MACGILLIVRAY FREEMAN'S
DREAM BIG
ENGINEERING OUR WORLD

GRADE 3:

MAGLEV TRAIN

Grade level: 3

Lesson length: 85 minutes

Most forms of transportation rely on fuels that come from oil, called fossil fuels. This type of fuel can be expensive because it comes from a source that is not renewable (the less there is of it, the more precious it is, and the more expensive it becomes). Fossil fuels can threaten our environment because they must be extracted from the earth and they pollute our air.

Thus, engineers are working to make transportation systems more green. Students will learn about one method as they design a train that can move three feet without making physical contact with the track. Magnetism provides the force required to levitate the train over the tracks, reducing the energy required to move the train.

In the Film

Transportation in the modern world is becoming a challenge as the population continues to grow beyond the capacity of the highways that once allowed civilization to flourish and expand. Today's engineers are working on new innovations, like bullet trains and the futuristic Hyperloop, to move people and goods more quickly, more safely, and with less dependence on fossil fuels.

NGSS Disciplinary Core Ideas

3-ESS3-1 Crosscutting Concepts

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 (fossil fuel consumption), and meet societal demands (greater mass transit).

NGSS Engineering Practices

3-PS2-3 Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.

3-PS2.B Types of Interactions

Objects in contact exert forces on each other.

Electric and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other.

Key Words/Vocabulary

Fossil fuel: An energy source that is produced through the million-year decomposition of dead organic material, such as trees and animals.

Attractive force: A force that attracts objects toward each other.

Repelling force: A force that pushes two or more objects away from each other.

Magnetic force: The attractive or repulsive force that exists between two bodies that contain a magnetic charge.

Materials

Per class:

- ☐ Track Assembly Instructions sheet
- ☐ Track template
- ☐ Video capture device (optional)

Per student:

- ☐ Bar or disc magnets
- ☐ Paper

Per group:

- ☐ Paper
- ☐ Pens or pencils
- ☐ Cardstock paper
- ☐ Scissors
- ☐ 6 inches of magnetic tape
- ☐ 4 disc magnets
- ☐ 4 bar magnets
- ☐ 1 foot of tape
- ☐ Washers for weight during testing
- ☐ Preassembled train track:
  - ☐ Cardboard
  - ☐ Track template
  - ☐ Scissors or box cutter
  - ☐ Strong tape
  - ☐ Magnetic tape
  - ☐ Glue gun or glue

Teacher Prep Notes

Preassemble track segments beforehand. You will find a template for tracing with the Track Assembly Instructions sheet (included later in this lesson plan). You can build just a couple as a class set for testing or build one track per group. The tracks are reusable.

Cheap and varied magnets can be sourced online from common vendors like Amazon or from your local craft store.

Be prepared to discuss how magnets work. You will also give a basic overview of how the maglev train in Japan uses magnets to float and accelerate trains. (For quick reference: web-japan.org/kidsweb/hitech/maglev).

To Do

Determine the Problem or Question to Solve: 15 minutes

1. Before watching the IMAX movie *Dream Big*, give students an overview of what they are about to experience. This film is about engineering and the ways that engineering can inspire, challenge, and enrich our lives. Give students the following questions to think about as they watch the film:
   - How is transportation shown and talked about in the film?
   - What role do engineers play in shaping our future modes of transportation?
   - What are some of the trends you see with future transportation?
2. Debrief as a whole class after viewing the film. Allow students to reflect on the guiding questions you gave them.
3. If necessary, remind students of some of the current challenges we face regarding transportation. These include too many vehicles on the roads, which causes traffic; safety concerns; and using fossil fuels, which pollute the air, water, and ground.
4. Introduce the design challenge. Sixty years ago, there weren't nearly as many people as there are today. When suburban neighborhoods were built around a city center, people could comfortably and safely travel back and forth to work each day. But as populations have increased, so have the number of cars on the road. Today we face long commutes in slow traffic, back and forth between our jobs and homes. Unfortunately, some public transportation services, like buses, are bogged down with the same challenges. Engineers are working now to develop solutions to these challenges. One of the methods of transportation being reimagined is trains. Imagine a train that can travel incredibly fast, yet be safe and consume very little energy from fossil fuel sources—or none at all. Today you will reimagine the way trains work and the potential they may have as a future form of public transportation.

Research and Gather Information: 20 minutes

1. First, give students time to experiment with magnets. Have bar or disc magnets available. Ask students to arrange the magnets so that they can hold a piece of paper in between them. Then ask the students to arrange the magnets so that they push away from each other. Explain the concepts of magnetic force having a negative and positive end (magnetic polarity). Demonstrate the repulsion of positive-positive and negative-negative interactions and the attraction of positive-negative interactions.
2. Students should attempt to float or hover an object with the bar or disc magnets. Note the challenges of doing this. The magnets will flip over so that the opposite sides attract and attach to each other, for example, or the magnets will fly away to the side rather than stay suspended.
3. Give a basic overview of how the maglev train in Japan uses magnets to float and accelerate trains. (For quick reference: web-japan.org/kidsweb/hitech/maglev).

Plan a Solution: 15 minutes

If students are unfamiliar with the concepts of criteria and constraints in engineering, take the time now to introduce these two key ideas. Engineers look at challenges through the lens of criteria (what does my device have to do?) and constraints (what are the limitations I face in making, testing, and using the device?). Spend some time as a whole class brainstorming the criteria and constraints of this particular engineering challenge.

Divide students into groups of three. Give each group a preassembled track and basic train platform (the piece of cardstock). Based upon their experimentation and research, tell groups to design and draw a magnet configuration that they believe will allow the train to float along the track. Give students a variety of options to choose from for magnetic materials, such as disc magnets, magnetic tape, and bar magnets.

Make It: 15 minutes

Instruct students to assemble the train and test it on the track. They should start building according to their plan, but they should not be surprised if they have to keep experimenting in order to create a functional floating train. Visit each group and review how their experiments shaped their overall design and plan. If students are making mistakes, let the mistakes happen. Avoid offering solutions; instead, encourage students to keep trying and allow their ideas to evolve.

Test: 15 minutes

To test their trains, have each group float their device along the track. Allow students to add washers, one at a time, to see how much weight their train can hold. Optional: make videos of the different tests to compare the trains afterward.

Evaluate: 10 minutes

Ask students to reflect on the following questions, and talk about their responses as a class:

1. Did your train float magnetically?
2. Was your train able to carry any washers?
3. What part of your design contributed to its successes?
4. What part of your design contributed to its failures?
5. What could you change to make your train better able to carry a heavy load?

Taking It Further

Allow students to reiterate and create a new design that they feel addresses the failure point of their previous design, and then test the new design.

Explore how civil engineers are overcoming transportation issues (mountains and inclement weather) by designing and building new tunnels like Switzerland’s Gotthard train tunnel that opened in 2016.

Watch YouTube videos about magnetic tracks/trains and their capabilities.

Document your students’ work through our social media outlet: #dreambigfilm

TRACK ASSEMBLY INSTRUCTIONS

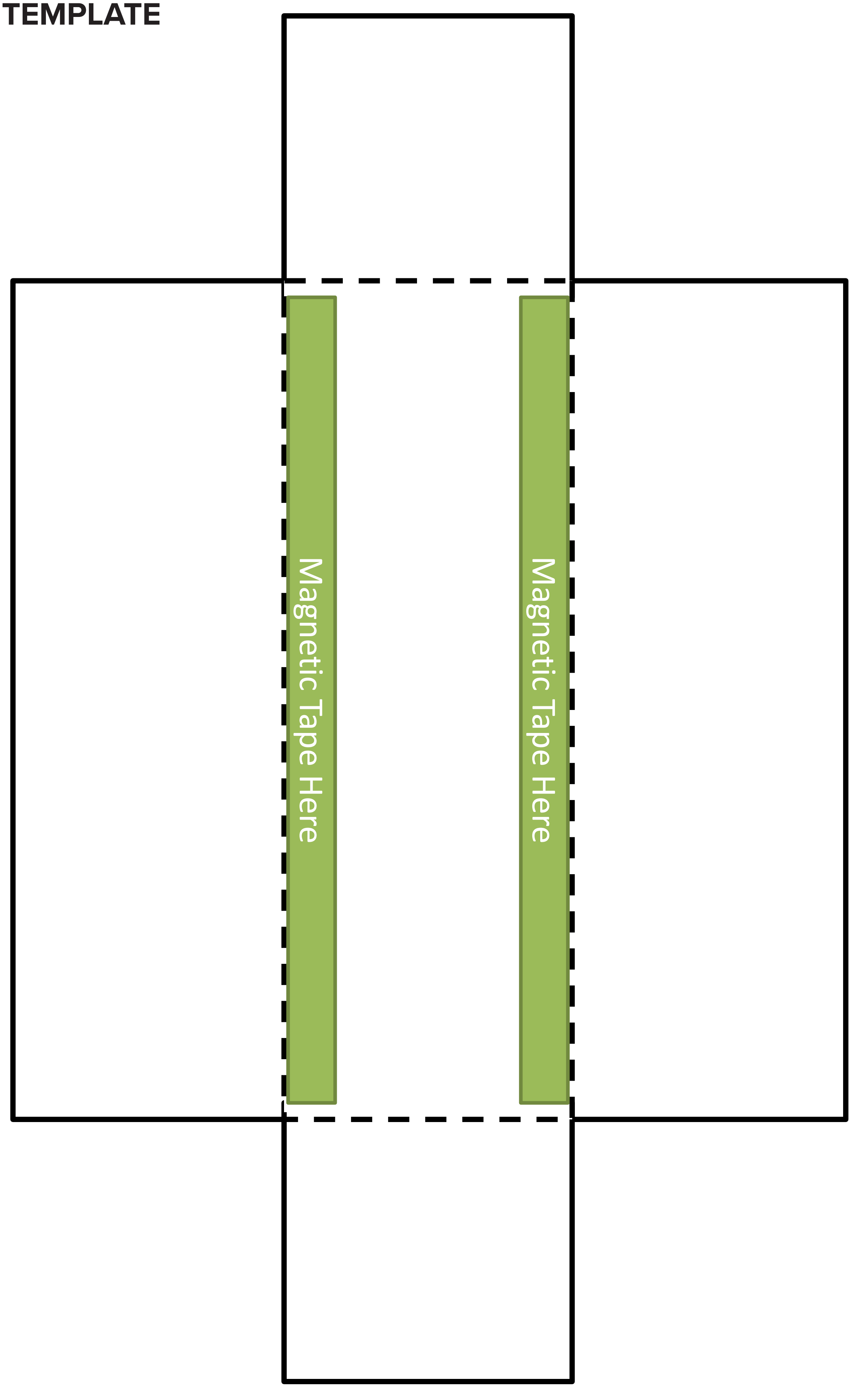
Obtain cardboard. Use the template (included as a separate sheet) for exact dimensions. Trace the cut lines with scissors or a box cutter. Fold the cardboard along the dotted lines. Tape the sides together with strong tape.

On either long side of the track, measure out a length of magnetic tape that would run from end to end. Use a glue gun to glue down the magnetic tape along the leftmost and rightmost sides of the top of the track.

Give students a piece of cardstock paper cut to the size of the width of the track. This will serve as the "train" for them to tape magnets onto in order for the train to float suspended above the magnetic tape on the track.

Hints: If you would like, you can have students create an actual train boxcar to place on top of the cardstock. Another option is to place an empty paperclip box on top of the cardstock and allow students to add washers, one at a time, to see how much weight their floating magnetic train can hold.

TRACK TEMPLATE



DREAM BIG VIDEO SERIES

WATCH *WHO'S IN THE DRIVER'S SEAT: AUTONOMOUS VEHICLES*

Go behind the scenes at Google X and other companies to discover how self-driving cars are engineered. Meet the teams who love the creative problem solving this challenge requires. Go to discovere.org/dreambig/media-assets and visit Educational Webisodes.

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GRADE 3:
CROSS-CURRICULAR SUPPLEMENT

In the *Dream Big* Maglev Train lesson, students designed a magnetic train system. The engineering challenge is to get a train to move three feet without making physical contact with the track. Magnetism provides the force required to levitate the train over the tracks, reducing the energy required to move the train.

The general topics covered in the Maglev Train lesson include transportation, conversion of energy from one form to another, and magnetic objects.

This cross-curricular supplement contains a math activity, an English language arts activity, and some additional ideas in both subject areas for exploring the topics and concepts introduced in the Maglev Train lesson.

Grade 3 Math: Measuring Magnetism

Estimated class time: 30 minutes

Summary

In the *Dream Big* Maglev Train activity, students experimented with creating their own magnetically levitating model trains. This lesson gives them a chance to learn more about the properties of magnets by mapping and measuring a magnet's magnetic field. Students explore answers to these questions:

- How far does a magnet affect the space around it?
- If you make a map showing this distance, what would the shape look like?

Learning Objectives

- Determine how best to measure the effect of a magnet on the space around it
- Display understanding of area as an attribute of plane figures
- Demonstrate the ability to measure areas by counting unit squares

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Materials

Per pair of students:

- ☐ the bar or disc magnets used in the *Dream Big* Maglev Train activity
- ☐ graph paper
- ☐ pencils
- ☐ rulers

Per student:

- ☐ Math handout

Preparation

Set context for students by holding a brief class discussion about the Maglev Train activity. Prompt students to explain what they understand about how these trains work in the real world. Ask students to summarize their own experiences with building levitating model trains using magnets.

Tell students that in this activity, they are going to find out how their magnets affect the space around them by measuring and mapping these effects.

Instruction

1. Distribute materials to each pair. Review these terms, which students learned in the Maglev Train activity, by asking students to demonstrate each type of force with their magnets:
   - Attractive force: A force that attracts objects toward each other
   - Repelling force: A force that pushes two or more objects away from each other
   - Magnetic force: The attractive or repulsive force that exists between two bodies that contain a magnetic charge
2. Ask partner A to place a magnet in the center of the graph paper and hold it there with their finger so it stays in that fixed position.
3. Ask partner B to place the second magnet along the edge of the paper. Have partner B move their magnet one square of graph paper toward the center magnet using a pencil to nudge it slowly. If nothing happens, the student should move the magnet another square toward the center magnet. The moment the students see this magnet move as a result of attractive force, they mark an x on that square of the graph paper.
4. Explain that the students' task is to work all the way around the paper, finding the spot of attractive force and marking it with an x on the graph paper. Ask partners to take turns being the person to hold the center magnet in place versus being the one to find the next spot of attractive force. Tell students to locate at least 12 points on their paper, including 1 from each corner and 2 from each side.
5. Instruct students to use a ruler to measure how far away the x's are from the center and to note these measurements on the edge of the paper. Ask several pairs to report on their findings to these questions:
   - Can you see any kind of pattern or shape made by the x's?
   - Is there any kind of pattern to the measurements of the x's from the center?
6. Have students use their rulers to connect all the x's. Ask partners to hold their papers up so that classmates can compare their findings.
7. Ask students to guess how many squares of graph paper it will take to fill in the shapes made by their x's. Then have each pair measure the area of their shape by counting graph squares. Tell them to write down how many squares they count.

Closure

Once all of the pairs are done figuring out the area of their shapes on the graph paper, list them all on the board to see how similar the results were. Hold a closing discussion, asking questions such as the following:

- Why do you think all of the areas turned out to be similar? What might explain any differences among the results?
- What kind of shape do you think you could make with a repelling force? Would it be the same or different?

Activity Extensions

- Ask two pairs to double up and stack two magnets in the center of the paper. How does the area of magnetic effect change?
- Try this activity with different kinds of magnets.
- Plot different measurements in a bar graph: the class results of the first activity, the results of single versus double magnets, or the results of different kinds of magnets.

Other Ideas for Math

Here are a few more ways to connect the Maglev Train lesson with your math curriculum.

- Have each student group use a ruler to measure the distance their train was able to travel along the track. Make a bar graph for the whole class to show all of the results.
- Have students use a small kitchen food scale to weigh their train. Using a list of the results on the board, have students deduce the minimum and maximum weight for a train that successfully floats over the track.

GRADE 3 MATH: STUDENT HANDOUT

Directions

1. Partner A: Put a magnet in the center of the paper and hold it there with your finger.
2. Partner B: Put the other magnet at the edge of the paper. Mark the spot with your pencil. Slowly slide the magnet one square of the graph paper, toward the other magnet.
   - As soon as you see the magnet move, mark this spot with an X.
   - Locate at least 12 points on the paper, including 1 from each corner and 2 from each side.
3. Take turns being the one to hold the magnet in the middle and being the one to mark X's all around the paper.
4. Use the ruler to measure the distance between the center and each X. Write these numbers down.
5. Use the ruler to connect all the X's and see what kind of shape they make.

Grade 3 English Language Arts:

Estimated class time: 50 minutes

Materials

Per class:

- ☐ A read-aloud book with descriptive words for train sounds, such as *Locomotive* by Brian Floca or *Train* by Elisha Cooper (More about these books is listed in the Book Connections section at the end of this activity.)
- ☐ Optional: YouTube video and/or audio recordings of different transportation sounds. Examples include trains sounds: youtube.com/watch?v=wqO2HC1QYuc, transportation sounds: youtube.com/watch?v=M5-eFEZ4fi8

Per student:

- ☐ pencil
- ☐ paper

Summary

In the *Dream Big* Maglev Train activity, students experimented with creating their own magnetically levitating model trains. This lesson gives them a chance to explore the rich vocabulary associated with the sounds made by different modes of transport. They also consider which of these sounds engineers have created intentionally. Students think about these questions:

- What sounds do different trains and other kinds of transportation make?
- Which words describe the different kinds of transportation sounds?
- Which transportation sounds do you think engineers make on purpose?

Learning Objectives

- Compare and contrast sounds made by different kinds of transportation
- Identify the best words for describing different transportation sounds
- Write an explanatory piece that distinguishes transportation sounds that seem useful versus those that are just noise

Preparation

Set context for students by holding a brief class discussion about the Maglev Train activity. Prompt students to describe the Maglev Train and what it might be like to ride in one. Ask students to relay any experiences they have had with riding in trains.

Tell students that to begin this activity, they are going to explore the differences between various kinds of trains based on the sounds they make and practice describing these sounds as vividly as they can.

Instruction

1. Tell students that you are about to read a book about trains aloud. Every time students hear a word that describes a sound a train makes, they should raise their hands. You will pick a student to say what the word is and start a list on the board.
2. After you've read the book, look at the list of words on the board. Ask, "Do you think other kinds of transportation also make these sounds? Why or why not?" Give students a moment to think and discuss with their neighbors before eliciting responses from the class. As students think of them, add more terms to the list.
3. As an option, help students to connect the words for sounds with the actual sounds by playing a YouTube video or audio recording of train and other transportation sounds. Students may come up with more words for the list on the board; encourage them to call these out and add them.
4. Explain that engineers want cars, trains, and boats to make certain kinds of sounds. They include these sounds on purpose; for example, cars have horns so that drivers can beep them to warn other drivers. Ask students to look at the list on the board. Which of these words describe sounds that engineers have designed intentionally—sounds that are helpful? Circle these terms on the list.
5. Distribute paper and pencils. Ask students to choose three sounds to write about. For each one, students should answer these questions:
   - Which kinds of transportation make this sound?
   - Is it a sound that engineers designed on purpose to be helpful? Why or why not?
   - Is it a sound that engineers are trying to reduce or eliminate? Why or why not?
6. Once students have finished writing, place them in pairs. Students should take turns telling their partners which sounds they picked and why they think they are intentionally designed or not. Note that partners may disagree, and it's okay if they do.

Closure

Ask for a show of hands: which pairs had different opinions about whether or not a sound was helpful? Call on some of these students to learn the source of disagreement. Hold a brief closing discussion, asking questions such as:

- Which transportation sound annoys you the most?
- If you were an engineer, how would you try to change this annoying sound?
- Which of the describing words we listed were new to you? What other things could you describe using these words?

Encourage students to be imaginative as they think of different ways to apply transportation sound descriptors.

Activity Extensions

- Assemble train research materials, such as books, magazines, and/or age-appropriate websites. Ask students to pick two different kinds of transportation and write about their similarities and differences.
- Play train sounds and have students guess which part of the train is making the sound and why.
- Ask students what their favorite book about transportation is and read several of them aloud. Ask, if you were to make up a story, what kind of transportation would your story feature?

Book Connections for English Language Arts

The following books relate to the Maglev Train activity. They can be incorporated into your ELA curriculum or used as a warmup for the activity provided in this supplement.

Locomotive by Brian Floca, A Richard Jackson Book/Athenium, 2013. A young family boards a train in 1869, bound for California on the transcontinental railroad. It is written for a wide age group and won the *New York Times* Best Illustrated Books Award for 2013.

Train by Elisha Cooper, Orchard Books/Scholastic, 2013. This book introduces students to many kinds of trains—commuter, passenger, freight, and bullet.

Trains for Kids: A Children's Picture Book about Trains by Melissa Ackerman, CreateSpace Publishing, 2016. This book describes specific trains in detail, including the Maglev, and will especially delight the train enthusiasts in the class.

The Polar Express by Chris Van Allsburg, Houghton Mifflin Harcourt, 30th Anniversary Edition, 2015. This Caldecott Medal Winner and *New York Times* Bestseller and Best Illustrated Book is a classic that students love to hear.