifically for this task and the engineers went through a lot of testing.* 2. What challenges might engineers face when constructing a ship as long as the Empire State Building? *Answers may vary.* *Possible answers may include: The weight of the cargo ships, navigating through narrow passages, the cost of the materials, getting enough materials.*

II. *The Make* Activity: Float Your Ship Challenge (40 minutes)

Instructions for remote use are located in Appendix A.
The following instructions are for in-person use.

1. Have the students read the Think Like an Engineer section in their student guides, or select students to read aloud.

2. Introduce the Strongest Ship Challenge:
    a. Today you will construct a ship capable of holding the most cargo containers. You will have 15 minutes to create and test your ship by placing the objects that represent the cargo containers onto your ship. You will present your final results to the class. If your ship has successfully floated all available cargo initially issued to you, your team will conduct a test in front of the class to determine the maximum cargo threshold of your ship before sinking.

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Prepare

3. Select which set of materials students will be using for this activity and provide a set for each group. 50 items representing "cargo weights" are suggested for individual team testing. Be sure that the type and number of "cargo weights" is the same for each team to promote fair testing.

4. Review the challenge with students in the Think Like an Engineer section of their student guide.

Test

5. Set the timer for 15 minutes. You can use an online timer.

6. Wish the design teams good luck and say *"let the design challenge begin!"* When the class is ready to begin, start the timer.

7. Move from group to group noting the different techniques that are being used to construct the ship. *For example, some students will want to brainstorm and sketch designs while other groups will want to immediately begin constructing.*
    a. As you walk around the room to observe the models, prompt any students who seem stuck to consider other alternative designs. *For example, if the original design is not working, have the students stop and think about ways they could modify and improve their original design.*

8. Alert the students when only five minutes remain so that they can finalize their models. Continue walking around, listening to their conversations, and observing when they may be making connections to the Design Thinking process. If a group asks a question, try to ask a question in return to get the students actively thinking. *Examples: Why do you think the ship is sinking? What adjustments could you make to improve the integrity of the structure? What specifically in the structural design was not working?*

9. When the 15 minutes is over, instruct the class to stop working and remove any cargo containers that might be in their ship. Then, collect the cargo containers from each group.

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Analyze

10. In their student guide, have the students draw their final ship design and record the final number of cargo containers that their ship can hold without sinking to the bottom.

    Example answers to the questions posed in the Student Guide are below.

Final Ship Drawing or Photo	**Observations**
Answers will vary. *Example structure may look like the example below.* 	1. Does your ship successfully support cargo containers without touching the bottom? *Student answers will vary based upon ship design.* 2. What observations and details did you notice when the cargo containers were placed on your ship? *Student answers will vary based upon ship design.* 3. What is the final number of cargo containers your ship could hold without sinking to the bottom? *63 pennies/cargo containers*

11. Line up all of the ships at the front of the classroom. At this point, none of the ships should have cargo containers on them. One by one, test each ship by adding the maximum number of cargo containers the ship can hold without sinking. On the board in front of the classroom, record the ship's name and data from testing.
    a. Student ships will be tested at this point for their ultimate cargo threshold. Therefore, the amount of "cargo containers" may surpass the initial cargo threshold determined during the 15 minute challenge interval if it could hold the maximum number of weights previously available.
    b. Encourage the students to make observations: Can the ship successfully support the mass of the cargo containers without taking in water or sinking?
    c. Repeat this process with all of the ships until all designs have been tested.
    d. *As an optional extension, use the Strongest Ship Class Data Chart (Appendix B) to track class data.*

12. Allow the students to analyze the successes and failures of the competing designs. Encourage a class discussion on effective design techniques by allowing the teams to share the design strategies and processes they used to succeed in the challenge. Then, use the data to determine which ship has won the challenge.

Reflect

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13. Direct the students to answer the Reflect questions in their student guide.

Reflect Questions
1. How did your team's ship compare with other ships in the classroom? *Tip: Compare ship shape, length, size, height of the sides of the ship, and hull design (flat vs. v-shaped).* *Answers will vary based on the final product designs.* 2. Study the ship that held the most cargo containers without sinking to the bottom. Describe the characteristics that made this design successful. *Answers will vary based on the comparison of the final product designs. The most successful designs incorporate a flat, raft-like or v-shaped configuration for stability.* 3. What were some of the obstacles that you/your group faced in this Ship Design Challenge? *Answers will vary based on the final product designs and the analysis of challenges the students faced.* *Possible Answer: Several team members had different ideas and it was difficult to decide which would be best.* 4. When designing a prototype, why is it important to have access to all materials/variables that relate to the identified problem? *It is important to have access to all materials/variables so that you can best replicate the real-world product by making the most accurate prototype and exposing that prototype to the conditions that the real product would be exposed to.* 5. If given the opportunity to repeat this challenge, what would you do differently to create a better ship? *Answers will vary based on the comparison of final product designs and the analysis of challenges the students faced.* *Possible Answer: Ensure the ship has a larger base.*

III. Create a Reference Guide (40 minutes)

1. Direct the students to reflect on their ship challenge, and encourage them to think about what their group did for each of the following steps:
    a. Understand the Problem
    b. Ideate/Brainstorm
    c. Prototype
    d. Test
    e. Refine/Repeat

2. Instruct the students to follow the instructions in their student guide to fill in their Design Thinking Reference Guide with the actions their group took for each step. If they did not

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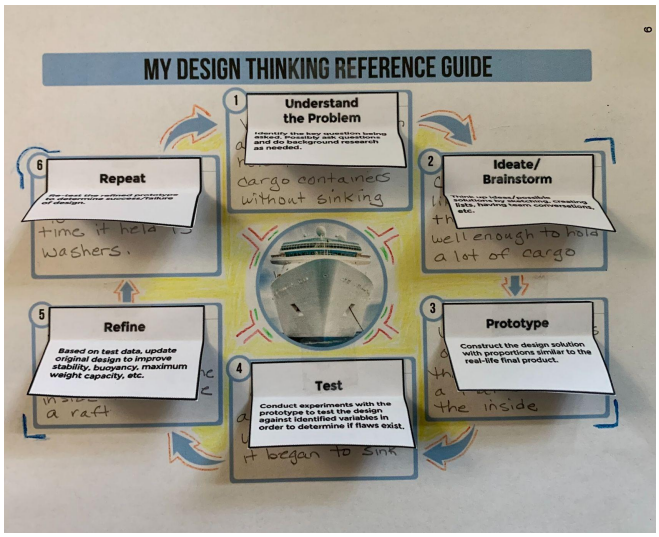
complete a step, encourage them to think about what they could have done. Check their work before they move on. If doing this remotely or online, the students will create a digital reference guide.

3. Walk around the room to monitor student progress and provide support and guidance as needed.
    a. Direct the students to draw connections between what they did and what they observed in the video. The students should fill in the Design Thinking Reference Guide in their Student Guide with the actions their group took for each step. If they did not do a step, encourage them to think about what they could have done. Check their work before they move on.
    b. The students will cut out the Design Thinking Vocabulary Cards and tape them on top of the corresponding boxes on their Design Thinking Reference Guide (they should be able to lift the flap to see their reflections on the Reference Guide).



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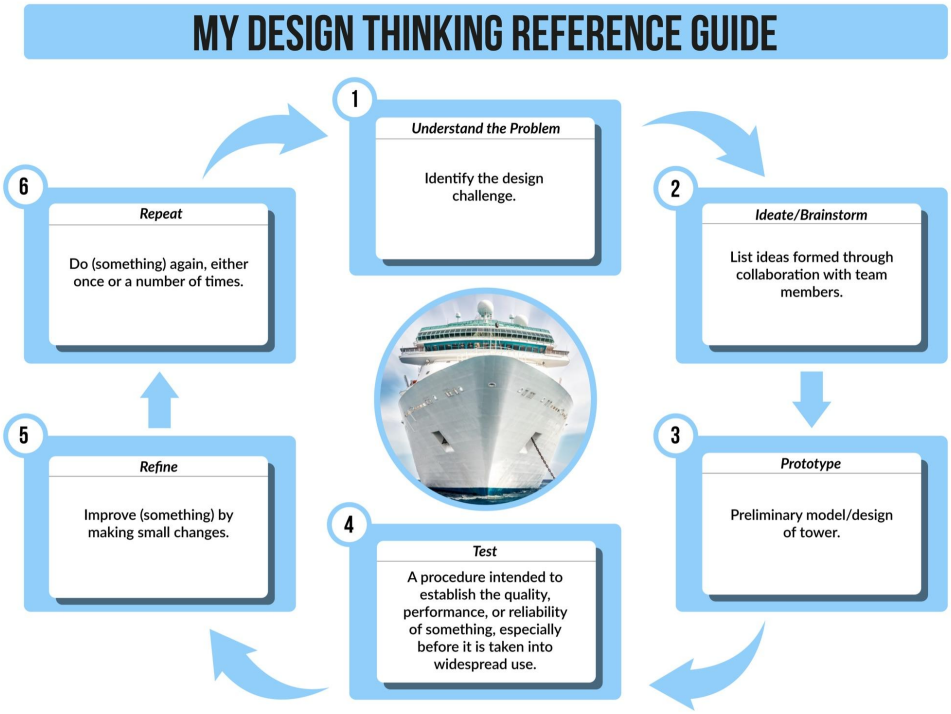
Design Thinking Reference Guide Example (Student Reflections)



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Name: _____ **Date: _____**

IV. Exit Ticket (5-10 minutes)

This quiz can be done in groups, pairs, individually, or more formally as an online quiz.

1. In order to brainstorm design solutions, one must be able to:
    a. Refine the design
    b. Retest the design
    c. Understand the problem needing to be solved
    d. Create a prototype

2. A prototype should be constructed:
    a. In order to test a model of the design solution
    b. With model proportions that are the exact same size as they are in real life
    c. Using precise details and color
    d. Answers a. and b.

3. True or false: If a prototype fails in a test run, the design should be refined and retested.
    a. True
    b. False

4. Thinking up ideas and sketching them out on a piece of paper would be part of what process?
    a. Identifying the problem
    b. Brainstorming
    c. Testing a design
    d. Collecting data

5. Which of the following would be an example of refining a ship design?
    a. Creating a proportional model of a ship
    b. Testing a model ship in a pool of water
    c. Adding a flat bottom and pontoons to an existing model ship to increase stability and buoyancy
    d. Floating a model ship in a pool of water with a fan blowing to provide wind current

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Appendix A: Directions for Remote Implementation

The ship building challenge can be completed during a virtual meeting. The activity can also be done asynchronously.

1. If students are doing this activity remotely, they will gather the suggested materials listed in their student guide and place them in a specific area of their room with enough room to complete the activity. Then they'll set their timer for 15 minutes.

2. The students are reminded in their student guides that there may be instances when they seem stuck or begin to feel frustrated. This is common when designing a solution to a problem, and they are encouraged to document the problem and think about other potential solutions. *For example, if the original design is not working, have the students stop and think about ways they could modify and improve their original design.*

3. When their 15 minutes is up, the students will stop working and remove the cargo containers from the ship.

4. The students will draw or photograph their final ship design. They will then record the final number of cargo containers that their ship was able to hold without sinking to the bottom.

5. The students will present their designs through a virtual class meeting time. During the meeting, they will:
    a. Report the final number of cargo containers that their ship was able to hold without sinking to the bottom
    b. Test their ship for the class by first emptying all containers from their boat, then adding them back on to see whether the ship floats.
    c. Share their design strategies and reflections on the building process. *What was difficult? What did you change about the ship?*

    Note: If sharing during a virtual meeting is not an option for your class setup, the students can submit their work digitally. You'll then arrange all of the submitted photos into a shared document (such as a Google Doc). Share this document with the class so they can analyze the designs.

    As an optional extension, the students can use the Class Data Chart (Appendix B) to track class data.

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Appendix B: Strongest Ship Class Data Chart

	Prototype – Test 1		**Refined Prototype – Test 2**		**Prototype Analysis**
Team Name	*Max # Containers*	*Total Container Mass*	*Max # Containers*	*Total Container Mass*	*Did the total mass held by the ship increase after the design was refined?*

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