THE TRAIN FACTORY

Teacher’s Guide

Dear Teacher,

The Train Factory celebrates the Baldwin 60000, a steam locomotive that has been part of the Franklin Institute since 1933, and the history of trains. The first steam locomotive was built in the early 1800s. Trains today are very different from what the first ones were like but much the same, too. In The Train Factory your students will trace the development of train engines through the years and then design their vision of what a train might look like in the future.

The Train Factory Exhibit

The exhibit is set up around the idea of having children act as mechanic trainees in The Train Factory, circa 1925. They read a job description at the entrance to The Train Factory and then work their way through the stations in four areas, the Assembly Shop, Baldwin 60000, Accident Investigation, and Research and Development. Each station has an explanatory panel in the form of a Work Order that describes what mechanic trainees are to do at that station. Along the way, students will learn about science concepts such as pressure, magnetic force, friction, and science as problem solving. The centerpiece of the exhibit is the 101-foot 60000, which is being readied for its first test run. You and your students can board the locomotive and help it roar to life.

In addition, your students will become sleuths when they visit the Accident Investigation station. They will have to determine why a fictional locomotive, the Meteor, crashed during a test run. This role-playing section involves observation, making and testing hypotheses, and drawing conclusions—much as scientists do.

Relevant Science Standards

While they explore the Train Factory, your students will also be experiencing a number of concepts from the National Science Education Standards.

Kindergarten to Grade 4

- People have always had problems and invented tools and techniques to solve them.
- Magnets attract and repel each other and certain kinds of other materials.
- Students should develop abilities of technological problem solving.

Grades 5 to 8

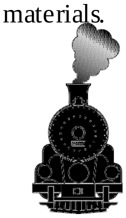
- The motion of an object can be described by its position, direction of motion, and speed.
- Unbalanced forces will cause changes in the speed or direction of an object's motion.
- Technologies cost, carry risks, and provide benefits.
- Science and technology have contributed enormously to economic growth and productivity among societies and groups within societies.

Teacher Support

To help your students get the most out of The Train Factory, this Teacher's Guide offers Previsit Activities to set the stage, In-Exhibit Activity Sheets to guide your students through the exhibit, and Post-Visit Activities to debrief your students and extend and apply what they have learned in the exhibit. Helpful background information, cues, and suggested student responses are presented in each lesson plan to provide solid science support for you. Rather than a data collection sheet for children in kindergarten through grade 2, an information and directed activity sheet for the teacher is provided to make the exhibit as interactive as possible for young visitors.

This Teacher's Guide is divided into three sections, one for kindergarten through grade 2, a second for grades 3 through 5, and a third section for grades 6 through 8. Finally, there is a Further Resources section listing fiction and nonfiction books as well as Web sites and magazines that will help set the stage for visiting The Train Factory and provide follow-up materials.

We hope you and your students enjoy The Train Factory and your time as mechanic trainees and science sleuths.



THE TRAIN FACTORY

Guide for Grades K-2

CONTENTS

Previsit Exploration

Some General Activities

When your pupils visit The Train Factory, they will be invited to think and act like a train mechanic and an engineer. So that they can make the most of the learning opportunities the exhibit offers, consider doing the following activities beforehand:

- Read aloud to the class some of the grade-level appropriate books on the Further Resources list and make as many as possible available to children for reading on their own in order to become familiar with the world of trains.

- Some of your pupils may already know a great deal about trains from the picture books, videos, and toys they have at home. Invite these train “experts” to bring in their train books and to share what they know with the rest of the class.

- The Train Factory has several devices that show how steam makes steam engines move. If your pupils are unfamiliar with steam, assign some homework: Ask pupils to watch (from a safe distance) while an adult boils water in a teakettle or a pan, so they can see how heated water becomes steam and how steam moves upward.

- Most of us take for granted the automated machines we see and use everyday, so it can be helpful to awaken pupils to the basic fact that things don’t move on their own—some force has to cause that motion. Help pupils begin to get curious about what kind of force moves something as big as a train. Encourage pupils to begin generating questions about trains.

- On the ride to The Train Factory, have them look at the various vehicles they pass along the way and think about what is making the vehicles move. Ask question such as: Do they see any trains or train tracks along the route? What do train tracks or roads do when a body of water, a hill, or another road crosses their path?

K–2 PREVISIT ACTIVITY

Working Together

Science Concepts

- Objects don’t move unless they are pushed or pulled (by some force).
- More force is needed to move heavier objects.

Skills

Predicting, recognizing cause and effect, asking questions

Suggested Time

15 minutes

Materials

1 picture each of a bicycle, car, locomotive engine, and plane with its wheels visible.
Optional: a scooter and a tricycle or bicycle

Procedures

1. Show the children the pictures of the bicycle, car, train and plane. Ask them how the four are alike and how they are different. Ask how each vehicle works—what makes each move. Then ask children to describe how a person makes the bicycle move. Talk about muscle power and relate it to the idea of how engines make trains, cars and planes move.

2. If you are able to bring in a scooter and a bicycle or tricycle, ask how the scooter is different from the bicycle. Push the scooter and then the bicycle to demonstrate how there are more parts that have to move in the bicycle than in the scooter. Ask children whether the scooter or the bicycle would take more muscle power to move and why. Guide them to understand that the bigger, heavier, and more complicated (has more moving parts) something is, the more power it takes to move it.

Suggested Student Responses

Children should respond that the bicycle, car, train, and plane are things that move, have seats and wheels, and carry people. They should also be able to tell you that something powers the vehicle to make it move. In the case of the bicycle it is the person riding it, whereas the car, plane, and train have engines.

Extension of the Activity

Have children create a line dance in which they mimic the actions of riding a scooter and a bicycle. They should emphasize the movements of pushing the scooter and gliding and of pumping the bicycle’s wheels.

In the Exhibit

Something needs to push or pull a train to start it moving. Engines, powered by steam, diesel fuel, electricity, or magnetic force, pull trains. The heavier the load, the more force is needed to start and stop the train.

K–2 PREVISIT ACTIVITY

Friction Races

Science Concepts

- Objects don’t move unless they are pushed or pulled (by some force).
- Objects are slowed by friction, which is caused when two things rub against each other.
- Objects have different characteristics, which can affect how quickly they move.

Skills

Working cooperatively, predicting, observing, drawing conclusions

Suggested Time

30 minutes

Materials

Metal trays (such as cookie sheets or cafeteria trays); large pieces of sandpaper; small toy cars, large pencil erasers, small blocks of wood, large metal paper clips

Procedures

1. Give each group of 4 pupils two metal trays, a large piece of sandpaper, 3 large metal paper clips, a small toy car, a small wooden block, and a large pencil eraser (or a similar group of objects). The class is going to have three sets of races to deter mine the fastest object on two different courses: a bumpy course (sandpaper clipped to the metal tray with two paper clips) and a smooth metal course (metal tray).
2. Have groups predict a ranking of the 4 objects (paper clip, toy car, wooden block, and eraser) from fastest to slowest. Record their predictions on a large class chart.
3. Have groups hold the No Force Race, that is, no pushing or pulling of the objects or moving of the trays, and no slanting the trays. Record group results from this set of races on the large chart. Ask: Which was the fastest? the slowest? Did any thing move? Why or why not?
4. Have groups hold the Finger Push Race. For this race, each pupil at the same time gently pushes one of the four objects. Record group results and ask: Are you sure this was a fair race? Through discussion, help pupils discover that because there’s no way to ensure that each object was pushed with exactly the same amount of force, it wasn’t a fair race or an accurate science experiment.
5. Have groups hold the Fair Race by lining up the objects along the edge of the tray and then slowly raising the top. The objects that experience less friction will move when the top is slightly raised, but the objects that experience more friction won’t move until the tray is raised higher. Chart the results and ask pupils to generalize what kinds of objects were faster and slower
6. Have pupils rub their hands together and describe what they’re feeling. Have them experiment with how hard they push their hands together while rubbing and how quickly they move them. Ask: When you’re pushing your hands together really hard, is it more difficult to move them quickly than when you’re not pushing them as hard? Discuss the heat and wearing they feel, and tell them that scientists call this force “friction.” Relate this to the races in that objects experienced more friction when moving on the rough bumpy sandpaper than on the smooth metal tray.
7. Ask groups to discuss, based on these races, what kind of vehicle and roadway they would design if they wanted to go as fast as possible using the least amount of force (experiencing the least amount of friction). Ask pupils why they think trains run on metal wheels on metal tracks.

Suggested Student Responses

In the No-Force Race, pupils will see that nothing moves if it isn’t pushed or pulled by some force. When children lift one end of the tray to get the objects to move, point out that their action is allowing the force of gravity to pull the objects. In the other races, pupils will see that objects move faster on metal than on sandpaper and that objects made of metal or with wheels move faster than objects made of softer, rougher, more flexible materials.

Extension of the Activity

Add other small objects to the races, such as rocks, small books, wood pencils, glue sticks, chalk, chalk erasers, metal pens. Ask pupils if some objects move differently depending on their position (circular objects such as pencils move more quickly when they are placed horizontally, so they can roll, rather than vertically when they just slide). Ask pupils if they can combine any of the objects to make them move faster. What if they attached the block to the glue stick with a rubber band?
Or put the eraser on the toy car?

In the Exhibit

Metal rails are hard and smooth and do not cause as much friction as dirt, grass, gravel, or asphalt, and wheels reduce the amount of area that can be slowed by friction. Trains run on metal rails with metal wheels because they experience less friction that way and, therefore, require less force to start moving and to keep moving. In the Track Shop area, children will be able to investigate the effect of wheel shape on how well a train travels. They will also read about how a huge number of grasshoppers in the 1800s made tracks too slippery for trains to start or stop. Engineers figured out how to add containers of sand to locomotives so that the sand would trickle onto the track, increasing friction.

K–2 INFORMATION AND ACTIVITIES FOR IN-EXHIBIT EXPLORATION

Tell pupils that for a long long time, the fastest way to move on land was by horse. But a about 200 years ago, people figured out how to make a steam engine, instead of a horse, pull a train along tracks. People called it the "Iron Horse." What made this iron horse go? Tell children that they will find out if they pretend to be a train assistant and follow the directions at each station in The Train Factory. As you go through the exhibit, be sure to name for children the different kinds of engines and trains they will be seeing—steam engine, diesel engine, electric train, and maglev train.

At the Assembly Shop

In this area children operate devices to see what makes steam engines move. They'll see how steam moves pistons, which in turn move rods, which then make the wheels they're connected to move round and round and drive the train. Remind children of steam engines they're familiar with from children's stories they've heard or read.

1. At Project: Steam Pressure Pushes, as children spray water into the boiler, ask: What happens to the water as it boils? Have them tell you what they know about steam from their own experiences. Ask them to remember what it feels like to be pushed by water, for example, a wave in the ocean or a big splash in a pool, or by air on a windy day. Point out that steam is pushing this piston just like that.

   Point to the Baldwin 60000 engine and say that there is a huge boiler that boils water into steam inside the Baldwin. Have them guess where it would fit. (most of the area that is in front of the engineer's cab and above the wheels) Ask them where they think the Baldwin kept its water. (in the tender, the rear vehicle) Tell them that in some children's stories about trains, it says the engine is "thirsty." Ask: What would that mean? (An engine can't make steam unless it has water. When it runs out of water, it needs to get more.)

2. At Project: Pushing to Spin, as children push the pistons, ask them the direction the pistons are moving. (back and forth) Ask what direction the pistons are making the wheels move. (round and round) A piston pushes a connecting rod, which is attached to the wheel. Ask them what they think pushes the pistons on a locomotive. (steam, as they saw at station #1) Point to the Baldwin 60000 again, and ask pupils to find the rods that turn its wheels.

3. At Project: Control the Flow, while pupils operate and watch the steam hose, ask them if steam is pulling or pushing or both. (pushing)

4. At Project: Boiler Race, tell pupils that at the Boiler Race, they're acting as the fireman of a train. The fireman needs to tend the fire, cranking in just enough coal at the right times. Challenge them to add enough coal to go fast but not so much that the fire will be too hot and make too much steam. If so, the steam will push so hard against the boiler, the boiler will burst.

5. At Project: Keeping on Track, have children predict which set of wheels they think will roll the easiest and stay best on the tracks. Then have them try each set of wheels on the track. Have children predict and then look at the People's Railroad #3 to see what kind of wheels it has. (trains use flanged wheels)

At the Baldwin 60000 Locomotive

1. Invite children to pretend they are the fireman or the engineer. Have them act out what these workers would be doing before, during, and after the ride. (The fireman takes care of the boiler, adding fuel into the firebox from an automatic coal feed when needed. A fireman who knows the route well will know when a hill or a long flat stretch is coming and can adjust the fire accordingly. The engineer checks the gauges, watches the way ahead, blows the whistle to alert anyone near the tracks, and starts and stops the engine. The engineer doesn't need to steer the train, because the tracks control where the train goes.)

2. Have pupils watch the locomotive from the outside as it moves. Ask: What makes the wheels move? Do all of the wheels move in the same way? (The connecting rod, the rod which attaches the large driving wheels to the steam-pushed pistons, makes the large wheels turn. The smaller wheels turn because the engine is moving.) Are all the wheels the same size? (no)

At Research and Development

1. At Project: Electric Train, have pupils turn the crank to see the electric train move. Explain that this is an electric train and ask them how the electricity gets to the train to make the motor work. (through the overhead wire) Have the children list things that move when they are plugged into an outlet with a cord, for example, a blender and fan.

2. At Project: Repel and Attract, have pupils hold magnets together in different ways to experience magnetic force. They saw earlier that steam couldn't push and pull. Ask: What about magnets, do they push, pull, or do both? (both) Have children show or describe how they have to hold the magnets to feel them pull together and to feel them push apart.

At the Accident Investigation

This area is probably too complex for children in the lower grades. Consider focusing your pupils' attention on the other parts of the exhibit.

K–2 POST-VISIT ACTIVITY

Magnetic Forces

Science Concepts

- Magnetic force

Skills

Working cooperatively, drawing conclusions, recording

Suggested Time

20-30 minutes

Materials

At least two bar magnets per group and, if possible, various other magnets of different shapes and sizes; one large sheet of heavy construction paper or thin cardboard per group, paper clips, string, and tape

Procedures

1. Ask pupils to recall the four kinds of engines and trains they saw at the exhibit—steam engine, diesel engine, electric train, and maglev train. Tell children that most people haven't seen or ridden maglev trains, because currently low-speed maglev trains only operate in two cities, Birmingham, England (linking the train station and the airport via a one-mile track), and Berlin, Germany. In the U.S. and a few other countries, scientists are researching and testing high speed maglev trains. Scientists in Japan have developed a full-sized model that reached speeds over 300 mph, almost as fast as an airplane.

2. Invite pupils to join in the research and testing of maglev trains, and specifically of the way magnetic force can push and pull. Give materials from the list to each small group, and challenge them to find answers to the questions below. Assign one specific question to each group for presentation afterwards, but have them all work on all the questions.

   - What happens when you hold a paper clip near a magnet? Feel and describe the power of the magnetic force at different heights above the magnet.
   - What happens if you put a piece of paper between the paper clip and the magnet? How does this change as you add more pieces of paper?
   - How long a paper clip chain can you make with a magnet? How does the number of paper clips change with different magnets?
   - How can you make one magnet pull another magnet?
   - How can you make one magnet push another magnet?
   - Is there any friction when you use a magnet to push another magnet across the table?

3. After pupils have experimented with the magnets, have each group share their responses to one of the questions. Have groups share if their results were different from other groups.

4. If it doesn't come up in discussion, be sure pupils understand the foundation of magnetic force: Magnets have two poles, called south and north; the same poles of different magnets repel each other, and opposite poles of different magnets attract each other.

Suggested Student Responses

As pupils experiment with magnets, they'll see that magnets exert a force. Among their responses may be like poles repel and unlike poles attract; some magnets are stronger than others; some materials are attracted to magnets (paper clips) and others are not (paper or cardboard). Have children focus on the idea that some metals are attracted by magnets, but some metals (like those in coins) and nonmetallic objects are not.

Extension of the Activity

Invite pupils to create a magnetic train line by drawing a train track on a large sheet of paper or cardboard, and using two magnets. Have them attach one magnet to a small train they've drawn and cut out from paper and the other magnet to a pencil or stick. Children can navigate their train on top of the paper track by using their pencil/magnet under the paper or cardboard to pull the train along. Two or more students can race their trains by drawing parallel tracks on the large sheet of paper.

In the Exhibit

The exhibit shows models of maglev trains, which are levitated and moved by magnetic force. Unlike the children's trains that work by magnetic attraction, maglev trains operate on the principle that unlike magnetic poles repel, which causes the train to float or levitate above the track.

K–2 POST-VISIT ACTIVITY

Science Fiction

Science and Language Concepts

- An object doesn't move unless it is pushed or pulled by some force.
- More force is needed to move heavier objects.
- Objects are slowed by friction, which is caused when two things rub against each other.
- Objects have different characteristics, which can affect how quickly they move.
- Science explains how things work
- Stories include problems that get solved.

Skills

Drawing conclusions, analyzing a problem, creative writing

Suggested Time

20-30 minutes

Materials

none

Procedures

1. Review with pupils how steam engines work and remind them of what they learned in the Previsit Activities about the force needed to move things and about the role friction plays.

2. Have pupils recall some of the stories about trains they know. Remind pupils that stories always include a problem that gets solved, and that the stories they've read about trains sometimes include problems that science explains and solves.

3. Tell pupils elements of different stories about trains that can be explained by science. Give each group of pupils one or more of these story elements to discuss together and then present to the class. Have them act out the fictional part and then explain the science behind it. They should also mention the particular part of The Train Factory or Previsit Activities that explained the fictional phenomena. Use these samples and/or create your own:

   - In some stories, a steam engine is said to be "thirsty." (An engine can't make steam unless it has water. When it runs out of water, it needs to get more)
   - In some stories, steam engines talk about not being strong enough to go up hills, or need another engine to help them get up a hill. (Like bike riders, steam engines need lots of "push" to go uphill, especially if pulling a heavy train. To go uphill, they need lots of steam, and, therefore, a very hot fire and plenty of water. Some engines can't handle a very hot fire, as pupils saw at the Boiler Race at The Train Factory. There, if they added too much coal to the fire they could explode the boiler. In such cases, two engines would be needed.)
   - In some stories, a train has trouble making it up a hill or stopping at the bottom of a hill, because the track is slippery from water, wet leaves, or snow, and the fireman has to get out and put sand on the tracks. (Metal wheels on metal tracks are meant to be somewhat slippery to avoid frictional slowing. Water decreases friction even more. Sand adds friction to a slippery surface, as pupils saw in the Previsit Activities.)
   - In some stories smaller engines are jealous that they can't pull long trains. (As pupils learned in the Previsit Activities, more force is required to push/pull heavier objects, so a larger engine capable of producing more steam pressure will be able to pull a longer train than a less powerful engine.)
   - In some stories, steam engines are junked and replaced with diesel trains because diesels are said to go faster and be less trouble. (As pupils saw in the exhibit, diesel engines don't require a fireman tending a fire. Most trains in most countries don't use steam engines anymore.)
   - In some stories, trains try to run away. (A steam engine that has steam built up can move on its own if the tracks are clear; no steering is required. But it will eventually stop when the fire goes out and can no longer boil water to make steam.)

Suggested Student Responses

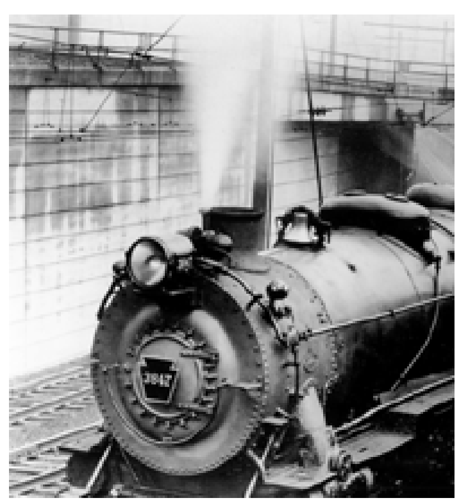
See the parentheses above for responses specific to each fictional element.

Extension of the Activity

Challenge pupils to write their own story, perhaps about the Baldwin 60000, that incorporates something they've learned about how steam engines work.

In the Exhibit

Steam engines need proper fires and amounts of water to create steam in order for them to pull or push a train. Train technology is always improving and thus often making older trains obsolete.



THE TRAIN FACTORY

Guide for Grades 3-5

CONTENTS

Previsit Exploration

Some General Activities

When your students visit The Train Factory, they will be invited to think and act like a train mechanic, a train engineer, a train designer, an accident investigator—all jobs that use a knowledge of science. So that they can make the most of the learning opportunities the exhibit offers, you might consider doing the following activities ahead of time:

- Most of us take for granted the automated machines we see and use everyday, so it can be helpful to awaken students to the basic fact that things don't move on their own—some force has to cause that motion. Help students begin to get curious about what kind of force moves something as big as a train.
- Encourage children to begin generating questions about trains.
- On the ride to The Train Factory, have them look at the various vehicles they pass on the way and think about what is making the vehicles move. Ask questions such as: Do they see any trains or train tracks along the route? What do train tracks or roads do when a body of water, a hill, or another road crosses their path?

GRADES 3-5 PREVISIT ACTIVITY

Getting Moving

Science Concepts

- Objects don’t move unless they are pushed or pulled (by some force).
- More force is needed to move heavier objects.

Skills

Predicting, recognizing cause and effect, asking questions

Suggested Time

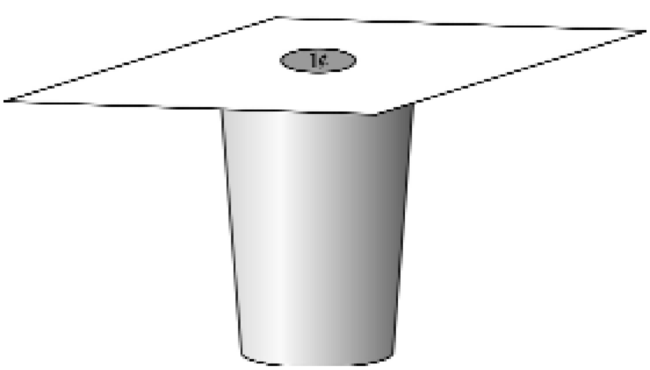
15 minutes

Materials

Plastic cups, index cards, pennies
Optional: paperback book; quarters, checkers, or poker chips; ruler, butter knife, or spatula

Procedures

1. Lay an index card flat over the mouth of a plastic cup and place a penny in the center of the card. Ask students to predict what the penny will do if someone flicks the card quickly.



2. Give each small group of students a cup, card, and penny so they can test their predictions.
3. Point out that this is similar to the popular "trick" of pulling out a tablecloth from a table set with dishes, glasses, and silver ware without knocking anything over. It’s not a trick really, but an example of a scientific principle: Objects at rest tend to stay at rest until something pushes or pulls them. Because the card was pushed but not the penny, the card moves forward and the penny does not (it had too much inertia to move forward and when it lost its support, it fell).
4. Ask students to think of examples of having to exert a force to start or stop something, for example, starting and stopping a bike, throwing and catching a ball. Ask: What do you think gets a train to start moving, keep moving, and stop moving? Does it matter how long the train is?

Suggested Student Responses

If the card is flicked quickly enough, the penny drops into the cup. Trains are powered by steam, diesel fuel, and electricity. (Students will probably not be aware of maglev trains.) A long, heavy train will be harder to start or stop.

Extension of the Activity

Have students predict what will happen if they exchange the index card for a small paperback book. When they actually try flicking the book, they’ll see another scientific principle in action: The heavier something is, the more force it needs to start moving. The students can also watch inertia in action by stacking coins, checkers, or poker chips and using a ruler, butter knife, or spatula to push the bottom coin out of the stack without knocking over the rest. With how high a stack can they do this? Does it matter how much the object weighs—penny vs. quarter?

In the Exhibit

Something needs to push or pull a train to start it moving. Engines, powered by steam, diesel fuel, electricity, or magnetic force, push or pull trains. The heavier the load, the more force is needed to start and stop the train. Students will investigate the crash of the Meteor, a fictional locomotive that was unable to stop quickly enough.

3–5 PREVISIT ACTIVITY

Feeling Friction

Science Concepts

- Friction slows movement.
- The characteristics of an object affect how it moves.

Skills

Working cooperatively, predicting, observing, drawing conclusions

Suggested Time

20 minutes

Materials

Metal trays (such as cookie sheets or cafeteria trays); large pieces of sandpaper; large metal paper clips, rulers; a variety of objects for each group to move on these two surfaces such as a small toy car, chalkboard eraser, large pencil eraser, chalk, glue stick, block of wood, small book, and pencil

Procedures

1. Give each small group of students a metal tray, a large piece of sandpaper, 2 large paper clips, and 4 to 5 objects to move. Tell them they will need to conduct races to determine the fastest object on two different courses: a bumpy sandy course (sandpaper clipped to tray) and a smooth metal course (metal tray). Have students rank the objects from fastest to slowest, first as a prediction and then after they've tested each one.

2. Remind students that as they discovered in the previous activity, objects must have some force exerted on them in order to start moving. To ensure an accurate ranking, the force must be exactly the same on each object. (If they need help, suggest they place all the objects at the top of the tray and then slowly raise the top. The objects that experience less friction will move when the top is slightly raised, and the objects that experience more friction won't move until the tray is raised higher. Groups can compare results by measuring the height of the tray when an object starts to move.)

3. After each group has ranked their objects, have them think about and discuss what made the fast objects fast and the slower ones slower.

4. Discuss the concept of friction, the force that causes heat and wear when two things rub against each other, and ask students how they think friction affected the race. (Objects experienced more friction when moving on the rough bumpy sandpaper than on the smooth metal tray.)

5. Ask groups to discuss, based on these races, what kind of vehicle and roadway they would design if they wanted to go as fast as possible using the least amount of force (experiencing the least amount of friction). Then ask students why they think trains run on metal rails with metal wheels. Ask them if they can think of any disadvantages to having a "perfect surface" to move on; consider walking on ice.

Suggested Student Responses

Most objects move faster on metal than on sandpaper. Objects with wheels or that can roll because they are circular in shape move faster. Objects made of softer, rougher, more flexible materials move slower. Very smooth surfaces, like the steel rails that trains run on, have very little friction, which can make it difficult to start or stop.

Extension of the Activity

Ask students if some objects move differently depending on their position. (Pencil, glue stick, and chalk move quicker when they are placed horizontally so they can roll, rather than vertically when they just slide) Ask students if they can combine any of the objects to make them move faster. Ask: What if you used several pencils under the book? What if you tried to attach the block to the glue stick with a rubber band? Or put the eraser on the toy car?

In the Exhibit

Trains run on metal rails with metal wheels because it's easier to move a heavy load when there's less friction. Metal rails are hard and smooth and do not cause as much friction as dirt, grass, gravel, or asphalt. Wheels reduce the amount of area that can be slowed by friction. Trains run on metal rails with metal wheels because they experience less friction that way and, therefore, require less force to start moving and to keep moving. Students will be able to investigate the effect of wheel shape on how well a train travels in the Track Shop area. They will also read about how a huge number of grasshoppers in the 1800's made tracks too slippery for trains to start or stop. Engineers figured out how to add containers of sand to locomotives so that the sand would trickle onto the track, increasing friction.

GRADES 3-5

IN-EXHIBIT EXPLORATION

Once, the fastest way to move on land was by horse. But about 200 years ago, people figured out how to make a steam engine, instead of a horse, pull a train along tracks. People called it the "Iron Horse." What made this iron horse go? You'll find out as you become a mechanic trainee in The Train Factory. What does a mechanic trainee do? Read about the job at the entrance to The Train Factory. The signs at each station will tell you what you need to do. Fill out this form as you go.

Be sure you see the four kinds of trains and engines in the exhibit. List them here as you find them.

At the Assembly Shop

1. At Project: Steam Pressure Pushes, spray water into the boiler. What happens to the water as it boils? What makes the piston move?

2. At Project: Pushing to Spin, push the pistons so that they turn the wheel. On a steam engine, what pushes the pistons?

   Look at the Baldwin 60000. Find the rods that turn its wheels. Do all the wheels have these rods? Draw the different kinds of wheels.

3. At Project: Control the Flow, as you move the steam hose, watch how it pushes the piston. Draw the path the steam follows.

4. At Project: Boiler Race, you're acting as the fireman of a train. The fireman needs to takes care of the fire, adding just enough coal at the right times. If you add too much coal, the boiler will explode. Why? (Hint: Check what the pressure gauge does when you add more coal.)

At the Baldwin 60000 Locomotive

1. How can you tell the Baldwin 60000 is a steam engine?

2. A fireman and an engineer worked in the cab when steam engines like this one pulled trains. What would the fireman do during the ride? How about the engineer?

At the Baldwin 60000 Locomotive (continued)

3. Watch the locomotive as it moves. What makes the wheels move? Do all of the wheels move in the same way?

4. About 75 years ago, the Baldwin 60000 was a test engine. What do you think train makers needed to test?

At the Accident Investigation

Your help is needed to find out why a test engine crashed during a test run.

- First, go to the bulletin board to read about what happened and who the suspects are.
- Next, go to each of the areas in the investigation room and listen on the telephones or intercoms to their stories.
- Then, test the evidence with the scientific tools provided. Do all four tests.
- Finally, when you know what caused the crash, call the hot line. Then write the cause of the accident here.

At Research and Development

1. At Project: Electric Train, why does the train move when you turn the crank?

2. Scientists talk about magnetic force. What ways do you feel that force when you hold two magnets together? Does it matter how you hold the magnets?

3. Look at Project: Electro-magnet. How does the electro-magnet change when you push the button? Can you turn a refrigerator magnet on and off? Why might it be helpful to be able to turn a magnet on and off?

GRADES 3-5 TEACHER INFORMATION FOR IN-EXHIBIT EXPLORATION

At the Assembly Shop

1. Water turns to steam as it boils. Steam expands as it is heated. As more and more steam fills the area, the steam gains enough pressure to push the piston.

2. The piston, which is being pushed by steam, moves the rods back and forth, which move the wheels round and round.

   Only the driving wheels, the large ones in the middle of the locomotive, have these rods. The four smaller wheels in front and the two smaller wheels behind hold up those sections of the engine but don't drive it. Be sure students have drawn the three sizes and two kinds of wheels.

3. Steam just pushes. This is why cylinders have valves that control the flow of steam in front of and behind the piston, pushing it one way and then the other. Be sure students' drawings are accurate.

4. If the fire gets too hot, the steam pressure can build so high that the boiler won't be able to withstand the pressure and so will explode. That's one of the reasons engineers and firemen use gauges in the cab that show them the level of pressure in the boiler.

At the Baldwin 60000 Locomotive

1. Steam engines have places to carry the water and the wood, coal, or oil used to heat the water. Large steam engines like the Baldwin 60000 use a tender, a separate car directly behind the engine, to hold the fuel and water.

2. The fireman tended the boiler, adding fuel into the firebox when needed. A fireman who knew a line well knew when a hill or a long flat stretch was coming and adjusted the fire accordingly. The engineer checked the gauges, watched the line ahead, blew the whistle to alert anyone near the tracks, and started and stopped the engine. The engineer didn't need to steer the train, because the tracks controlled where the train went.

3. The connecting rod, the rod which attaches the large driving wheels to the steam-pushed pistons, makes the large wheels turn. The smaller wheels turn because the engine is moving.

4. They wanted to make safer, faster, more efficient engines, so they'd test things such as brakes, boiler components, and wheel size. This Baldwin 60000 was used for experiments with very high steam pressure. Designers wanted to figure out the best temperature for the steam, and the best way to get it that hot.

At the Accident Investigation

Cause of the accident: The Meteor had too much steam pressure in its boiler, but no one could tell because the pressure gauge did not work properly.

At Research and Development

1. Electricity from the generator moves through the wire above the train. The wire on the train, called the pantograph, carries this electricity to the electric motors on the train.

2. When students held two unlike poles together, they should have felt the strong attracting force of the magnets. When they held two like poles together, they should have felt the strong repelling force of the magnets.

3. Turning electricity on causes the battery to act like a magnet. Refrigerator magnets can't be turned off. If a magnet could be turned off and on, the magnetic force could be controlled. By controlling an electro-magnet, some inventors have been able to use magnetic force to lift and propel things, such as maglev trains.

GRADES 3-5 POST-VISIT ACTIVITY

Magnetic Forces

Science Concept

- Magnetic force

Skills

Working cooperatively, drawing conclusions, recording

Suggested Time

30 minutes

Materials

At least two bar magnets per group and, if possible, various other magnets of different shapes and sizes

Procedures

1. In groups, have students create a group chart that summarizes what they saw at the exhibit, specifically the four types of train engines there: steam, diesel, electric, and maglev. Suggested chart categories: what makes the engine go; where the engine's power is created; advantages and disadvantages; have seen or ridden this kind of train outside of the museum.

2. After they finish their charts, ask students to use what they learned from their group chart to predict the kind of train the least number of classmates have actually seen or ridden outside of the museum. Tell them that most people haven't seen or ridden maglev trains, because currently low-speed maglev trains only operate in two cities, Birmingham, England (linking the train station and the airport via a one-mile track), and Berlin, Germany. In Japan, Germany, the U.S., and other countries high-speed maglev trains are being researched and tested. The Japanese have developed a full-sized model that reached speeds over 300 mph.

3. Invite students to join in the research and testing of maglev trains, and specifically of the way magnetic force can push and pull.

4. Show students the materials available and challenge them to experiment with the magnets in their groups, including finding answers to the following questions:
   - What happens when you hold a metal paper clip near a magnet? Feel and describe the power of the magnetic force at different heights above the magnet.
   - What happens if you put a piece of paper between the clip and the magnet? How does this change as you add pieces of paper to the stack?
   - How long a paper clip chain can you make with a magnet? How does the number change with different magnets?
   - How can you make one magnet pull another magnet?
   - How can you make one magnet push another magnet?
   - Is there any friction when you use a magnet to push another magnet across the desk?
   - How can you make one magnet float on top of another magnet? (They will need to keep the upper magnet from falling off to one side using some sort of wall.)

5. After students have experimented with the magnets, have each group share their responses to one of the questions. Have groups share if their results were different from other groups.

6. If it doesn't come up in discussion, be sure students understand the basis of magnetic force: Magnets have two poles, called south and north; the same poles of different magnets repel each other, and opposite poles of different magnets attract each other.

Suggested Student Responses

See sample chart next page.

As students experiment with magnets, they'll see that magnets exert a force. Among their responses may be like poles repel and unlike poles attract; some magnets are stronger than others; that some materials are attracted to magnets (paper clips) and others are not (paper or cardboard). Have children focus on the idea that some metals are attracted by magnets, but some metals (like those in coins) and most nonmetallic objects are not.

Extension of the Activity

Challenge students to use the magnets to start, turn, and stop an object along a specific course. Ask: Is there a way to control speed?

In the Exhibit

The exhibit introduces students to steam, diesel, electric, and maglev trains and shows how each is powered.

Chart

Type of Engine	What Makes the Engine Go	Where the Engine's Power Is Created	Advantages	Disadvantages	Seen/Ridden Kind of Train Outside Museum
Steam	steam pressure	Steam in boiler pushes pistons in cylinders.	faster than horse	lots of wood or coal needed to fuel train, lots of smoke caused, not as fast as maglev or electric trains; require more people to operate	Answers will vary.
Diesel	diesel fuel	Diesel fuel ignites explosion that pushes pistons in cylinders.	needs fewer people (no fireman)	needs lots of fuel, dirty exhaust, not as fast as high-speed electric or maglev	
Electric	electricity	Electricity at a generating station is carried to train by overground or ground wire.	no exhaust, small train because doesn't have to house engine, high speeds	needs overhead or underground wire; can't pull a great amount of weight	
Maglev	magnetic force	Magnets are located on the bottom of the train and on the track.	no friction, no need for fuel, no exhaust, high speeds	costly special tracks and trains required	

GRADES 3-5 POST-VISIT ACTIVITY

The Real McCoy

Science and Social Studies Concepts

- Lubrication reduces friction.
- Inventors apply scientific principles to solve problems.

Skills

Recognizing cause and effect, analyzing a problem, communicating ideas

Suggested Time

30 minutes

Materials

Small pieces of sandpaper, vaseline

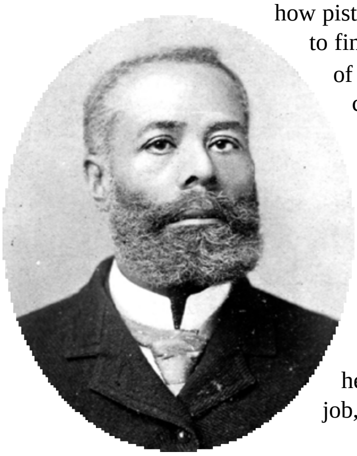
Procedures

1. Ask students to picture the Baldwin 60000. Have them recall any parts that rubbed against each other (wheels and rods).

2. Have small groups of students rub two pieces of sandpaper together and observe and describe what happens. Remind them of their experiences with friction in the Previsit Activity. Ask what would happen if they rubbed the two pieces together for hours or days. Ask what can be done to avoid the friction, and the heat, wear, and slowing down that friction causes.

3. Have students spread vaseline on both pieces of sandpaper and compare the difference. Ask: What do you think steam engine crews used to do about friction? Tell them that the firemen/oil men on steam engines used to stop their trains periodically and walk the length of the train oiling all the parts that rubbed against each other, such as the cylinders and pistons. Ask students to hypothesize what problems this procedure might cause. (It took too much time; Walking under the train to oil it was dangerous.)

4. Tell students about Elijah McCoy, the oilman/fireman who wanted to solve these problems and used his understanding of how pistons on a steam engine work to find a solution. He was the son of two escaped slaves. As a child in Canada, he was always taking things apart and putting them together and showed a remarkable aptitude with mechanical devices. At 15, he went to Scotland to study and earned a mechanical engineering degree. Afterwards, he had a hard time finding a job, because few people expected a black man to be educated in those days, but he finally got a job as a fireman/oilman for the Michigan Central Railroad. In 1872, he patented his invention of an automatic oil cup, a device that used steam pressure in the cylinders to regulate the oil needed to lubricate the cylinders and pistons. The device worked so well that many other oilmen wanted one for their trains. Imitation devices did not work as well, so train engineers would ask for "the real McCoy." Millions of machines have since been equipped with some version of this automatic lubricating invention—from naval ships to moon landing equipment. McCoy kept on inventing and eventually received 57 patents during his lifetime.



5. Discuss how McCoy took a problem he encountered daily and used his understanding of how steam engines work to design a machine to solve the problem.

6. Have students work in small groups to identify problems they encounter because of too much or too little friction, for example, skateboarding on rough surfaces, walking in socks on a smooth floor, hitting an icy patch on a bike, sliding into base across dirt, trying to deflect a smooth soccer ball as a goalie. Challenge the groups to find a solution, mechanical or otherwise, to solve their friction problem. Ask students to prepare drawings, so they can present their work to the class.

Suggested Student Responses

When students rub the pieces of sandpaper against each other, the pieces don't move easily and they begin to wear each other down. However, they slide easily when they've been lubricated.

Extension of the Activity

Ask students to think about which objects at school slide against each other and need oil to keep friction from restricting their movement. If possible, ask the school custodian to give students a tour of the school, pointing out the elements that need lubrication. Students can also take a survey of their homes looking for things that need to be oiled.

In the Exhibit

There have been many advances in train technology through the years, as shown on the timeline and in the research and development areas of the exhibit. Transportation advances often include new ways to reduce friction. Maglev trains, for example, float above the ground, reducing the amount of friction that comes when vehicles roll across the ground. Ask students to recall the Accident Investigation. Did any of the characters remind them of Elijah McCoy? In what way?

THE TRAIN FACTORY

Guide for Grades 6-8

CONTENTS

Previsit Exploration

Some General Activities

When your students visit The Train Factory, they will be directly involved in designing, investigating, and powering trains. Because most of us take for granted the automated machines we see and use everyday, use the previsit activities to encourage students' curiosity about the basic fact that things don't move on their own—some force has to cause that motion. Help students become curious about what kind of force moves something as big as a train. Have them begin generating questions about trains.

GRADES 6-8 PREVISIT ACTIVITY

Boardom

Science Concepts

- Objects don't move unless they are pushed or pulled (by some force).
- More force is needed to move heavier objects.

Skills

Working cooperatively, describing, comparing

Suggested Time

20-30 minutes

Materials

One skateboard per group (ask volunteers to bring theirs in) If having skateboards in school is a problem, provide students with materials to make mini skateboards, such as sets of toy wheels, small pieces of wood, and rubber bands. Toy cars, trucks, motorcycles, and train engines will also work.

Procedures

1. Put a skateboard in front of the class and challenge them by saying something such as: Someone's going to have to prove to me that skateboarding is fun. Look, the skateboard just sits there. How boring. After students bring out the point that the skateboard has to be moved in order to have fun, have them briefly explain different ways a person can make it move.
2. Remind students they will be going to The Train Factory and ask them to list all the ways a skateboard is like a train. In the discussion, note that one of the major similarities is that both will only move if they have been pulled or pushed by some force. Point out the major difference: The force that moves a person on a skateboard is usually that person's muscle power, whereas the train is moved by some outside force.
3. Give each group a skateboard (or substitute) and challenge them to find a way to move the skateboard 10 feet without using their own muscle power. Have them note materials they wish they had available in the classroom and try to improvise with the materials that are in the classroom. Have groups share their efforts.
4. Ask groups to discuss what they know about how trains are powered. Tell students that for many years, people were able only to go as fast on land as they could propel themselves by their own or an animal's muscle power. About 200 years ago, people figured out how to make steam, rather than a horse, move a wagon on rails and the train was invented. Ever since trains have been improved upon. When the class goes to The Train Factory, they will see how trains are powered, and when they return, they'll use what they learned to try to move their skateboards in new ways.

Suggested Student Responses

Some of the basic similarities are that both have wheels, that both are used to transport people, and that both are moved by some kind of force. To make the skateboards move, students may try to blow on the skateboards, use ramps, construct sails, and so on. The focus should be on having students start to look at what can be used and is used to make things move.

Extension of the Activity

Have students add weight (a few books) to the skateboards and try to make them move without muscle power. Ask such questions as: How can you make the skateboard stop? How do you stop a skateboard when you are riding it normally?

In the Exhibit

Something needs to push or pull a train to start it moving. Engines, powered by steam, diesel fuel, electricity, or magnetic force, push or pull trains. The heavier the load, the more force is needed to start and stop the train.

GRADES 6-8 PREVISIT ACTIVITY

Feeling Friction

Science Concepts

- Friction slows movement.
- The characteristics of an object affect how it moves.

Skills

Working cooperatively, predicting, observing, drawing conclusions

Suggested Time

20 minutes

Materials

Metal trays (such as cookie sheets or cafeteria trays); large pieces of sandpaper; large metal paper clips, rulers; a variety of objects for each group to move on these two surfaces such as a small toy car, chalkboard eraser, large pencil eraser, chalk, glue stick, block of wood, small book, and pencil

Procedures

1. Give each small group of students a metal tray, a large piece of sandpaper, 2 large paper clips, and 4 to 5 objects to move. Tell them they will need to conduct races to determine the fastest object on two different courses: a bumpy sandy course (sandpaper clipped to the tray) and a smooth metal course (metal tray). Have them rank the objects from fastest to slowest, first as a prediction and then after they've tested each one.

2. Remind students that as they found out in the previous activity, objects must have some force exerted on them in order to start moving. To ensure an accurate ranking, the force must be exactly the same on each object. (Students may begin by pushing the objects. If so, emphasize the idea of using exactly the same amount of force. If students become stumped, suggest they place all the objects at the top of the tray and then slowly raise the top. The objects that experience less friction will move when the top is slightly raised, and the objects that experience more friction won't move until the tray is raised higher. Students can compare results by measuring the height of the tray when an object started to move.)

3. After each group has ranked their objects, have them discuss what made the fast objects fast and the slower ones slower.

4. Discuss the concept of friction, the force that causes heat and wear when two things rub against each other, and ask students how they think friction affected the race. (Objects experienced more friction when moving on the rough, bumpy sandpaper than on the smooth metal tray.

5. Ask students if some objects move differently depending on their position (pencil, glue stick, and chalk move more quickly when they are placed horizontally so they can roll, rather than vertically when they just slide). Ask students if they can combine any of the objects to make them move faster, for example, place several pencils under the book or attach the block to the glue stick with a rubber band.

6. Ask groups to discuss, based on these races, what kind of vehicle and what kind of roadway they would design if they wanted to go as fast as possible using the least amount of force (experiencing the least amount of friction). Ask students why they think trains run on metal rails with metal wheels. Have them consider the possible disadvantages to moving on a "perfect" surface, such as walking on ice.

Suggested Student Responses

Most objects move faster on metal than on sandpaper. Objects with wheels or that can roll because of their circular shapes move faster. Objects made of softer, rougher, more flexible materials move more slowly. On a perfectly smooth, fast surface, such as ice, it is harder to start and to stop.

Extension of the Activity

Have students compare skateboards with different kinds of wheels on different kinds of surfaces, such as carpet, concrete, asphalt, grass. Ask: Which wheels and surfaces make starting easier? staying in motion easier? stopping easier? When does a skateboarder want more friction and when does he/she want less friction?

In the Exhibit

Trains run on metal rails with metal wheels because it's easier to move a heavy load when there's less friction. Metal rails are hard and smooth and do not cause as much friction as dirt, grass, mud, gravel, or asphalt. Wheels reduce the amount of area that can be slowed by friction. Trains run on metal rails with metal wheels because they experience less friction that way and, therefore, require less force to start moving and to keep moving. In the Track Shop area, students will be able to investigate the effect of wheel shape on how well a train travels. They will also read about how a huge number of grasshoppers in the 1800's made tracks too slippery for trains to start or stop. Engineers figured out how to add containers of sand to locomotives so that the sand would trickle onto the track, increasing friction.

GRADES 6-8

IN-EXHIBIT EXPLORATION

Welcome aboard! You've been drafted as a mechanic trainee in The Train Factory. As you'll soon find out, your help is needed in trying to solve an embarrassing mystery—a test train crashed into the wall on one of its test runs, and no one is willing to take the blame for the accident. Before you'll be much help, though, you've got some things to learn about how trains work and what you'll need to do as a mechanic trainee. First, read the job description at the entrance to The Train Factory. The signs at each station will then tell you what to do. Be sure to fill out this form as you go.

At the Assembly Shop

1. At Project: Steam Pressure Pushes, spray water into the boiler. What happens to the water as it boils? What makes the piston move?

2. At Project: Pushing to Spin, push the pistons so that they turn the wheel. On a steam engine, what pushes the pistons?

   Look at the Baldwin 60000. Find the rods that connect the wheels to the pistons. Are all the wheels connected to the pistons?

3. At Project: Control the Flow, as you move the steam hose, watch how it pushes the piston. Draw the path the steam follows.

4. At Project: Boiler Race, you're acting as the fireman of a train. The fireman needs to tend the fire, adding just enough coal at the right times. If you add too much coal, the boiler will burst. Why?
   (Hint: Check what the pressure gauge does when you add more coal.)

At the Baldwin 60000 Locomotive

1. How can you tell the Baldwin 60000 is a steam engine?

2. A fireman and an engineer worked in the cab when steam engines like this one pulled trains. What would the fireman do during the ride? What would the engineer do?

At the Baldwin 60000 Locomotive (continued)

3. Watch the locomotive as it moves. What makes the wheels move? Do all of the wheels move in the same way?

4. About how many times bigger is the actual Baldwin 60000 than the model in Project: Boiler Race? How can you find out?

5. About 75 years ago, the Baldwin 60000 was a test engine. What do you think train makers needed to test?

At the Accident Investigation

Your help is needed to find out why a test engine crashed during a test run.

- First, go to the bulletin board to read about what happened and who the suspects are.
- Next, go to each of the areas in the investigation room and listen on the telephones or intercoms to their stories.
- Then, test the evidence with the scientific tools provided. Do all four tests.
- Finally, when you know what caused the crash, call the hot line. Then write the cause of the accident here.

At Research and Development

1. At Project: Electric Train, why does the train move when you turn the crank?

2. Scientists talk about magnetic force. What ways do you feel that force when you hold two magnets together? Does it matter how you hold the magnets?

3. Look at Project: Electro-magnet. How does the electro-magnet change when you push the button? Can you turn a refrigerator magnet on and off? Why might it be helpful to be able to turn a magnet on and off?

4. What moves the model maglev train forward? Why would a permanent magnet be a poor choice to move the train?

GRADES 6-8 TEACHER INFORMATION FOR IN-EXHIBIT EXPLORATION

At the Assembly Shop

1. Water turns to steam as it boils. As more and more steam fills the area, the steam gains enough pressure to push the piston.

2. The piston, which is being pushed by steam, moves the rods back and forth, which move the wheels round and round.

   Only the driving wheels, the large ones in the middle of the locomotive, have these rods. The four smaller wheels in front and the two smaller wheels behind hold up those sections of the engine but don't drive it.

3. Steam just pushes. This is why cylinders have valves that control the flow of steam in front of and behind the piston, pushing it one way and then the other.

4. If the fire gets too hot, the steam pressure can build so high that the boiler won't be able to withstand the pressure and so will explode. That's one of the reasons engineers and firemen use gauges in the cab that show them the level of pressure in the boiler.

At the Baldwin 60000 Locomotive

1. Steam engines have places to carry the water and the wood, coal, or oil used to heat the water. Large steam engines like the Baldwin 60000 use a tender, a separate car directly behind the engine, to hold the fuel and water.

2. The fireman tended the boiler, adding fuel to the firebox when needed. A fireman who knew a line well knew when a hill or a long flat stretch was coming and adjusted the fire accordingly. The engineer checked the gauges, watched the line ahead, blew the whistle to alert anyone near the tracks, and started and stopped the engine. The engineer didn't need to steer the train, because the tracks controlled where the train went.

3. The connecting rod, the rod which attaches the large driving wheels to the steam-pushed pistons, makes the large wheels turn. The smaller wheels turn because the engine is moving.

4. The real 60000 is about 20 times larger than the model. One way students can find the approximate scale used is to measure a section of the 60000 and its model using their arms or legs and then approximating how many times bigger the larger measurement is.

5. Railroad people wanted to make safer, faster, more efficient engines, so they'd test things such as brakes, boiler components, wheel size. This Baldwin 60000 was used for experiment with very high steam pressure. Designers wanted to figure out the best temperature for the steam, and the best way to get it that hot.

At the Accident Investigation

Cause of the accident: The Meteor had too much steam pressure in its boiler, but no one could tell because the pressure gauge did not work properly.

At Research and Development

1. Electricity from the generator moves through the wire above the train. The wire on the train, called the pantograph, carries this electricity to the electric motors on the train.

2. When students held two unlike poles together, they should have felt the strong attracting force of magnets. When they held two like poles together, they should have felt the strong repelling force of magnets.

3. Turning electricity on causes the battery to act like a magnet. Refrigerator magnets can't be turned off. If a magnet could be turned off and on, the magnetic force could be controlled. By controlling magnetic force, some inventors have figured out how to use it to lift and propel things, such as maglev trains.

4. Electromagnets in the middle of the track are turned on at just the right moment to repel a magnet on board the train, pushing the maglev model forward. If permanent magnets were used in the track instead of electromagnets, they would always be on, and there would be no way for them to push just at the correct moment.

GRADES 6-8 POST-VISIT ACTIVITY

A Rube Goldberg™ Skateboarder

Science and Social Studies Concepts

- An object doesn't move unless it is pushed or pulled (by some force).
- Magnets have repelling and attracting forces.
- Simple parts act together to make something complex.
- Creativity has allowed people throughout history and across the globe to solve problems and improve technology.

Skills

Working cooperatively, planning and conducting simple investigations, thinking critically, recognizing cause and effect, designing and testing

Suggested Time

1-2 class periods

Materials

At least two bar magnets per group and, if possible, various other magnets of different shapes and sizes; assorted materials for causing movement such as dominoes, wind-up toys, rubber bands, cardboard sheets and tubes, marbles, plastic cups, balloons, straws, paper clips, strong tape; some kind of skateboard rider, such as a plastic toy or stuffed animal; skateboard for each group

If having skateboards in school is an issue, provide students with materials to makes mini skateboards, such as sets of toy wheels, small flat pieces of wood, and rubber bands. Toy cars, motorcycles, trucks, and train engines will also work.

Procedures

1. Have students discuss what they liked and learned at The Train Factory. Be sure mention is made of the inventiveness of the people who created the original train engines and of those who continue to research new ways to travel such as maglev trains. In some ways, the machines that move these huge trains at high speeds are remarkably simple.

2. Remind students of the Previsit Activity challenge to move a skateboard 10 feet without using their own muscle power. They are now going to use their inventiveness to build a Rube Goldberg™ machine that will move a skateboard (or a substitute) at least 10 feet using at least 3 steps. Explain that Rube Goldberg designed inventions to complete simple tasks using a number of unusual steps to overcomplicate the process. For example, the string of a flying kite raised the door on a moth cage, so the escaped moths could eat a shirt, which when it weighed less tipped a balance that made a shoe hit a switch that turned on an iron whose smoke eventually led to a woodpecker sharpening a pencil.

3. Give each group a skateboard (or substitute), a toy rider, and time to discuss and experiment with the materials. Encourage students to remember what they saw cause movement at The Train Factory and to think about how the materials provided can cause movement, for example, magnets can push and pull, a line of dominoes can transfer movement from one place to another, and a balloon moves when it loses air. Students will need to figure out some combination of three elements to get their skateboards to move 10 feet.

4. If needed, extend the activity to the next day to allow plenty of trial and error time. At various intervals and upon completion, have students present their machines to the class.

Suggested Student Responses

As students experiment with their materials, they will find that simple parts can be combined to create something complex.

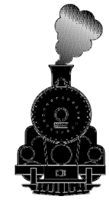
Extension of the Activity

Extend the number of steps by requiring that the skateboard turn or stop. Have students create a test track that the skateboard must clear.

In the Exhibit

The exhibit introduces students to steam, diesel, electric, and maglev trains and shows how each is powered.

FURTHER RESOURCES



FOR STUDENTS

Fiction

- *Bear on the Train*, Julie Lawson. Kids Can Press. (K-2)
- *Choo Choo: The Story of a Little Engine Who Ran Away*, Virginia Lee Burton, Houghton Mifflin. (K-2)
- *The Caboose Who Got Loose*, Bill Peet, Houghton Mifflin. (K-2)
- *Freight Train*, Donald Crews, Scholastic. (K)
- *The Little Engine That Could*, Watty Piper, Platt & Munk, Publishers Co. (K-2)
- *Smokey*, Bill Peet, Houghton Mifflin. (K-2)
- *Thomas the Tank Engine: The Complete Collection*, Rev. W. Awdry. Random House. (Or any of Awdry's Thomas the Tank Engine stories) (K-2)

- *The Great Railway Adventures Series*, Lin Oliver, Learning Curve Publishing. (K-5)
- *The Polar Express*, Chris VanAllsburg, (K-5)
- *The Boxcar Children Series*, Gertrude Chandler Warner, Scholastic. (Especially those with train terms in the title) (3-5)
- *The Railway Children*, E. Nesbit, Dover. (3-8)

NonFiction

- *All Aboard ABC*, Doug Magee and Robert Newman, Puffin Unicorn. (K-2)
- *All Aboard Trains*, Mary Harding, Grosset & Dunlap. (K-2)
- *Eye Openers: Trains*, Angela Royston, Aladdin Books. (K-2)

- *The Big Book of Real Trains*, Walter Retan, Grosset & Dunlap. (K-5)
- *DK Big Book of Trains*, National Railway Museum, DK Publishing. (K-5)
- *Railways & Trains*, Caroline Young and Colin King, Usborne. (K-5)

- *Machines and How They Work*, David Burnie, Dorling Kindersley. (K-8)
- *Stephen Biesty's Incredible Cross-Sections*, Richard Platt, Knopf. (K-8)
- *Trains*, Julian Holland, Barnes & Noble. (K-8)

- *How Things Work*, Neil Ardley, Reader's Digest. (3-8)
- *Locomotive: Building an Eight-Wheeler*, David Weitzman, Houghton Mifflin. (3-8)
- *New Technology: Transportation on Land and Sea*, Nigel Hawkes, Aladdin Books. (3-8)

- "A Race from Dawn to Dusk on the Pioneer Zephyr," by Dave Shurna. Explore!, May/June 2001, pp.22-25. (3-5)

Web Sites

- Elijah McCoy is featured on many websites such as http://web.mit.edu/invent/www/inventorsI-Q/mccoy.html. A particularly interesting site includes a reproduction and explanation of the automatic oil drip cup he invented: http://deepcnet.usi.edu/engintech/emccoy/emccoy.htm

- For trains in general, check these sites:
  - http://www.factmonster.com/spot/trains1.html
  - http://www.howstuffworks.com/steam.htm
  - http://www.howstuffworks.com/diesel-locomotive.htm
  - http://www.bytrain.org/redbarinfo/kidsrail/trainterms.html
  - http://www.ggrm.org for the Golden Gate Railroad Museum

- For train safety and classroom activities
  - http://www.oli.org/for_teachers/oli_cdrom/cdindex.html

- For the national science standards, see: http://books.nap.edu/html/nses/html/index.html . For a hard copy of National Science Education Standards, contact the National Research Council.

- For state science standards, see the following Web sites:
  - http://www.pde.psu.edu/standard/science.pdf
  - http://www.state.nj.us/njded/cccs/10sciintro.html
  - http://www.doe.state.de.us/Standards/Science/science_toc.html

- Also be sure to visit the Franklin Institute site for additional science activities: http://www.fi.edu/learning.html

Magazines

- *Science Weekly*, Subscription Department, Science Weekly, P.O. Box 70154, Washington, DC 20088-0154. http://www.scienceweekly.com Published 16 times year, this is designed for elementary classrooms.

- *Scientific American Explorations*, 415 Madison Ave., New York, NY 10017. http://www.explorations.org A magazine of family science activities that can be adapted for classroom use.