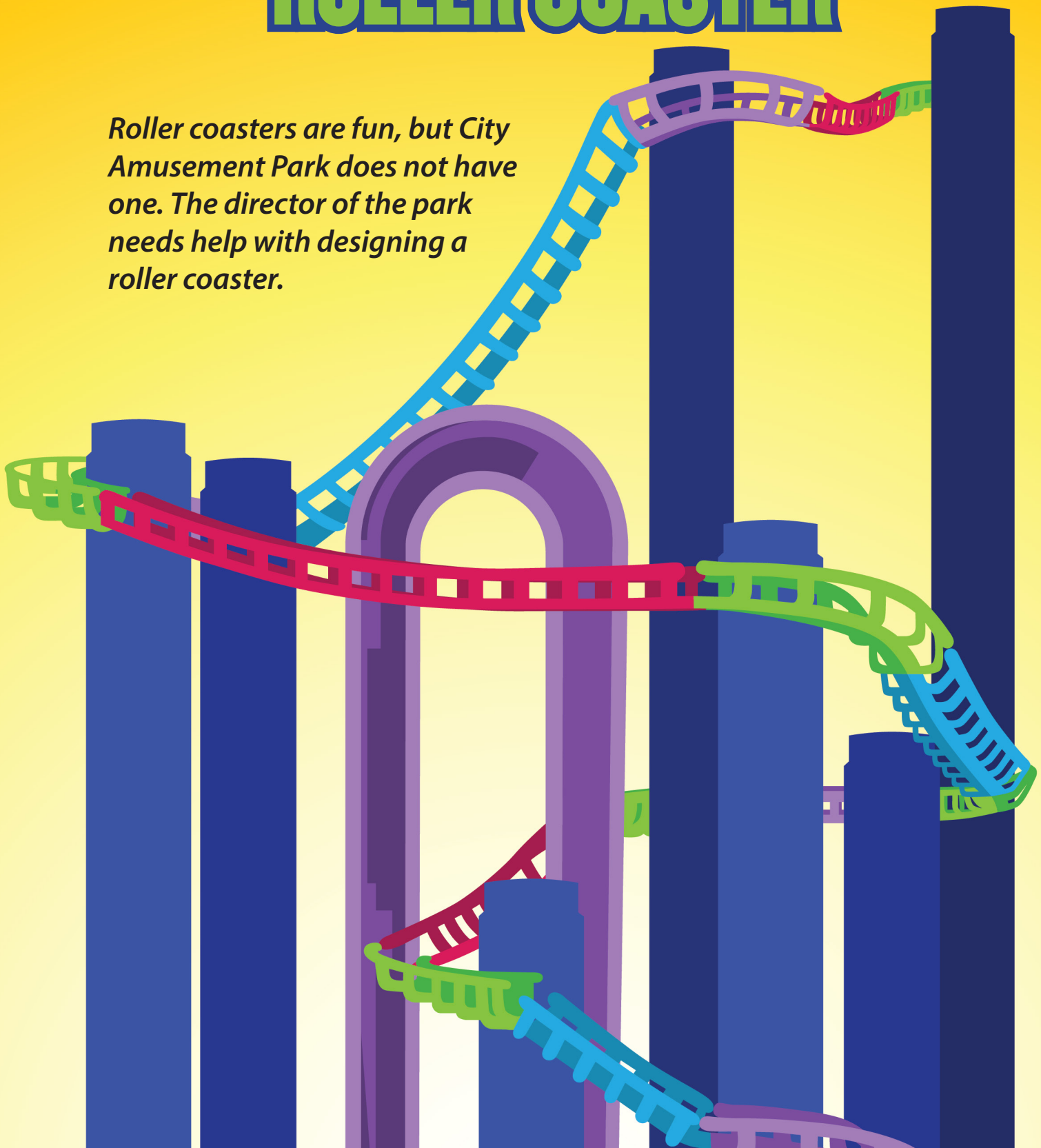
INSPIRE
Research Institute for Pre-College Engineering

PURDUE
UNIVERSITY

School of Engineering Education
COLLEGE OF ENGINEERING

DESIGN AN AMUSEMENT PARK ROLLER COASTER

Roller coasters are fun, but City Amusement Park does not have one. The director of the park needs help with designing a roller coaster.



About the Authors

Hoda Ehsan is a Ph.D. candidate in the School of Engineering Education at Purdue University. She received her B.S. in mechanical engineering in Iran and obtained her M.S. in Childhood Education from City College of New York. Hoda had also obtained a teaching certificate for elementary education from the state of New York. She is now a graduate research assistant for an NSF funded STEM+C project. Her research interests include investigating young children's engagement in engineering design in informal settings and ways to promote engineering thinking in all including neurodiverse children. She is also interested and involved in designing engineering learning resources to be used in informal environments.

Elizabeth Gajdzik, M.S.Ed. is the assistant director of the INSPIRE Research Institute for Pre-College Engineering in the School of Engineering Education at Purdue University. Gajdzik has co-authored or served as a major contributor to notable curriculum such as hand2mind's STEM in Action kits and the PictureSTEM curriculum. Prior to her work at INSPIRE, Gajdzik was a district curriculum mathematics specialist in San Antonio, Texas, and a middle school mathematics teacher at a Title I school in Waco, Texas. She received both her B.S. in interdisciplinary Studeies, with a specialization in mathematics education, and M.S.Ed. in Curriculum and Instruction, with an emphasis in mathematics education from Baylor University.

Acknowledgments

We would like to thank Audrey Moeller for her graphic design work as well as the numerouse families who participated in the testing of this resource.

About INSPIRE

The INSPIRE Research Institute for Pre-College Engineering is a center in the School of Engineering Education at Purdue University focused on pre-college engineering education research and integration of engineering with science, technology, mathematics, computational thinking and literacy. INSPIRE is composed of 15+ faculty, staff, and postdoctoral researchers and 40+ graduate and undergraduate research assistants on a mission to study pre-college engineering experiences and environments in order to impact educational systems. You can learn more about INSPIRE and its work at **engineering.purdue.edu/INSPIRE**.

EDUCATOR GUIDE

Activity Overview

In this engineering design activity, children will think like an engineer to design a roller coaster for an amusement park that does not have one. The activity begins with a letter from the client, Hannah Noah, the director of the amusement park. In the letter, she states the problem and asks "engineers" to solve it. Before beginning their designs, Hannah Noah requests that children complete a set of warm-up challenges to explore the materials they will use to construct a prototype, a testable model, of their roller coaster design. After children learn how the pieces work together, they will receive a second letter from the client that provides them with additional information to consider when designing their roller coaster for the amusement park. Children should think of multiple solutions to the problem, select a solution they would like to explore, construct a model, test it, make any necessary changes based on their observations, and then send back a message to the client describing their roller coaster design idea and why they think their idea is a good solution for the park..

Materials

- Engineering toy: Roller Coaster Challenge, Thinkfun, MSRP $29.99
- *The Most Magnificent Thing*, by Ashley Spires, Kids Can Press, MSRP $16.95
- Building material categories sheet (p. 11)
- Client letters (Letter 1 and 2) (p. 10, 17)
- Warm-up challenge 1-4 (p. 12-16)
- Criteria signage (p. 18)
- Optional: Markers/color pencils/crayons the same color as the pieces in the kit (red, blue, light blue, light green, fuchsia, yellow, orange, black)

Set Up

- Print out the following: Letter 1 and 2, building material categories page, Explore How the Materials Work! Challenges 1-4 (including the two prompts for challenges 3 and 4), and the design criteria signage.
- Cut the Explore How the Materials Work! Challenge pages in half.
- Use the Building Material Categories page to organize all the roller coaster building materials into eleven piles.

Learning Objectives

The learning objectives of this challenge includes increasing children's technological literacy by

1. Knowing engineering problems have multiple possible solutions.
2. Knowing that engineers' solutions can fail several times until they get the best solution
3. Knowing and applying engineering design process.
4. Employing creativity and spatial thinking to solve problems.
5. Employing troubleshooting and learning from failure.

EDUCATOR GUIDE

Engineering Design Process

Engineers use a process like the one below to solve problems and create inventions that help make the world around us better.

This engineering design process is created by Monica Cardella. It is a modified version of the Museum of Science, Boston's Engineering is Elementary design process. The modifications (addition of Learn and Test, and re-phrasing of Plan to Model It) allow for better alignment with NGSS and with empirical research (e.g. Atman et al. 2007 & Dorie, Cardella & Svarovsky 2014).

EDUCATOR GUIDE

The engineering design process is a series of actions that engineers follow to solve engineering problems. When children engage in engineering design on their own they may not follow the process in a particular order and may revisit steps a number of times. In addition, children do not inherently verbalize all of their thoughts and ideas so you may not easily recognize when they are completing a particular step. However, it is very helpful to teach children about the engineering design process and help them utilize it during an engineering problem.

ASK

Ask is when engineers try to define and frame an engineering design problem. Ask is often called Problem Definition by professionals.

Prompts/Questions to be asked:

- What is the problem?
- What are the constraints (limitation of available materials and resources)?
- What are the criteria (design considerations/features that make the solution successful)?
- Who will be impacted?
- What do they need?

LEARN

Learn, also called information gathering, is when engineers do research about the problem to gain more information. Learn is often called Information Gathering by professionals.

Prompts/Questions to be asked:

- What background knowledge is needed?
- How have other people solved the problem?

IMAGINE

Imagine is when engineers think of multiple solutions to the problem by considering what they know and have learned about the problem. Imagine is often called Generating Ideas by professionals.

Prompts/Questions to be asked:

- What are ways of solving the problem?
- Think of several solutions

MODEL IT

Modeling is when engineers create representations of their design. Modeling is often called Idea Representation by professionals.

Prompts/Questions to be asked:

- Draw a sketch or a diagram
- List materials you might use

CREATE

Create is when engineers build/create/tryout the solutions that they have modeled before. Create is often called Prototyping by professionals.

Prompts/Questions to be asked:

- Use your diagram & materials to create your prototype!
- Create more than one solution!

TEST

Test is when engineers plan and carry out fair tests to diagnose flaws in their solutions, and identify the elements of the solutions that need to be improved or optimized. Test also helps to determine the best solution to the problem. Test is often called Feasibility Analysis and Evolution by professionals.

Prompts/Questions to be asked:

- Plan a fair test
- Carry out a fair test
- Record your results

IMPROVE

Improve is when engineers generate new solutions or find way to make their solutions better. They may need to iterate engineering design process. Improve is often called Revising and Iteration by professionals (or practitioners or engineers).

Prompts/Questions to be asked:

- What could work better?
- Ask, Learn, Imagine, Model, Create and Test again!

COMMUNICATION

Communicating is an important part of the design process, and shared ideas can lead to improved designs.

EDUCATOR GUIDE

Notes for the educator

1. This is a group-based activity that adults (parents or educators) and children play together and it is designed with specific considerations for children with autism. We encourage adults to let the children lead the activity while they help facilitate the activity. To help ease this process, we defined roles that can be assigned to all players. The main roles are engineers and consultant. The child with autism will be assigned to "engineer" and the parent should be the "consultant". In case of having two children, the role of "builder" will be added, and children will switch roles at times. The description of the roles is as below:
   - **Engineer** leads the design activity and is the main player who solves the challenge. He/she generates ideas and plans for the design solution. The engineer is the one who explores materials of the kit and builds the planned design using the kit. This role should be assigned to the child with autism.
   - **Consultant** is the engineer's helper. He/she provides guidance when ideas are being generated, asks questions and facilitates the conversation to make the engineer make the best design decision, and helps with troubleshooting problems that arise without directly pointing to the problem. The consultant should provide emotional support for the engineer in case of failure or as needed. This role should be assigned to the parent/adult.
   - **Builder** is not a main role and will only be filed in cases where two children with or without autism are playing. The builder is the one who builds the design following the engineer's direction or using the planned ideas. We suggest that adults assign the role of Builder to the child without autism first and have the child with autism be the engineer as the activity is designed to help those on the spectrum. Children can then switch roles.
2. It is up to the group of players to decide who wants to read the challenge set (the child with autism, the child without autism or the adult).
3. For warm-up challenges number 3 and 4, we ask that adults use the **Least Prompt Strategy**. In this strategy, parents will use a prompt hierarchy ranging from least to most intrusive (written, partial visual, fully visual). Each prompt level should be accompanied with verbal prompting from parents. For example, the prompt first includes short written instructions that the adult (or children) need to read. If the child with the help of the adult is able to build the structure that is asked, the group moves on to the next challenge. If they are NOT able to build the structure, the adult will provide the next level of prompting which is a picture of the material needed (labeled Prompt 2). If the child still is not able to build the structure, a shape of the structure will be provided (labeled Prompt #3), so the child can build the structure he/she is asked.

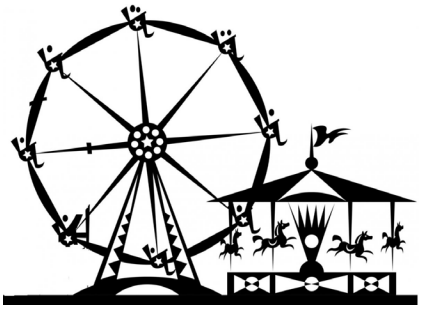
EDUCATOR GUIDE

Instructional Guide

1. Do a picture walk of *The Most Magnificent Thing* and then read it. Talk about what the main character learns in the story.
2. Read the first letter from the client.
3. Discuss the problem presented through the letter. If your child needs help discussing the problem, consider asking questions like: Who needs help? Why do they need help? Who will use the roller coaster? What does Hannah want you to do?
4. Introduce the building materials.
5. Complete Challenge 1.
    - Your child should locate each of the pieces provided in the list.
    - After this task is complete, have him/her return the building pieces back to their piles for future use.
6. Complete Challenge 2.
    - Your child should select the building pieces he/she sees in the photo and then put them together to create the exact roller coaster pictured.
    - He/She should use the coaster car to test the roller coaster.
    - Your child should count how many black posts the coaster car drops down.
7. Complete Challenge 3.
    - Allow your child to complete the challenge.
        - If your child <u>is</u> able to complete the challenge go to step 8.
        - If your child <u>is not</u> able to complete the challenge, use the Least Prompt Strategy. Read note 3 in the Notes for the Educator section on page 7 for details about how to use this strategy.
            - Prompt 1: The original problem with hints is considered Prompt 1.
            - Prompt 2: Show your child the provided image.
            - Prompt 3: Show your child the provided images.
    - For each roller coaster your child constructs, have him/her count how many black posts the coaster car drops down.
    - Encourage your child to share other observations as he/she tests the coaster car on each roller coaster and have him/her reflect on the challenge. Does he/she notice the car going faster or slower? When would it be good for a roller coaster to go fast? Slow?
8. Complete Challenge 4.
    - Allow your child to complete the challenge.
        - If your child <u>is</u> able to complete the challenge go to step 8.
        - If your child <u>is not</u> able to complete the challenge, use the Least Prompt Strategy. Read note 3 in the Notes for the Educator section on page 7 for details about how to use this strategy.
            - Prompt 1: The original problem with hints is considered Prompt 1.
            - Prompt 2: Show your child the provided image.
            - Prompt 3: Show your child the provided image.
    - Discuss what he/she learned about having the coaster car make a turn.
9. Have your child write a letter/email back to the director or record a video message reporting back the information she asked for in her letter. You may choose to just pretend to respond by going through the actions but not actually emailing anyone or videotaping your child.
10. This is an ideal spot to take a break to make the emails or letters feel more real.
11. Read the second letter.
12. Discuss the new information provided by the second letter. Consider asking your child: What features must the roller coaster have? How much space can the roller coaster take up? What are other features

that will make this a fun and exciting roller coaster? What building pieces can you use to add those features to the roller coaster?

13. Ask your child to share possible solutions he/she is thinking about.
14. Have your child select a solution and use the building pieces to construct a model.
15. Use the coaster car to test the model to see if it performs as expected. Allow multiple tests so your child can pinpoint areas that need improvement.
16. Have your child share what they observed during testing. Consider asking your child: What do you think went well? What do you think needs improvement? Why? How do you know? What are some possible solutions for fixing the problem areas?
17. Allow your child to make changes to the model and continue to test, discuss what they observe, and provide possible solutions.
18. When your child is happy with his/her design, have him/her share the roller coaster design idea with Hannah. This can again be done through a letter, email, or video message and can be expressed through words, pictures, or diagrams.
19. Optional: Print out and personalize the certifcate of completion on page 19.



City Amusement Park
123 Amusement Road
West Lafayette, IN 47906

Dear Engineers,

My name is Hannah Noah. I am the director of City Amusement Park.

Many kids visit the park. They enjoy the rides and games. One thing they do not like is that the park does not have a roller coaster. I want to add one to make them happy.

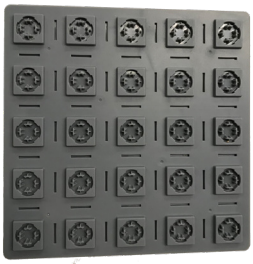
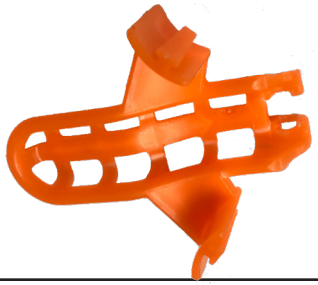
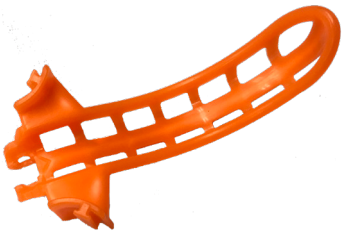
I need your help to design the roller coaster. I have sent a box of materials you should use to create a model of your design. Before you start designing, explore how the materials work and then send me a message about what you learned.

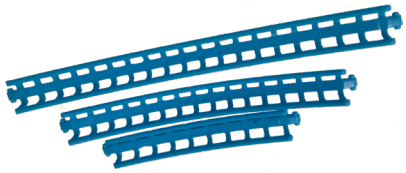
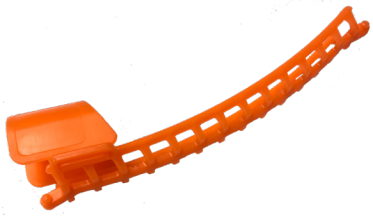
I look forward to hearing back from you soon!

Thank you,

Hannah Noah
Hannah Noah
Director of City Amusement Park

BUILDING MATERIAL CATEGORIES

Material Name	Image
gray base	
coaster car	
start track	
end track	
black post	
loop	

Material Name	Image
curved tracks	
tunnel	
blue slide tracks	
green slide tracks	
orange slide tracks	

EXPLORE HOW THE MATERIALS WORK!

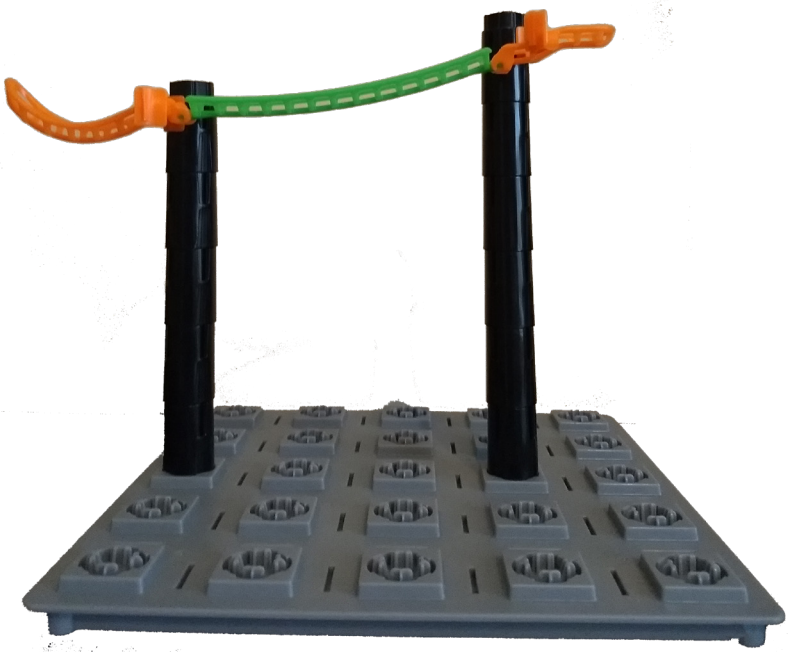
Challenge 1: Locate the materials listed below.

- 1 gray base
- 12 black posts
- 1 start track
- 1 end track
- 1 large blue slide track
- 1 orange slide track
- 1 small green slide track
- 1 medium green slide track
- 1 loop
- 1 coaster car

Return the materials back to their category piles.

EXPLORE HOW THE MATERIALS WORK!

Challenge 2: Build the roller coaster you see in the picture. Use the coaster car to test it!



How many black posts did the coaster car drop down?

EXPLORE HOW THE MATERIALS WORK!

Challenge 3: Build a steeper roller coaster than the previous roller coaster you made.
Hint: Try other slide tracks. Try a different number of black posts.

For each roller coaster you make, count how many black posts the coaster car drops down.

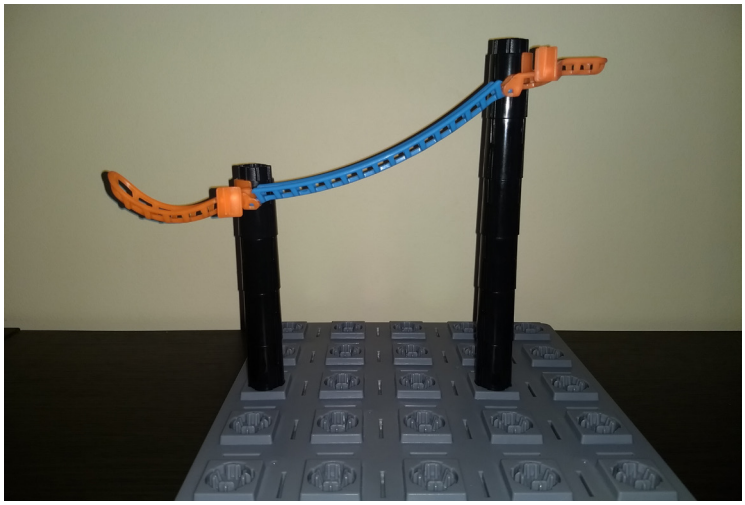
What do you notice about how the coaster car performs on the different roller coaster models?

EXPLORE HOW THE MATERIALS WORK!

Challenge 3: Prompt 2

EXPLORE HOW THE MATERIALS WORK!

Challenge 3: Prompt 3



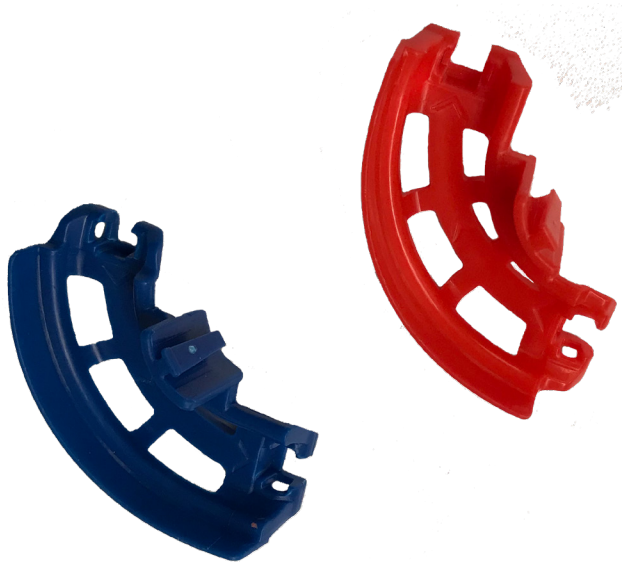
EXPLORE HOW THE MATERIALS WORK!

Challenge 4: Build a roller coaster that makes the coaster car complete a turn before it stops.
Hint: Use a curved track (red or black)

What did you learn has to be true in order for the coaster car to make a turn?

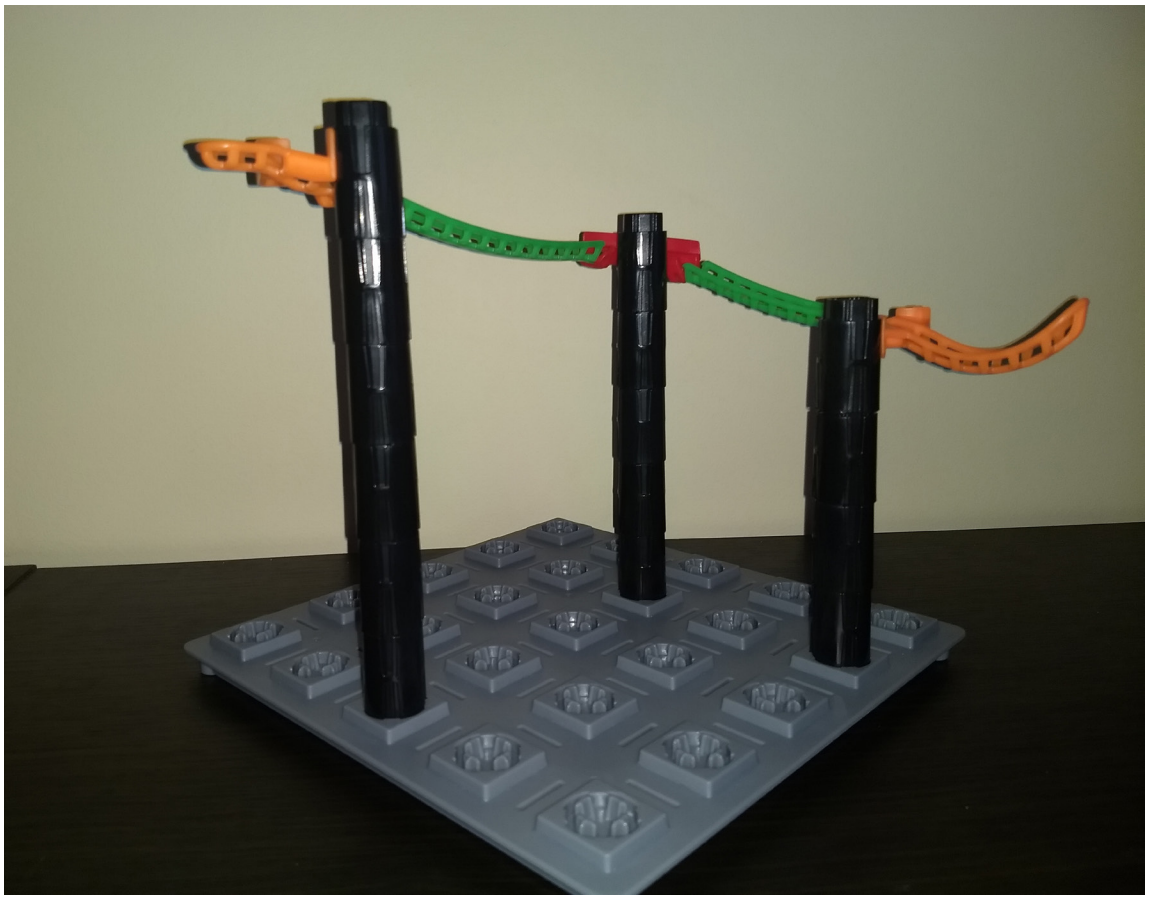
EXPLORE HOW THE MATERIALS WORK!

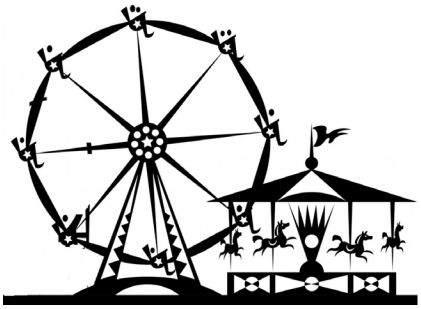
Challenge 4: Prompt 2



EXPLORE HOW THE MATERIALS WORK!

Challenge 4: Prompt 3





City Amusement Park

123 Amusement Road
West Lafayette, IN 47906

Dear Engineers,

Thank you for sharing what you learned about the materials and how they work. Please use what you learned to design a roller coaster for City Amusement Park.

The park has a limited space for the roller coaster to be built. The gray base I sent you represents the amount of land the park can use for the roller coaster. The black posts must be built on the gray base. All other roller coaster pieces may go beyond the gray base.

Remember, I want the roller coaster to be exciting for kids to ride. The roller coaster must:

- start very high and end low
- have a loop
- include at least one turn

What other features do you think would make the roller coaster thrilling and fun for riders? Use your ideas to construct a model of the roller coaster. Don't forget to test your design.

When you have your final design solution, please send me a message to inform me about it. You can describe, draw a picture, or send me a video of it. Finally, also include why you think your roller coaster design is a good solution.

Thank you again,

Hannah Noah

Hannah Noah
Director of City Amusement Park

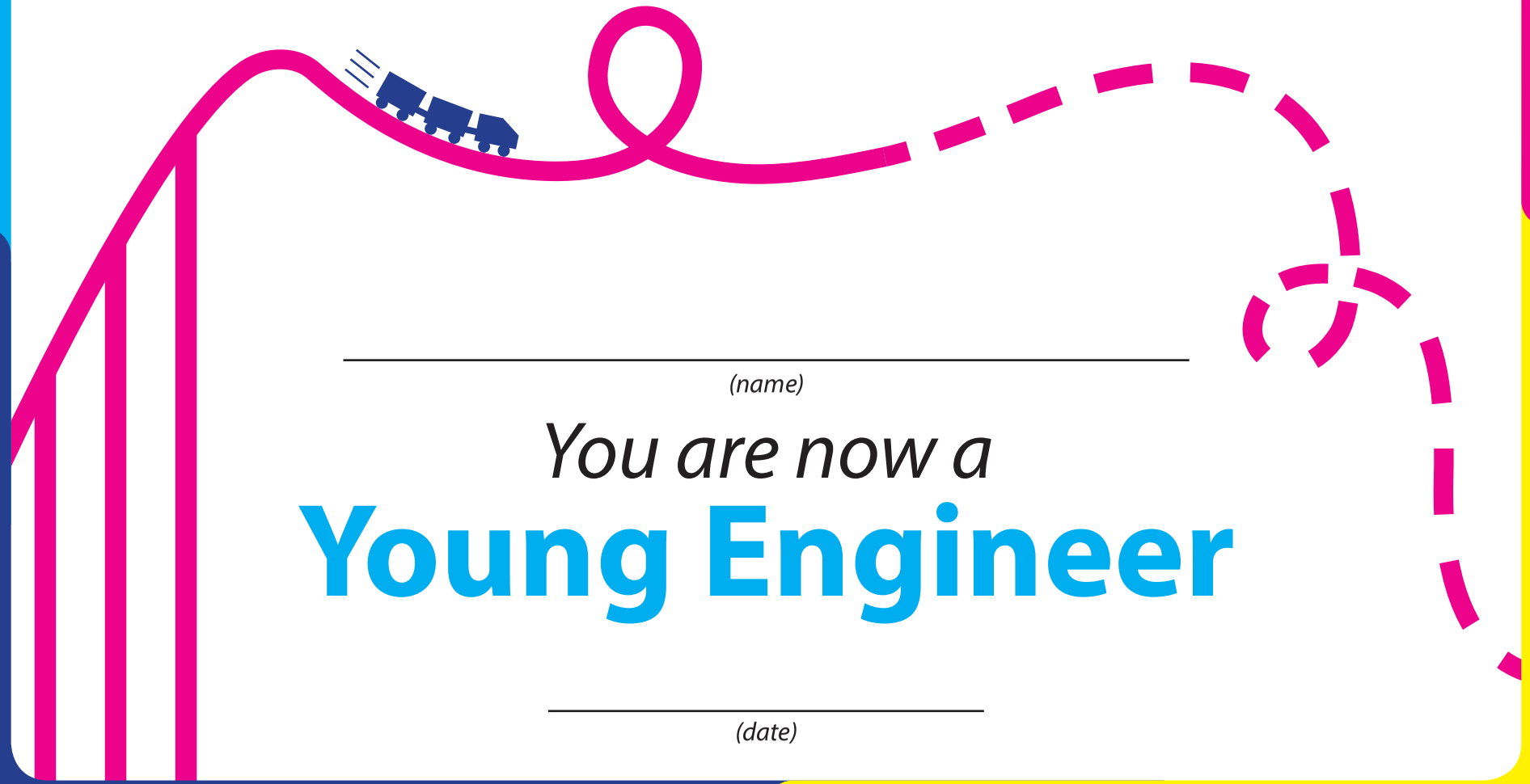
CRITERIA

A **very exciting** roller coaster:

- starts very **high** and ends **low**.
- has a **loop**.
- includes at least one **turn**.

What other features makes a roller coaster **exciting**?

CONGRATULATIONS



_____

(name)

You are now a

Young Engineer

_____

(date)