Teaching through Trade Books

Activities inspired by children's literature

Design Dilemmas

By Christine Anne Royce

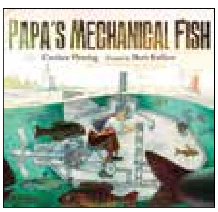
Through two different stories, students are introduced to the process—including the frustrations—of designing something to solve a problem. The experiences of the books' characters are brought into the classroom by having students engage in an engineering and design process. The activities support the development of these practices and assist students in acquiring and applying scientific knowledge.

This Month's Trade Books

The Most Magnificent Thing
By Ashley Spires
ISBN: 978-1-55453-704-4
Kids Can Press
32 pages
Grades preK–2

Synopsis

The young girl in the story demonstrates that making the perfect thing can be challenging. Even though the reader does not know what the perfect thing is until the end of the book, the girl demonstrates the trial, error, perseverance, and adaptation aspects of the design process.



Papa's Mechanical Fish
By Candace Fleming
Illustrated by Boris Kulikov
ISBN: 978-0-374-39908-5
Farrar, Straus, and Giroux
40 pages
Grades 2–4

Synopsis

This is a fictional story based on true events and highlights the life of inventor Lodner Phillips. Papa (the story is told from the perspective of his daughter) tinkers and tries to develop a variety of things but is rarely successful. Finally, he designs a mechanical fish—a submarine that takes friends and family beneath Lake Michigan.

Curricular Connections

Younger students are introduced "to 'problems' as situations that people want to change" (NGSS Lead States 2013, Appendix I, p. 105). They "[a]sk questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool" (performance expectation ETS1-1, NGSS Lead States 2013, p. 23). However, "before beginning to design a solution, [students do need to clearly] understand the problem" (disciplinary core idea ETS1-A, NGSS Lead States 2013, p. 23) and are not expected to come up with original solutions necessarily. The "[e]mphasis is on thinking through the needs of goals that need to be met, and which solutions best meet those needs and goals" (NGSS Lead States, 2013, Appendix I, p. 105). One key thing to note is that the engineering and design process is not simply allowing young students to freely build; there needs to be a definite problem that they are working to solve.

At the upper elementary grades, engineering design "engages students in more formalized problem solving … that define[s] a problem using criteria for success and constraints or limits of possible solutions" (NGSS Lead States 2013, Appendix I, p. 105). In the design challenge, students are realizing that "[p]ossible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria)" (disciplinary core idea ETS1-A, NGSS Lead States 2013, p. 53).

Because this process is most likely new to students, keep in mind that improvement of and reflection on solutions (even if the solution does not yield a positive outcome) does meet the standard and helps students in their learning progressions. ■

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Grades K–2: Magnificent Things Solve Problems

Purpose

Students will solve a problem through the design and engineering process.

Engage

Share with students either a picture of a snow shovel and a digging shovel or actual shovels and identify each for them. Ask them to brainstorm why these two shovels look different and when they would use each. Ask them to continue to brainstorm why the shape of each shovel helps to solve the problem of either digging a hole or removing snow. A question to have the students consider at this point is "Do different things with different designs help to solve different problems?" After students have had an opportunity to discuss this idea, open to page 30 of *The Most Magnificent Thing* and show only that page with the statement bubbles to the students. On this page, people are looking at a variety of different things that the young girl has made and identifying what each can do. Ask students what they think is happening in this picture and allow them to elaborate on what they see. Follow up their answers with questions that help them understand that different things help to solve different problems people have in everyday life (CC ELA: Reading Standards for Informational Texts K–5 – Integration of Knowledge and Ideas). Return to the beginning of this book and read the entire book to the students, stopping at points to ask the following questions:

- What are some of the steps the girl goes through in designing her magnificent thing? (knowing what she wants, sketching it, making it, changing it, using it)
- Why do you think she almost gave up in making the most magnificent thing? What did she do to calm down? (She was mad that it wasn't working out, she stepped away, and she took a walk)
- On page 30, why were the things exactly what the people wanted in the picture? (The things helped to solve a problem they had.)
- What problem do you think the girl is trying to solve? (She's trying to design a sidecar for her dog to attach to her scooter. This is shown on the last page of the book.)

Materials

The Most Magnificent Thing, pictures of a digging shovel and a snow shovel or actual shovels, student data sheet (see NSTA Connection), matchbox car, toy pickup or dump truck, marbles or tennis balls, pieces of wood to serve as a ramp, various types of paper (different weights and lengths) to construct the bridge, 2×4 pieces of wood to serve as the foundation pillars of the bridge, straws or craft sticks, masking tape, foil, plastic wrap, other materials that could be used to build an object to contain the marbles or tennis balls, and safety glasses.

Explore

Return to the idea of the shovels and discuss the idea that sometimes people have a problem they need to solve and may need to design or create something to solve that problem. Present one of the following problems to the students:

- Move a car from one point to another with the points being spread approximately 20 cm apart. The solution will result in different types of bridges being constructed by students.
- Keep tennis balls or marbles from falling out of a toy vehicle that must go up a ramp and then down the ramp.

At this point, the teacher should make a choice between which problem task will be presented to all students during the Explore stage. They will do the second problem during the Elaborate stage. Ask students to work in

groups of three or four students to develop a solution to the problem presented by the teacher. Younger students may need classroom aides to help facilitate the process through questions/suggestions. Once a problem has been identified, ask students to discuss where in the real world they may see a similar problem and how it has been solved there. Have them examine the different materials they have to solve the problem and sketch out on their student data sheet what their solution will look like (CC ELA: Writing Standards K–5 – Text Types and Purposes). Have them build their design and then test it, note if it worked or failed, and add any other observations they noted. Ask the students to return to their groups and discuss how they could improve their design. Students will repeat the process of sketching/explaining the design changes on the student data sheet and testing their new design. Depending on the age level, students may want to revise once or twice after the initial trial.

Explain

After the trial and revision process, ask each group to reconstruct their best solution and identify why they selected it. Have each group present their best solution to the class and demonstrate their solutions to the problem as well as explain to the class what makes this solution their best choice (CC ELA: Speaking and Listening Standards K–5 – Presentation of Knowledge and Ideas). After all groups have shared their solution, bring the class together to discuss the different best solutions. How are they similar? Different? Can part of one idea be combined with part of another idea? Why would this improve the design? Return to the story and ask the students to explain how the young girl changed her design over several of the trials (see last page of the book). Compare their process of solving a problem to hers.

Elaborate

Now that the students have had an opportunity to try an engineering problem and go through the process, give them a second problem. Ask them to repeat their experiences of discussion, questioning, observations, sketching a potential solution, testing that solution, and adjusting the design with the second problem. Younger students may need more adult guidance than older students. Being creative and fluid in their thinking will take practice and providing different opportunities will help students develop thinking skills in this area.

Evaluate

In addition to being able to see the progression of the designs to solve the problem from the illustrations on the student data sheets, the teacher can follow up on what the students were thinking and feeling as they went through the process as some students may feel the frustration similar to the young girl in the story. It is important that students discuss why they were feeling this way and be reassured that sometimes finding the solution to a problem takes time. It is important that they feel comfortable returning to similar situations in the future. Ask the students to either write or illustrate one way they are similar to the young girl in the story on the back of their student data sheet.

Grades 3–5: STEM's Own Amazing Race

Purpose

Students will participate in a design challenge that requires them to construct a boat that can cross a distance of water the quickest.

Materials

Papa's Mechanical Fish, chart paper, markers, student data sheet (see NSTA Connection), safety goggles, stopwatch, straws, 4 marbles per group, large plastic "under the bed" bin, pictures of different sail boats, foil, white paper, newsprint paper, tissue paper, craft sticks, skewers, paper cups, and other building materials that are available.

Engage

Show the cover art of *Papa's Mechanical Fish* to the class and ask them to make predictions about what the story might be about. Once students have developed the idea of an underwater boat or submarine, ask them to consider why someone might want to travel in a submarine. Share the book with the students, making sure to stop at the individual two-page spreads and discuss not only the words but also the information conveyed in the illustrations (CC ELA: Reading Standards for Informational Texts K–5 – Integration of Knowledge and Ideas). Questions that can be asked throughout the book to help generate connections to the story include:

- Have you ever invented something that worked or didn't work like the Papa in the story?
- Why does the Papa want to build a mechanical fish or in other words, what problem is he trying to solve? (He has wondered what it would be like to be a fish.)
- Why did Papa change his design several times? Using the sketches provided in the story, discuss some of the changes that were made? Explain why each change or modification was made.

For the last question, create a T-chart on the board or chart paper that identifies the change made and the reason why the change was needed. Helping students consider the answer to these questions also starts to set up an understanding of the need to approach engineering design in a more formalized process. It should be noted that similar to the problem presented in this story, not all problems are the same for each person. Different students may see different problems for different situations.

Explore

Explain to them that they will be putting on Papa's hat so to say but the problem they are presented with is building a boat that travels across a distance of water the fastest with the criteria and constraints presented in the problem card (Figure 1).

The method by which the boat will be propelled will be wind, which will be created by one team member blowing through a straw while remaining at the starting point (departing shore of the channel). Materials to build the boat can truly be anything, but paper construction is the easiest. After looking at pictures of boats, particularly sailboats, have students begin to design their boats. Ask the students (in teams of four) to first think about how they would design the boat and sketch it out on their student data sheet (CC ELA: Writing Standards K–5 – Text Types and Purposes). After each has had a chance to consider what they personally would do, ask them to share

FIGURE 1.

STEM's Own Amazing Race

Problem: You and your teammates are participating in a treasure hunt and stranded on one side of a channel but must make it to the other side in order to continue the treasure hunt. You are competing against other teams in a way that is similar to the Amazing Race. There are four people, including yourself, on your team which will be represented by marbles. You have at your disposal building materials provided to construct a boat that will take you and your teammates all at once across the channel.

Criteria: Design a boat that will carry you and your teammates (a total of four marbles) across the channel in the fastest amount of time. The boat must float. Only the materials provided can be used in the construction of the boat.

Constraints: Boats can only be propelled with wind which will be generated by one person blowing through a straw and remaining on the shore of the channel from which you depart. Boats must be no larger than 6-in. (15 cm) × 6-in. (15 cm). There is no constraint for height.

their designs with the team and collaborate on which parts of the boat design they want to include and the reason why in the overall team design. Before actually building the boat, students should have discussed several possible design solutions and the positives and negatives they see with each design feature. They should agree on one design that is a combination of the best parts from each individual design and sketch that on their student data sheet and label what each part of the boat is intended to do. As they are designing the boat, circulate around the room asking them why they are selecting a certain design or material for that; what do they think a particular part of the design will do; and other questions that relate to the criteria of the problem design as well as the constraints of the problem (CC ELA: Vocabulary Acquisition and Use). Allow the students to design their boats.

Students should then be allowed to test their initial design without penalty. While an unsuccessful attempt would penalize the team in a real race, the design process involves generating and testing solutions so that students learn to optimize the best possible design. An ideal situation would be to allow one initial design and two revisions to the design. Each revision would require students noting on their student data sheet what they changed on their design and the reason why. Students are encouraged to only change one aspect at a time to determine what results it produces.

Explain

Let the race begin! After students have tested and revised their designs, let each team present their boat design to the class and explain the following points (CC ELA: Speaking and Listening Standards K–5 – Presentation of Knowledge and Ideas):

- The features on the boat and what benefit they bring to the design.
- What changes they made to their initial design and why. Students can use their sketches to help explain the changes as well as any prototypes.
- Any challenges they still have with the design.

Once each group has presented their design to the class, allow them to engage in the race by identifying which student will be responsible for creating the wind by blowing through a straw. Have that student stand at the narrow edge of a shallow plastic storage container (40 in. × 20. in × 6 in.) which has been filled two-thirds with water. When the boat is placed in the water, they should bend over and blow through the straw only to create wind to move the boat forward. They are not allowed to move to a different edge of the bin. The teacher should serve as the official time keeper and starter for each team trial. Times should be recorded on a piece of chart paper. Once a boat sinks, tips over and cannot go any further, or reaches the other side, the time should stop and the attempt should be labeled as successful or unsuccessful. The fastest time for a successful run would win the race and make it to the treasure. Each group should be making notes about what design features they thought worked best from other teams. Have students identify what design features created positive aspects in the design and how they would incorporate those features into their design on a different trial.

Elaborate

Now that the students have had a chance to practice the design and revision process, have them become evaluators of someone else's design by asking them to watch a video on middle school cardboard boat races (see Internet Resource). Play the video, allowing the students to see all of the different boat races, then go back and play it through again, stopping to discuss each boat. Ask students what worked in that design and what they would change if they were the boat designers. Why do they think a design was successful or unsuccessful?

Evaluate

Through their designs and sketches, explanations throughout the process, and presentation to the class, the teacher should be able to determine if students understand the ideas of design, criteria, constraints, testing, and revision, which is the main focus of this lesson and not necessarily accomplishing the problem task put before them (CC ELA: Vocabulary Acquisition and Use). A final evaluation measure would be asking the students to turn their student data sheet over and describe in a few sentences the similarities and differences between the experience Papa had in the story Papa's Mechanical Fish and their own experience in designing a boat for the challenge (CC ELA: Reading Standards for Informational Texts K–5 – Key Ideas and Details).

Internet Resource

Middle School Cardboard Boat Races
www.youtube.com/watch?v=MHyqAaFKWe8

Connecting to the *Next Generation Science Standards* (*NGSS* Lead States 2013):

K–2-ETS Engineering Design

www.nextgenscience.org/k-2ets-engineering-design

The materials/lessons/activities outlined in this article are just one step toward reaching the performance expectations listed below. Additional supporting materials/lessons/activities will be required.

Performance Expectations	**Connections to Classroom Activity**
K-2-ETS1-1 Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.	Students identify, ask questions about, and acknowledge a problem that is provided to them in the lesson.
K-2-ETS1-2 Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.	Throughout the design process, students sketch their solution to the problem and revise the sketch after testing their solution.
Science and Engineering Practices	
Asking Questions and Defining Problems Developing and Using Models	Students ask questions of each other and the teacher as they work on solving a problem and create two-dimensional sketches to serve as a model for their solution.
Disciplinary Core Ideas	
ETS1.A: Defining and Delimiting Engineering Problems	Students:
• A situation that people want to change or create can be approached as a problem to be solved through engineering.	• are presented with two different problems throughout the entire lesson that need to be solved.
• Asking questions, making observations, and gathering information are helpful in thinking about problems.	• ask questions of each other and the teacher as they work on solving a problem.
• Before beginning to design a solution, it is important to clearly understand the problem.	• verbalize the problem and what a successful outcome to the problem will be.
ETS1.B: Developing Possible Solutions • Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people.	• sketch their solution to the problem and revise the sketch after testing their physical models.
2-PS1.A: Structure and Properties of Matter • Different properties are suited to different purposes.	• select and test different building materials in the design of their solution.
Crosscutting Concept	
Structure and Function	By building bridges and moving objects up and down a ramp, students will participate in two tasks that help them understand that structure and function help in solving certain problems.

Connecting to the *Next Generation Science Standards* (*NGSS* Lead States 2013):

3-5-ETS Engineering Design

www.nextgenscience.org/3-5ets-engineering-design

Performance Expectations	Connections to Classroom Activity
3-5 ETS1-1 Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time or cost. 3-5 ETS 1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. 3-5 ETS 1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.	• Students are presented with and explain a design problem to include criteria and constraints. • By creating individual designs, comparing those designs with their teammates, and selecting the best options, students examine multiple solutions to an assigned problem. • Students construct and test their team prototype, make modifications to the model after discussion, and compete in a water race with their model.
Science and Engineering Practices	
Asking Questions and Defining Problems Planning and Carrying Out Investigations Constructing Explanations and Designing Solutions	Students: • ask questions of each other and the teacher as they work on solving a problem. • design, test, and modify their boat. • create two-dimensional sketches to serve as a model for their solution and explain their design to the class.
Disciplinary Core Ideas	
ETS1.A: Defining and Delimiting Engineering Problems • Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.	Students • understand the criteria for and constraints given to them for their Amazing Race Challenge. • compare their design with their teammates in order to select which features best meet the criteria for building a boat.
ETS1.B: Developing Possible Solutions • At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs.	• have ongoing discussions with their teammates and the teacher associated with their boat design and modifications to be made after testing.
ETS1.C: Optimizing the Design Solution • Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.	• consider different designs to solve the problem both during the design feature and during the evaluation of the video boat races.
3-PS2.A: Forces and Motion • Each force acts on one particular object and has both a strength and direction.	• identify that blowing through a straw creates a force that moves their boat across the bin of water.
Crosscutting Concept	
Influence of Engineering, Technology, and Science on Society and the Natural World • Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands.	Students describe their initial design and the changes they made to their boat prototype after testing it as well as why these changes were made.

Connecting to the *Common Core Standards* (NGAC and CCSSO 2010):

This section provides the *Common Core for English Language Arts and/or Mathematics* standards addressed in this column to allow for cross-curricular planning and integration. The Standards state that students should be able to do the following at grade level.

English/Language Arts

Reading Standards for Informational Texts K–5 – Integration of Knowledge and Ideas

- Grade 1: "use the illustrations and details in a text to describe its key ideas."
- Grade 3: "use information gained from illustrations and the words in a text to demonstrate understanding of the text."

Reading Standards for Informational Texts K–5 – Key Ideas and Details

- Grade 4: "refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text."

Language Standards

Writing Standards K–5 – Text Types and Purposes

- Grade K: "use a combination of drawing, dictating, and writing to compose informative/explanatory texts in which they name what they are writing about and supply some information about the topic."
- Grade 2: "write informative/explanatory texts in which they introduce a topic, use facts and definitions to develop points, and provide a concluding statement or section.
- Grade 4: "write informative/explanatory texts to examine a topic and convey ideas and information clearly."

Vocabulary Acquisition and Use is one of the standards for language. This particular standard is across grade levels. "Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on grade [appropriate] reading and content."

Speaking and Listening Standards K–5 — Presentation of Knowledge and Ideas

- Kindergarten: "add drawings or other visual displays to descriptions as desired to provide additional details."
- Grade 1: "add drawings or other visual displays to descriptions when appropriate to clarify ideas, thoughts, and feelings."

Furthermore, the Common Core for ELA provide a standard related to the Range of Text Types for K–5 where it indicates that students in K–5 should apply the Reading standards to a wide range of texts to include informational science books.

References

National Governors Association Center for Best Practices and Council of Chief State School Officers (NGAC and CCSSO). 2010. *Common Core State Standards.* Washington, DC: NGAC and CCSSO.

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press. *www.nextgenscience.org/next-generation-science-standards.*

Resources

Beaty, A. 2007. Iggy Peck, architect. New York: Abrams Books for Young Readers.

Beaty, A. 2013. Rosie Revere, engineer. New York: Abrams Books for Young Readers.

Belloni, G. 2011. Anything is possible. Berkeley, CA: Owl Kids.

Novak, B.J. 2014. The book with no pictures. New York: Dial Books for Young Readers.

Van Dusen, C. 2005. If I built a car. New York: Puffin Books.

Yamada, K. 2013. What do you do with an idea? Seattle, WA: Compendium.

Internet Resources

Making Matters! How the Maker Movement Is Transforming Education
www.weareteachers.com/blogs/post/2015/04/03/how-the-maker-movement-is-transforming-education

Middle School Cardboard Boat Race
www.youtube.com/watch?v=MHyqAaFKWe8

STEM Design Challenge: Edible Cars
www.teachingchannel.org/videos/engineering-design-process-stem-lesson

Why the Maker Movement Is Important to America's Future
http://time.com/104210/maker-faire-maker-movement/

NSTA Connection

Download the student data sheets and a list of additional resources at *www.nsta.org/SC1509*.