Motion & Design of Accessible Playgrounds

A Community-Connected Elementary Science & Engineering Unit

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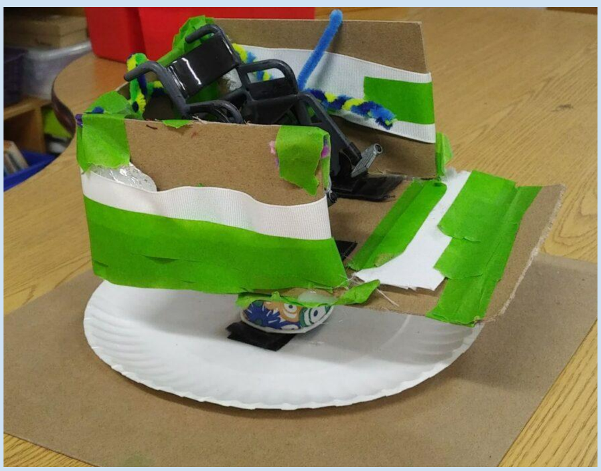
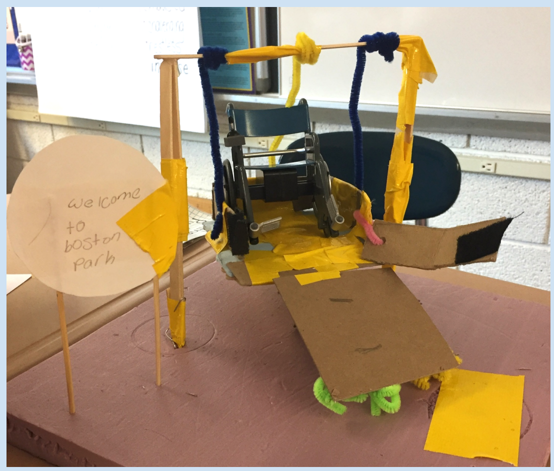
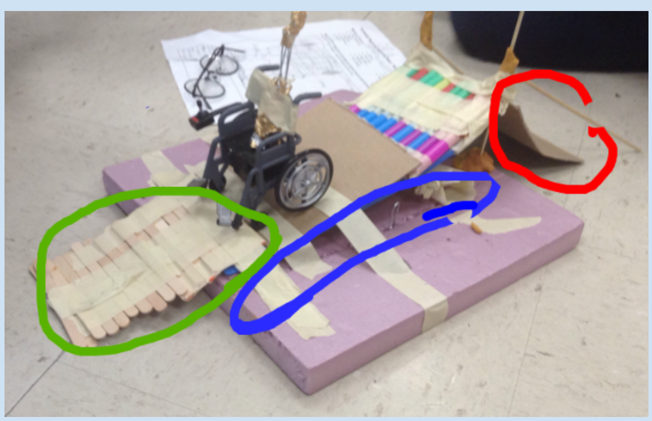






Unit Overview

In the “Motion and Design of Accessible Playgrounds” unit, 3rd grade students will explore core ideas of balanced and unbalanced forces, changes in motion, and interactions between magnets. They will have an opportunity to extend and refine these ideas as they address engineering and technology standards during an accessible playground design challenge.

This teacher guide begins with a navigation guide that overviews each day of the unit, focus questions, NGSS and Massachusetts (MA) standards, and science and engineering practices (SEPs), followed by the detailed lesson plans and required resources.

The unit addresses standards in the engineering and technology strand (3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3, 3-5-ETS1-4[MA], 3-5-ETS1-5[MA]) and in physical science (3-PS2-1: forces, 3-PS2-3: magnets).

Materials

All materials can all be purchased at general merchandise stores or through internet retailers. For a full list of material quantities and links to purchase, see the materials spreadsheet at the end of this document.

Recommended Classroom Structures

Design teams

Students should work in design teams throughout the unit. We recommend assigning students to teams of three or four before beginning the unit and having them work in the same design teams throughout the unit.

Discussing science and engineering ideas with peers can help students build knowledge in more sophisticated ways, as they articulate their own thinking, understand peers’ ideas, and decide whether and how to resolve discrepancies. Students may need explicit practice with strategies for listening to each other, re-voicing what they hear, agreeing and disagreeing, asking for clarification, and justifying their own thinking. Remember that friction can be productive, literally and figuratively! Instructors should allow students to disagree about a science explanation or design solution, but help them justify their thinking and identify the source of their disagreement. Helpful resources for supporting student collaboration in science and engineering include the Talk Science Primer[1] and WGBH Design Squad[2] videos.

[1] https://inquiryproject.terc.edu/shared/pd/TalkScience_Primer.pdf
[2] http://pbskids.org/designsquad/

Design days

On Design Challenge days in the second half of the unit, teams will plan, create, test, and iterate their designs to solve the accessible playground problem, subject to the criteria and constraints. Ideally, they will draw on and extend knowledge from previous lessons to make progress on the task.

Notebooking

We recommend students document their progress as a design team in a shared project notebook throughout the unit. With one shared notebook, students must articulate their ideas to each other to record; this allows ideas to be debated and negotiated and requires the team to come to a consensus.

Students build knowledge in more sophisticated ways when they have support for documenting their ideas, investigations, and design solutions. Not only does the act of documenting help students slow down and reflect on the quality of their ideas, but it also creates a record they can refer back to while designing, and use for end-of-unit reports or presentations. We recommend a multimedia project notebook, so that students can store text, photos, and videos. This can be done through Google Slides, or any online resource with which your students are familiar.

Note If you have access to iPads, you can use the Design Keeper app, developed by the curriculum team and available for free on the Apple App Store. First, make a free account at www.designkeeper.me and then download the app from the App Store. The app provides templates for different design activities such as ideation and testing. Each template includes fields for photos, videos, and sketches, as well as prompts for text.

Resources

All digital resources required for this unit can be accessed via hyperlinks embedded within this document. Student handouts are included at the end of this guide.

Sharing and discussion

Throughout the unit, students should have time to discuss ideas with other teams. The goals of this time are for students to reflect on their own ideas and work, to interact with their classmates' ideas and work, and to get feedback on their work. This is an intentional time to step back from the hands-on activities and dig into reasoning. For some classes, this works best at the beginning of a session, when physical materials are not yet out on tables or desks. For other classes, it's a great way to close out a lesson, when students' energy is flagging and they're no longer making much progress on hands-on work. Some structures we recommend:

- **Share-out**: Each team takes a few minutes to describe where they are in the design process and solicit classmates' feedback. Other students ask questions and give advice.
    - *Pros*: Teacher-facilitation keeps discussion on track; hear from all teams

    - *Cons*: If there are many teams, students may tune out; hard to concentrate when they want to be designing
    - *Good times*: Near beginning, to get feedback on plans and initial ideas before spending too much time designing; at end, to share final designs

- **Gallery walk**: Each team leaves their designs (and documentation) at their workspace and walks around to check out other designs (can do 5 minutes at each team, then all switch together). Often, teams leave feedback (e.g., on sticky notes) for other teams.
    - *Pros*: Get to see all designs in a shorter time period; less likely to tune out
    - *Cons*: With less teacher oversight, some teams can get off track; takes time and practice to write useful, actionable feedback for other teams
    - *Good times*: After all teams have gotten to test and can report on their results; when students are feeling stuck or frustrated and need new ideas

- **Whole class discussion**: Teacher facilitates a discussion that can be focused on a few selected designs, a problem multiple teams are encountering, a scientific explanation that needs more time or evidence, etc. For example, one approach is to pull out 2 to 3 really different designs that are all performing well to discuss what about the designs is working (which has a side benefit of highlighting solution diversity). On the other hand, if students are frustrated with designs not working well, it can be productive to discuss as a whole class specific problems students are facing and brainstorm strategies to address those issues.
    - *Pros*: Teacher can keep discussion on track; can support deeper reasoning and connections between test results and design features; teacher can push students' thinking; can change focus of discussion if interesting ideas pop up
    - *Cons*: Teams might tune out if the discussion doesn't seem directly applicable to their design
    - *Good times*: Whenever students aren't very engaged in building and wouldn't be upset at an interruption; can be any time—beginning or end of class, after some natural stopping point, when a team has a really interesting test result that the whole class would benefit from thinking about

Other recommendations

- **Access to materials**: We recommend allowing students to access samples of the building materials as they are sketching design plans for their playground structure prototypes. Most elementary students need physical models in front of them to create useful sketches of 3D systems. They benefit from planning in '3D', by holding up and gesturing with materials. Handling and manipulating materials also acts as brainstorming for many students. Encourage students to take pictures of manipulated materials to record ideas.
- **Access to testing:** Encourage students to test their playground design prototypes with the miniature model wheelchairs early and often. If students can't test on their own at their own work area, consider setting up one or more testing stations where students can bring their prototype and test it against the design criteria.

Engineering Design Problem:
Accessible Playground Structure

You are working as engineers to design one element (like a slide, swing, or merry-go-round) of a playground structure that would be fun and safe for all children, including children who use wheelchairs.

Criteria for your playground structure:
(Criteria are like a checklist for solving an engineering design problem.)

- ❏ **Is it accessible?** (Can kids in wheelchairs use it?)
- ❏ **Does a wheelchair fit on it?** (Can you show a miniature wheelchair on it?)
- ❏ **Is it stable?** (Does it stand up on its own, even when the weight of a wheelchair is on it?)
- ❏ **Is it functional?** (Can you show it really moving or working?)
- ❏ **Is it fun?** (Would real kids enjoy playing on a life-size version of it?)

Constraints for your playground structure:
(Constraints are like limits, or things that your engineering design can't do.)

- ❏ It can only use materials from the list.
- ❏ It must fit on the cardboard square.
- ❏ It must be a single element (like a slide, swing, or merry-go-round), not an entire playground.
- ❏ You only have a limited amount of time to build it.

How will you test your playground structure?

You should be able to show it working with a miniature wheelchair.

Navigation Guide

Learning Goal(s)

- Students will refine their ideas about motion and forces and engage in an engineering design process to generate multiple possible solutions for an accessible playground structure.

NGSS and Massachusetts Standards Addressed

- **3.3-5-ETS1-1.** Define a simple design problem that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost that a potential solution must meet.
- **3.3-5-ETS1-2.** Generate several possible solutions to a given design problem. Compare each solution based on how well each is likely to meet the criteria and constraints of the design problem.
- **3.3-5-ETS1-4(MA).** Gather information using various informational resources on possible solutions to a design problem. Present different representations of a design solution.
- **4.3-5-ETS1-5(MA).** Evaluate relevant design features that must be considered in building a model or prototype of a solution to a given design problem.
- **4.3-5-ETS1-3.** Plan and carry out tests of one or more design features of a given model or prototype in which… failure points are considered to identify which features need to be improved. Apply the results of tests to redesign a model or prototype.
- **3-PS2-1.** Provide evidence to explain the effect of multiple forces, including friction, on an object. Include balanced forces that do not change the motion of the object and unbalanced forces that do change the motion of the object.
- **3-PS2-3.** Conduct an investigation to determine the nature of the forces between two magnets based on their orientations and distance relative to each other.

Anchoring Phenomenon, Driving Question, and/or Design Challenge

Accessible Playground Problem: Many playgrounds have structures that are safe and fun for only some children. For playgrounds to be accessible to all children, they need to be safe and fun for children who use wheelchairs. Investigating how rolling objects move can help us design more accessible playgrounds.

- How can we use ideas about force and motion and the engineering design process to design accessible playground structures?

Meeting the Needs of Diverse Learners

- Anchor Charts, labels, consideration of groupings for ELLs and students with disabilities.

Safety Considerations

- If providing sticks or skewers as building materials, consider removing skewer points or requiring safety goggles during building sessions.

Field Trips and Outdoor Learning Opportunities

- Outdoor extension activities could be planned to visit and compare various local playgrounds.

Lesson	NGSS Alignment	What are we doing? Primary Learning Tasks	What are we figuring out? Evidence of Sensemaking
Day 1 Unit Launch	**3.3-5-ETS1-1.** Define a simple design problem that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost that a potential solution must meet. **3-5-ETS1-5.** Evaluate relevant design features that must be considered in building a model or prototype of a solution to a design problem SEP 1. Asking questions and defining problems SEP 8. Obtaining, evaluating, and communicating information	Discuss disability and language around disability. Begin scoping the design problem and researching solutions with the 7 Principles of Universal Design Launch the wheelchair-accessible playground design challenge	*What is "disability"?* *What is "accessible" and "inaccessible"?* *What is "inclusivity"?* *What's wrong with existing playgrounds?*
Day 2 INQUIRY: Motion with Ramps	**3-PS2-1.** Provide evidence to explain the effect of multiple forces, including friction, on an object. Include balanced forces that do not change the motion of the object and unbalanced forces that do change the motion of the object. SEP 3. Carrying out investigations SEP 4. Analyzing and interpreting data SEP 6. Constructing explanations	Investigate forces and motion with ramps of different heights and different surfaces	*How can we get a rolling object to move and help it to slow down?*
Day 3 INQUIRY: Motion with Weights and Stretch	**3-PS2-1.** Provide evidence to explain the effect of multiple forces, including friction, on an object. Include balanced forces that do not change the motion of the object and unbalanced forces that do change the motion of the object. SEP 3. Carrying out investigations SEP 4. Analyzing and interpreting data SEP 7. Engaging in argument from evidence	Investigate forces and motion with falling weights and stretchy materials (springs and rubber bands)	*How can we get a rolling object to move and help it to slow down?*
Day 4 INQUIRY: Floating Magnets	**3-PS2-3.** Conduct an investigation to determine the nature of the forces between two magnets based on their orientations and distance relative to each other. SEP 3. Carrying out investigations SEP 4. Analyzing and interpreting data SEP 6. Constructing explanations	Investigate how magnets interact with each other while aligned on a pencil	*How do magnets influence the motion of other magnets and objects?*

Day 5 INQUIRY: Magnets and Motion	**3- PS2-3** Conduct an investigation to determine the nature of the forces between two magnets based on their orientations and distance relative to each other. SEP 3. Carrying out investigations SEP 4. Analyzing and interpreting data SEP 6. Constructing explanations	Explore how interactions between magnets can cause changes in an object's motion	*How do magnets influence the motion of other magnets and objects?*
Day 6 DESIGN: Plan	**3-5-ETS1-1.** Define a simple design problem that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost that a potential solution must meet. **3-5-ETS1-4(MA).** Gather information using various informational resources on possible solutions to a design problem. Present different representations of a design solution. SEP 1. Asking questions and defining problems SEP 6. Designing solutions	Revisit the design problem, generate design ideas, and explore available materials and tools	*How can we use engineering design and ideas about motion and forces to solve the accessible playground design problem?*
Day 7 DESIGN: Build and Test	**3-5-ETS1-2.** Generate several possible solutions to a given design problem. Compare each solution based on how well each is likely to meet the criteria and constraints of the design problem. SEP 6. Designing solutions	Build, test, and iterate on design solutions	*How can we build our ideas for accessible playground structures?*
Day 8 DESIGN: Peer Feedback	**3-5-ETS1-5(MA).** Evaluate relevant design features that must be considered in building a model or prototype of a solution to a given design problem. SEP 6. Designing solutions	Pair up with another team to request and provide feedback on playground designs and notebooks	*How can we improve our ideas for accessible playground structures?*
Day 9 DESIGN: Iterate and Document	**3-5-ETS1-3.** Plan and carry out tests of one or more design features of a given model or prototype in which … failure points are considered to identify which features need to be improved. Apply the results of tests to redesign a model or prototype. SEP 6. Designing solutions	Make final changes to design and finish notebooks to prepare for the Design Expo	*How can we improve and document our ideas for accessible playground structures?*
Day 10 Design Expo	**3-5-ETS1-5(MA).** Evaluate relevant design features that must be considered in building a model or	With visitors, share designs, notebooks, and recommendation for	*How can we share what we have learned about the accessible playground design problem?*

	prototype of a solution to a given design problem. SEP 6. Designing solutions SEP 8. Obtaining, evaluating, and communicating information	accessible playground design	

Lesson 1: Unit Launch

Lesson 1 Overview

Activities

1. Anchor the engineering challenge to a community context. (5 min)
2. Introduce the design problem: Inaccessible playgrounds (20 min)
3. Introduce design notebooks (10 min)
4. Begin design notebooks (10 min)

Focus Questions & Objectives

- What is engineering?
- What is “accessible” and “inclusive”?
- What’s wrong with current playgrounds? Why are they inaccessible?

NGSS Alignment

3.3-5-ETS1-1. Define a simple design problem that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost that a potential solution must meet.
3-5-ETS1-5. Evaluate relevant design features that must be considered in building a model or prototype of a solution to a design problem

Materials

- Videos, books, or resources you plan to use (see note below)
- Student notebooks
- Miniature model wheelchair
- Photos(s) of design expo (link in Step 4)

Preparation

Optional: Borrow, download, or purchase any books or resources you might like to have on hand for students to learn more about disabilities.
Some resources include:

- Shane Burcaw’s "Not So Different: What You Really Want to Ask about Having a Disability" for grades 1-3
- Teaching Tolerance: https://www.tolerance.org/classroom-resources/tolerance-lessons/understanding-disabilities
- Little Parachutes’ books for purchase: https://www.littleparachutes.com/category/health/disabilities/

Lesson Sequence

1. Anchor the engineering challenge to a community context (5 min)

Ask students what they like to do in their free time and connect it to the playground. Have students describe what the playground or park in their neighborhood looks like and invite students to draw pictures of what they want their playground in their community to look like. Some questions to ask include:

a. What do you like the most about your playground?
b. What did you include in your playground design?
    - *Ideas can include music instruments for students who like music, monkey bars for students who like heights, or toddler swings for students with younger siblings*

2. Introduce the design problem: Inaccessible Playgrounds (20 min)

If you have access to educators who specialize in working with students with physical disabilities, invite them to visit your classroom and lead parts of this lesson. They may be able to provide valuable insight and are experienced in conversation about disability.

A. Discuss "disability" with students:
    a. What is a disability? (Focus on physical disabilities. Disabilities can include deafness, blindness, cerebral palsy, epilepsy, spinal cord injury…)
    b. Do you know anyone who has a disability?
    c. How can having a disability affect the way people navigate through the world? (Focus on how people do things differently, not wrong. Be careful with wording and be sure to make use of person-first language, such as "people with disabilities" vs. "the disabled". Remember their disability is not their whole identity.)

B. Show a video of a child in a wheelchair being unable to get around a playground ["4yo daughter struggling in wheelchair at Gianetti Park in Carbondale CO May 2015"]
    a. Debrief the video with students, ask what the problem was and how it made them feel when they saw the girl struggling to get across the playground.
    b. Discuss the concepts of "accessibility" and "inclusion"—Why do we want playgrounds to be accessible? Why is it important that all kids can play together?

C. Introduce The 7 Principles of Universal Design, which are listed below in kid-friendly language. Explain to students that these universal design rules are used to create inclusive design solutions that allow people of all levels of ability to use and access things on their own.
    1. Everyone can equally use it.
    2. It can be used in different ways by people with different abilities.
    3. It is simple and easy to understand.
    4. Information and instructions are easy to understand.
    5. It is safe to use.
    6. It does not require a lot of muscle.
    7. It has enough size and space for anyone to use.

    a. Ask "How can everyone benefit from universal design regardless of disability?"
    b. Ask "Which of these 7 universal design rules do you think will be most important to keep in mind while you are doing playground design?"

D. Show this video of an inclusive playground ["Bremerton Beyond Accessible Playground"]
    a. Ask "How is this playground different from the first one we saw?"
        - *Students might share ideas like: "ALL kids can play on it", "Kids can play together," and "Wheelchairs fit on the structures"*

b. Ask: How is universal design used in the Accessible playground? Responses can include:
    - *Equitable Use (#1): Open playground to children on all abilities*
    - *Flexible in Use (#2): Children are laying down, sitting up, and standing on the spinning carousel thing*
    - *Size and Space for Approach and Use (#7): wheel-chair user on the wide ramp*

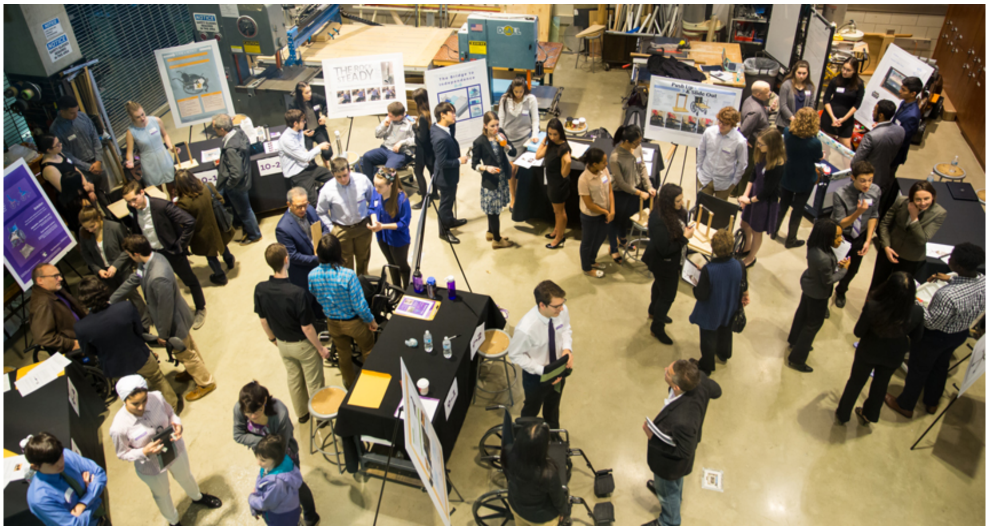
E. Generally describe the task students will be solving: designing one element (like a slide, swing, or merry-go-round) of an accessible playground structure . First, they will figure out ways to make things move and slow down, then they will get to design, build, and test their playground element. You can show students the model wheelchair they will be using to test their playground element to give them an idea of scale. They'll get many more details and unpack the task in the next few weeks.

3. Introduce engineering design, design notebooks, and design expo (10 min)

A. Elicit students' ideas about engineering by asking:
- What is engineering?
- What do engineers do?
- How do engineers use universal design principles in their work?
- What do engineers use to solve their problems and create design solutions?

B. Introduce design notebooks by helping students think about why and how they might want to document their process during an engineering design project:
1. Where have they kept notebooks before?
    - *Students might say: "reading", "science"*
2. What kind of information did they keep in those notebooks?
    - *Students might say: "reflections," "ideas," "sketches," "predictions," "results"*
3. Why is it important to write down our observations, instead of just noticing them in the moment?
4. In addition to *observing* the world, engineers also design solutions to *change* the world. For example, engineers design bridges to cross rivers and wheelchairs to help people move around. What things might *designers* need to write down in a notebook?
    - *Students might say: "lists of materials," "examples of designs they see"*
5. Other than words, what might we want to include in an engineering design notebook?
    - *Students might say: "pictures", "videos", "drawings", "diagrams"*

C. Choose from among these [photos of a design expo] and show them to students to preview how the unit will culminate.[3] Tell students that they will use their notebooks and constructions to present their recommendations at a “design expo” for accessible playground structures. The notebooks will be an important source of evidence for supporting their recommendations.



4. Start design notebooks (10 min)

A. Help all students begin to use their design notebook to document the goal of the accessible playground design task. You may distribute or display the Design Brief, which lists criteria and constraints. Emphasize that each team is not designing a whole playground, but just one element (like a slide, swing, or merry-go-round) of a playground structure.

Engineering Design Problem:
Accessible Playground Structure

You are working as engineers to design one element (like a slide, swing, or merry-go-round) of a playground structure that would be fun and safe for all children, including children who use wheelchairs.

Criteria for your playground structure:
(Criteria are like a checklist for solving an engineering design problem.)

- **Is it accessible?** (Can kids in wheelchairs use it?)
- **Does a wheelchair fit on it?** (Can you show a miniature wheelchair on it?)
- **Is it stable?** (Does it stand up on its own, even when the weight of a wheelchair is on it?)
- **Is it functional?** (Can you show it really moving or working?)
- **Is it fun?** (Would real kids enjoy playing on a life-size version of it?)

Constraints for your playground structure:
(Constraints are like limits, or things that your engineering design can't do.)

- It can only use materials from the list.
- It must fit on the cardboard square.
- It must be a single element (like a slide, swing, or merry-go-round), not an entire playground.
- You only have a limited amount of time to build it.

How will you test your playground structure?

You should be able to show it working with a miniature wheelchair.

[3] http://www.mccormick.northwestern.edu/news/articles/2017/12/segal-design-expo-showcases-innovative-projects.html

Lesson 2: Inquiry: Motion with Ramps

Lesson 2 Overview

Activities

1. Introduce the toy car as a wheelchair model (5 min)
2. Ramp stations (20 min)
3. De- brief and sense-make as a whole class (15 min)
4. Playground design idea brainstorming (5 min)

Focus Questions & Objectives

How can we get a rolling object to move and slow down?

Students investigate how the motion of a car is changed by the forces it experiences on ramps of different heights and ramps with different surfaces.

NGSS Alignment

3-PS2-1. Provide evidence to explain the effect of multiple forces, including friction, on an object. Include balanced forces that do not change the motion of the object and unbalanced forces that do change the motion of the object.

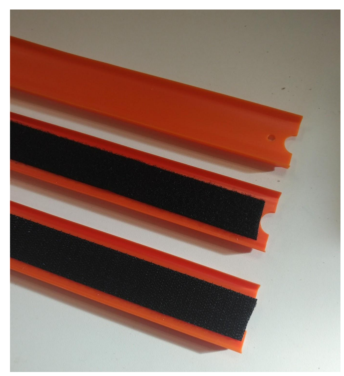
Materials

Station 1—Varying-height ramp station: (x 2-4, depending on number of student groups)

- Hot Wheels track (1)
- Various heights to prop up the track (books, buckets, etc)
- Small wooden toy car (1)
- Measuring tape

Station 2—Varying-surface ramp station: (x 2-4, depending on number of student groups)

- Hot Wheels tracks with different surface properties (3)
  - Hook side of velcro
  - Loop side of velcro
  - Without Velcro
- Small wooden toy car (pictured above) (1-2)
- An item to prop up tracks
- Measuring tape



Other:

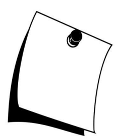
- At each station, copies of the Motion Inquiry Instructions handouts (included at the end of this guide)
- Miniature wheelchair
- Student notebooks

Core Science Ideas for Lesson 2

The main idea we want to get across to students in all of these inquiry lessons is that they have the ability to figure out how ramps, springs, magnets, etc., work on their own-- they don't have to obtain the "right answers" from the teacher or a book. We want to emphasize starting from their ideas and pushing for evidence to help refine their ideas, rather than attempting to get to a textbook definition.

Content: The goal is for students to develop a deeper conceptual understanding of things like "gravity" and "friction" beyond just stating that "gravity" makes cars speed up and "friction" slows them down. Some ideas students might start to grapple with:

- Multiple forces can act on an object at the same time.
- There is a force (that we call "gravity") that pulls things toward the earth, which can make a car speed up down a ramp, or slow down a rocket blasting up.
- There is a force (that we call "friction") that acts between two surfaces, usually slowing down motion. The amount of friction depends on the properties of the surfaces and whether something is already moving or not (it's harder to get something started moving than to keep it moving).



Note: There is friction between the wheels and the surface, but there is also friction between the wheels and axles (at the wheel bearings). Students might bring this up, especially if their wheels don't spin well!

- **BALANCED forces DO NOT change motion**
  - If there are no forces acting on an object OR if the forces acting on an object balance each other out (e.g., the pull toward the left has exactly the same amount of force as the friction pushing to the right), it will not *CHANGE* its motion. The object can still be moving, just not speeding up, slowing down, or changing direction (e.g., a car is traveling at a constant speed, it either has no forces acting on it, or the forces are balanced).
- **UNBALANCED forces DO change motion**
  - A CHANGE in speed or direction is a result of UNBALANCED forces (e.g., if gravity is stronger than friction, the car will speed up as it goes down the ramp. If friction is stronger than gravity, it will slow down.)

Preparation

Prepare the varying-surface ramps by adhering the "hook" side of the velcro to one length of track and the "loop" half of the velcro to another length of track. Make sure to also include a plain smooth piece of track at each varying-surface station. To keep the investigation manageable, use the same length of track for all three surface conditions so that **ramp height** and **ramp surface** are the only variables.

Lesson Sequence

1. Introduce the toy car as a wheelchair model (whole class: 5 min)

A. Remind students of the overall unit goal: *Design accessible playground structures*. Playgrounds involve lots of movement, so in order to accomplish this goal, we will spend the first four lessons figuring out how to make things move and stop safely.

B. Engage and elicit: Hold up a toy car and a miniature wheelchair (or have students briefly explore them In small groups) and have students identify how the two objects are similar and different. Then facilitate a whole-class discussion asking students:
   a. What is a wheel?
   b. Why do we use wheels?
      - Help students extend their ideas by letting them know the wheel is an important human invention that helps solve daily problems, such as moving heavy loads
      - Reference objects they know that use wheels (e.g., Heelys, skateboard, etc.)

C. Explain that the toy car will serve as a substitute for the miniature wheelchair for the students' explorations of rolling objects. We are using the car as a *better model of a wheelchair rolling on a real playground* because the wheels of the miniature wheelchairs don't roll smoothly. Ask the focus question:

   How can we get this rolling object to move and to slow down?

D. Allow students to brainstorm ideas and record their ideas on a whiteboard or big paper. Display these ideas in a location that can be revisited frequently as students work toward the accessible playground design task.

E. When students run low on ideas, tell them that today they will focus on figuring out a basic way to change an object's motion: a ramp.

2. Ramp stations (in groups: 20 min total)

Explain to students that they will be working in their design teams. These are the groups with which they will eventually design, build, and test a playground structure element. They'll use one notebook per group to record what they do and observe at each station.

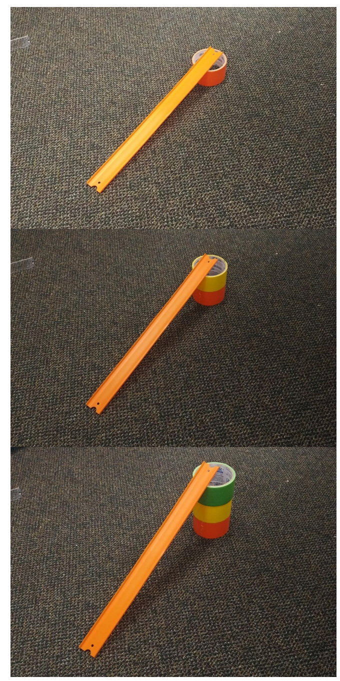
Tell students they'll have plenty of time at each station to explore (10 minutes). Their main goal is to notice differences in the car's motion on different ramps, and try to figure out why those differences occur. This is an opportunity for students to practice coming up with questions and attempting to answer them through experimentation.

A. **Think-pair-share about the station materials:**
Briefly show the materials for the two stations. Allow students to make observations of the materials and set-up. Then, have them quickly do a Think-Pair-Share or Turn-and-Talk about some of the questions they can investigate.

Using students' ideas, help them understand that Station 1 involves investigating how ramp height influences the car's motion and that Station 2 involves investigating how ramp surface influences its motion.

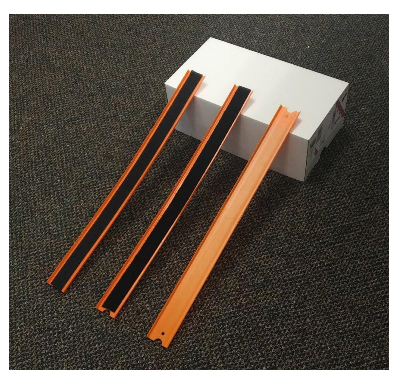
Note: A graphic organizer such as a T Chart can assist students with organizing their thinking.

B. **Describe the two stations:**
Read the station instructions to the whole class, or let students know they will be reading the instructions at the stations.



1. **Varying-height:** Show ramps set at different heights (or draw a few on the white board).
   Ask students:
   "If we release a toy car at the top of each of these ramps, will the cars reach the bottom at the same time? Which one will go faster?"
   - Have students record their predictions. They can choose to share for a moment with their neighbor or silently predict on their own..

Note: You can use anything to prop up the track. Books, rolls of tape, tissue boxes, shoe boxes, etc. The ramp does not need to be very high to work.



2. **Varying-surface:** Show the different tracks (hook velcro, loop velcro, without velcro) and again, ask students: *"If we release a toy car on track with ___ material and ___ material, will they reach the bottom at the same time? Which one will go faster?"*
   - Again, have them record their predictions, share quickly, or silently predict.

C. **Have teams go to each station:**
Allot 10 minutes for students to explore at each station. Circulate as students work with their groups. Ask for their observations and then prompt them to try to explain WHY they think things are happening (e.g., press for reasons why "steeper is faster"). Help students pay attention to the differences in the car's motion between different ramp set-ups

3. De-brief and sense-make as a whole class (15 min)

A. First, talk about the **varying-height station**. Ask students:
   a. What did you notice at this station?
   b. What do you think might be causing the car to speed up or slow down?
   c. Under what conditions was the car faster or slower?

B. Then, press for deeper understanding:
   a. Ask for evidence: **HOW** do they know that car went faster?
      - *Did they measure and record it, or was it obvious to see? Prompt students to consult or share from their notebooks to provide evidence for their statements.*
   b. Probe deeper: **WHY** do they think the higher/taller/steeper ramp made the cars go faster?
      - See if they bring up ***gravity*** on their own. If they do, probe their understanding of gravity--is it the same force on all the cars?

C. Then, talk about the **varying-surface station**. Again, ask students what they observed:
   a. **WHY** do they think the cars went different speeds on different surfaces?
      - If they bring up ***friction***, ask what that means to them. What is friction? Why does it slow things down? Do the different surfaces have different amounts of friction?

4. Brainstorm playground design ideas (5 min)

A. Have students get back into groups and use what they have figured out about ramps and motion to document their first ideas about what to build for their element of an accessible playground structure (like a slide, swing, or merry-go-round).

Extension questions (extend and reflect on initial ideas).

A. How is the toy car situation different from a wheelchair?
   - *Students might say: safety, different size/shape*

B. How is the toy car situation different from a real car?
   - *Students might say: real cars have ways to generate their own power to go faster and slow down*

Lesson 3: Inquiry: Motion with Weights and Stretch

Lesson 3 Overview

Activities

1. Anchor the inquiry to shared experiences (10 min)
2. Explore motion stations: falling weights and stretch (20 min)
3. De- brief and sense-make as a whole class (15 min)

Focus Questions & Objectives

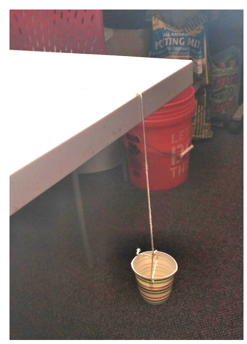
How can we get a rolling object to move and slow down?

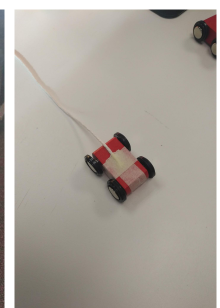
Investigate forces and motion with falling weights and stretchy materials (springs and rubber bands).

NGSS Alignment

3-PS2-1 Provide evidence to explain the effect of multiple forces, including friction, on an object. Include balanced forces that do not change the motion of the object and unbalanced forces that do change the motion of the object.

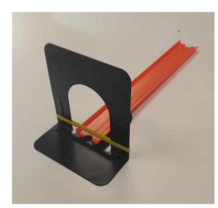
Materials





Station 1—Falling weight station (x3):

- Small wooden toy car
- Cup, string, and weight (washers or pennies)
  - Assemble: Attach string to cup (poke holes through sides), attach other side of string to car (tape, hot glue).
- Measuring tape



Station 2—"Stretch" station (x3):

- Small wooden toy car
- Spring assembly (see *Preparation*)
- Rubber band assembly (see *Preparation*)
- Measuring tape

Other

- At each station, a few copies of Motion Inquiry Instructions handouts
- Student notebooks

Core Science Ideas for Lesson 3

While Lesson 2 explores gravity and friction, Lesson 3 adds elastic, or "spring," forces. Trust students' capacity to reason about how objects move on their own--they don't have to get the "right answers" from the teacher or a book. The main goal is to give students an opportunity to observe and wrestle with the idea that only UNBALANCED forces change motion.

If no forces are acting on an object OR the forces acting on an object are balanced, it will not CHANGE motion. It can still be moving, but it will not speed up, slow down, or change direction (e.g., if a car is traveling at a constant speed, it either has no forces acting on it or the forces are balanced.)

A CHANGE in motion is a result of UNBALANCED forces (e.g., if gravity is stronger than the friction acting on the car, the car will speed up as it goes down the ramp. If friction is stronger than gravity, it will slow down.)

In Station 1, the car attached to a falling weight is only affected by gravity and friction. In this case, gravity is pulling down on the cup, thus the more the cup weighs , the faster the car will go. The length of the string affects how much time gravity has to pull on the cup, which pulls the car.So, the longer the string, the faster the car will go because of the unbalanced forces acting on the cup and car.

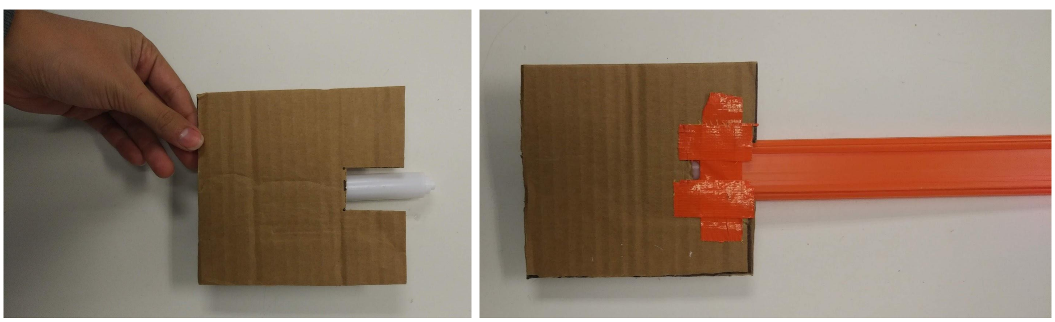
In Station 2, the springs and rubber band look different from each other, but they are actually very similar in how they affect motion. Students will likely notice that the farther you pull back the spring or rubber band, the more force they will impart to the car and the faster the car will travel.

Preparation

1. **Falling Weight Set-up.** Attach string to a small paper cup by poking holes through the sides of the cup and hanging it from one end of the string like a basket. Attach the other side of the string to the car with tape or hot glue. Place pennies in the cup as weights.

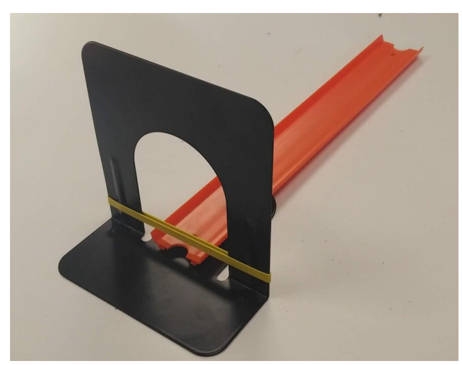
2. **Spring Set-Up**. Students use the spring in a toilet paper holder to launch a car down the track. To make this easier, use hot glue to attach a toilet paper holder to a piece of cardboard, as shown below. Cut a slot on the cardboard to attach a piece of hot wheels track with tape along the bottom.

TOP VIEW OF SPRING SET-UP



BOTTOM VIEW OF SPRING SET-UP

3. **Rubber Band Set-Up.** Tape a piece of plain hot wheels track to the metal bookend. Choose a rubber band to stretch around the bookend and slide it down near the track. You may choose to provide each station with a few different rubber bands with a variety of thickness and stretchiness. If you choose to use one type of rubber band, the thicker ones tend to work better.



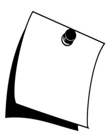
Lesson Sequence

1. Introduce the new motion inquiry stations (10 min)

A. Review what students figured out in the ramp lesson. What forces were important with the ramps? (gravity and friction; maybe they'll think of something else). Either introduce or review the idea that:
Balanced forces do NOT change motion, unbalanced forces DO change motion

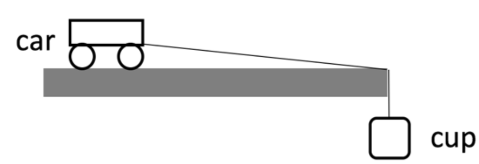
B. The previous stations focused just on ramps. Today we'll consider other simple ways to change motion -- that is, to make the car speed up, slow down, or change directions. Students will again be working in their design teams. As before, they'll record what they do and observe at each station in their notebooks. Today we're thinking about the same focus question:
How can we get a toy car to speed up and how can we get a toy car to slow down?

C. Show students the materials for the falling weight station and the stretch station. Then, have them quickly do a Think-Pair-Share or Turn-and-Talk about some questions that they can investigate with these materials.

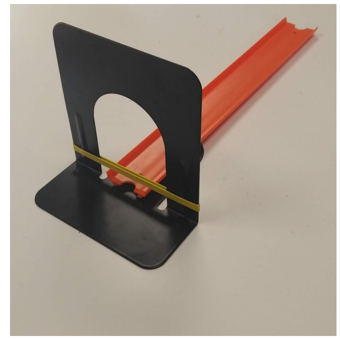


Note: You might make a T Chart or some kind of graphic organizer to record student ideas about how each station might be used. Students can then connect back to their initial ideas during the de-brief discussion.

D. Demonstrate how to use each station.

Falling weight station: Show students the set-up— a car on the table, with a string tied around the car that hangs off the table and is connected to a cup with weights. Explain that they will change the amount of weight in the cup and see how it affects the car's speed.	

Stretch station - spring: Show the spring assembly (the cardboard with the toilet paper holder attached). Show students how they can push a car back against the holder to the different lines and see what happens. It may be interesting to take apart a toilet paper holder to show students the spring inside.	

Stretch station - rubber band: Stretch a rubber band across the bookend close to the track as shown. Show students how they can pull back the rubber band to hit the car and see what happens. Tell students they can experiment with different ways of making the car speed up and slow down with the rubber band by pulling the rubber band different distances or using different types of rubber bands.	

E. To summarize, reiterate that Station 1 (falling weight) involves investigating two variables—weight and speed. *How will the weight change the car's speed?* Station 2 involves investigating how the stretchiness of the spring/rubber band changes the car's speed. *How will the amount of stretch change the car's speed?*

2. Explore motion stations (in groups: 20 min total)

A. Allot students 10 minutes to explore at each station before they rotate.

B. Circulate as students work with their groups. Ask for their observations and then prompt them to try to explain WHY they think things are happening. Help students pay attention to the difference in the car's motion as they make changes to the station set-up.

3. De-brief and sense-make as a whole class (15 min)

A. Review the stations:
   - What did you notice at this station?
   - What do you think is causing the car to speed up or slow down?
   - Under what conditions was the car faster or slower?

B. Create a table to organize what students have figured out from the different stations (see next page). Depending on what students have been figuring out at the stations, it might make sense for you to fill in the "Forces" column and then facilitate students' contributions to the "What affected how strong the force was?" side. Creating this chart and discussing it can also become part of the extension lesson (see page 25), if you have an extra day.

	What forces changed the car's motion?	What affected how strong the force was?
Ramp	Gravity, friction	Steepness, surface properties
Falling weight	Gravity, friction	Amount of weight (or number of weights)
Spring	Spring force	How far it was pushed back, how many springs were used
Rubber band	Spring force (Can also be labeled "elastic force" or whatever seems natural)	How far pulled back, 'strength' of rubber band, thickness of rubber band
Other forces	(Allow students to name other forces)	

(Optional) Lesson 3 Extension: Refocus on design task

If you have time after exploring the ramps, falling weight, springs, and elastic, you may want to revisit the design task before moving on to explore magnetic forces.

Part 1: Further define the design problem (10-15 min, whole class)

Have groups sit together with their design notebooks. Have every group turn to the page where they initially recorded the design goal of creating accessible playground structures. Today, groups will add detail to their design goal by filling in **criteria** and **constraints**.

a. Generate a class list for "Our accessible playground structure designs will be successful if…."
    - Examples are provided in the table below.
    - After generating the list, give it the heading **criteria**, which means *things the design needs to have or be able to do*.
b. Generate another list for "The limits on our playground structure designs are…"
    - Examples are provided in the table below.
    - After generating the list, give it the heading **constraints**, which means *limitations or rules for the designer or design process.*

"Our accessible playground structure designs will be successful if…." **(Criteria)**	**"The limits on our playground designs are…"** **(Constraints)**
• Wheelchair fits on the structure • Safe (can have discussion around safety) • Easy to use/get on (some students feel strongly that kids can use it independently, that's fine! But don't have to insist every group uses that criteria) • Non-wheelchair bound students can also use • Some groups might want it to be accessible for little kids, blind students, more than one kid at a time…whatever a group decides they're passionate about is generally fine! • (These can also be modified during the design days, if some criteria is too difficult)	• 3 days to build • Only provided materials • Fits on cardboard • Only one element, not a whole playground • Whatever else students want that are reasonable

Part 2: Brainstorm design ideas (15-20 min, in design groups)

Have students get into design groups and use what they figured out during the two force and motion days to sketch and label a few ideas about what to build for their element of an accessible playground structure. Emphasize that at this stage, all ideas are welcome—recording an idea does not commit a student to actually creating and testing that idea! It's better to have too many ideas recorded than too few. It's fine at this stage for individual students to record different ideas—they don't have to agree as a team on ideas right now.

Lesson 4: Inquiry: Floating Magnets

Lesson 4 Overview

Activities

1. Introduce focus question with a hidden magnet (5 min)
2. Floating magnets exploration (20 min)
3. Whole-class sensemaking discussion (15 min)
4. Label magnet poles (5 min)

Focus Questions & Objectives

How do magnets influence the motion of other magnets and objects?

Investigate how magnets interact with each other while aligned on a pencil.

NGSS Alignment

3-PS2-3 Conduct an investigation to determine the nature of the forces between two magnets based on their orientations and distance relative to each other.

Materials

Hidden magnet

- Needle
- Pile of non-metallic objects
- Bar magnet wrapped in paper or a bag

Floating magnets (1 set-up per small group)

- Unsharpened pencils (2) stuck vertically in clay balls (or play-doh cups)
- Ring magnets (3) with sticker (any kind) on south pole side
- 2” x 2” squares of craft foam and/or cardstock (or manila folder, index card, etc.) (2)
- Ruler

Other

- Floating magnets instructions handout
- Student notebooks

Core Science Ideas for Lesson 4

The goal for today is for students to begin to play with the idea that magnets can cause changes in motion because they can push and pull. Students have the ability to figure out how magnets work on their own--they don’t have to get to the “right answers. Start from students’ own ideas and language, and then press for evidence to help them refine their ideas.

Magnets exert magnetic forces in the space around them, and this area where their force can be felt is called the *magnetic field*. Magnetic fields exert forces that are invisible. However, the *effects* of these forces can be observed. Certain objects experience magnetic forces as a push or pull; these are magnetic objects. However, not all objects are magnetic. Examples of non-magnetic objects include paper or foam. These non-magnetic objects do not feel any magnetic forces, nor do they change the magnetic field around a magnet. The strength of magnetic forces increases as a magnetic object moves closer to the magnet and decreases as the object moves away from it. All magnets are bi-polar, meaning they have two *poles*, called north and south. Note that poles are an important *property* of magnets; they are not a physical part within the magnet.

A bar magnet has a north and a south pole. If cut into two parts, it does not lose its polarity. Rather the two new pieces will each have their own north and south pole. Note that magnets of the same shape can have poles in different locations. A magnet marked with its north and south pole can help you identify the location of poles on an unmarked magnet. The same pole of two magnets will *repel* each other while unlike poles will *attract* each other (i.e., “opposites attract”!).

The explorations in Lessons 4 and 5 highlight the following properties of magnets and magnetic forces:

- Some objects are magnetic, while some are not.
- Like poles of a magnet repel each other while opposite poles attract.
- Magnets have a “magnetic field” around them. Any magnetic material coming in this field feels a magnetic force of attraction or repulsion.
- The strength of the magnetic force of attraction or repulsion changes with changing magnetic field.

Preparation

1. Add stickers to the magnets on their south pole sides. Students will notice that interacting “stickered sides” exhibit different behaviors than interactions between stickered and non-stickered sides. We will wait to introduce the conventional labels of “north pole” and “south pole” until after students have observed that different sides of the magnets do different things. For now, mark the **SOUTH** side of every magnet with a small sticker, paint, or marker). You can use the labeled N/S magnet to determine which side is south.

2. Set up for the hidden magnet introduction
    - Hide a needle in a pile of non-metallic objects (eraser, pencil, sticky notes, paper scraps, etc.) in a tray.
    - Hide a bar magnet in paper or a bag so that students cannot tell there is a magnet inside. Check that the needle is clearly visible when stuck to the outside of the paper or bag.

3. Prepare materials for floating magnets exploration
    - Push pencils into clay or play-doh, 2 per small group.
    - Cut 2”x2” squares of cardstock (or index cards or manila folders, etc.) and/or craft foam. Poke a hole in the center, so that it fits over the pencil.
    - Allot 4 or more stickered ring magnets for each small group.

Lesson Sequence

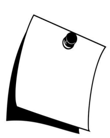
1. Introduce focus question with a hidden magnet (5 min)

A. Without mentioning magnets, tell students: *"I lost a needle somewhere in a big messy pile and I need help finding it!*." Before students share their ideas, ask students if they know what a needle is. Ask, *"What does it look like? What does it feel like?"* Also communicate the safety procedures of using needles.

B. Hide a needle in a pile of non-metallic objects (eraser, pencil, sticky notes, bits of paper, etc.) on a tray to show to the students. Tell the students about the different objects that might be in the pile. Ask students to suggest ways to help you find the needle. Then, use a bar magnet wrapped in paper or a bag as your "detective wand" to help you separate the needle from the pile. *Don't tell students that there is a hidden magnet.*

C. Ask students if they can guess how the needle was detected and ask why. Finally, reveal the hidden magnet and present the focus question of the day: **"How do magnets affect motion?"**

2. Floating magnets exploration (in groups: 20 min)



Note: This activity asks students to "float" or "levitate" ring magnets above each other using an unsharpened pencil to keep them aligned. If the magnets are stacked so that the like poles face each other, the magnetic force of repulsion will cause the top magnet to float, or levitate, above the bottom magnet. The pencil keeps the magnets aligned, ensuring that they cannot slide out or flip.

A. Show the pencil-clay stand and put one ring magnet on the pencil. Ask *"What do you predict will happen if I put another magnet on top of this one?"*

B. Record a few predictions, but don't yet add another magnet. Students will try this in small groups.

C. Review the handout with instructions about how to explore magnet interactions with the materials you have prepared. Make sure students are prepared to record their observations.

D. Circulate as students work with their groups. Ask for their observations and then prompt them to try to explain WHY they think things are happening. Help students pay attention to the difference in interactions between "stickered" sides of magnets and non-stickered sides.

E. **Optional:** Once students have all the magnets floating on top of another, challenge students to slowly pick up the pencil and hold it horizontally. Ask students what they observe and why they think it is happening. The magnets will spread apart further when the pencil is held horizontally. If they stand the pencil again, the magnets will slide closer to each other, but still spread apart with some space. The magnets are closer to each other in the vertical orientation because gravity acts along the pencil, and gravity pulls downward on the top magnet. Gravity's downward pull reduces the effect of the magnetic force that is pushing the magnets apart. In the horizontal orientation, only the magnetic force affects the magnets' motion along the pencil. There is nothing to pull them together, only the magnetic force to push them apart.

3. De-brief and sense-make as a whole class (15 min)

A. Ask students what they observed and noticed:
   - What did you notice at this station?
   - Were you able to get the magnets to hover or levitate? How? (Have students demonstrate.)
   - What does that tell us about magnets?
   - What effect did adding more magnets have?

B. Press for deeper understanding:
   - Ask for evidence: "How do you know that *X* happend?"
     - Did they measure and record it, or was it obvious to see? Prompt students to consult or share from their notes to provide evidence for their statements.
   - Probe deeper: "**WHY** do you think adding more magnets did *X?* Why did the foam or paper do *X"*
     - Allow them to bring up ***forces*** on their own. Do they see a connection between magnetic forces and other forces like gravity?

4. Label magnet poles (5 min)

A. Take a moment to help students align the idea of magnetic poles with the sticker/plain sides of the ring magnets.
   - "We noticed in our exploration that magnets have two sides, the sticker side and the non sticker side. Scientists have a fancy word for that called "poles." All magnets, just like the ones you explored today, have two poles. Scientists call these two poles "north" and "south".
   - Show that a bar magnet that is colored and labelled N/S.
   - Ask the class how they could find out which pole the "sticker" side of your class magnets is. *It will be the same pole as the one it repels* or *It will be the opposite pole as the one it attracts*.

- Choose one of these methods and reveal that the sticker side of the ring magnet is the conventionally called south pole.

B. If you have time, you can distribute some other kinds of magnets and let students practice finding poles using labelled bar magnets. You could also do this as a whole class.

Lesson 5: Inquiry: Magnets and Motion

Lesson 5 Overview

Activities

1. Make predictions about magnets and motion (5 min)
2. Make an exploration plan (5 min)
3. Explore how magnets can change wheelchair motion (15 min)
4. Whole-class sensemaking discussion (15 min)
5. Brainstorm design ideas (5 min)

Focus Questions & Objectives

How do magnets influence the motion of other magnets and objects?

Explore how interactions between magnets can change an object's motion

NGSS Alignment

3- PS2-3 Conduct an investigation to determine the nature of the forces between two magnets based on their orientations and distance relative to each other.

Materials

For each group

- MIniature wheelchair with ring magnets taped to its front and back
- 6 ring magnets with sticker on south pole side
- Student notebooks

Preparation

1. For each small group, prepare a miniature wheelchair with one ring magnet taped to its back and one ring magnet taped to its front, stickered sides facing out.

2. Set out 6 additional stickered (on south pole side) ring magnets for each group.

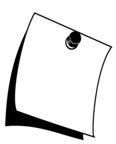
Lesson Sequence

1. Make predictions about magnets and motion (whole class, 5 min)

A. Show students a miniature wheelchair with ring magnet taped to its front and back, sticker side (south pole) side facing out. Hold up a second ring magnet, sticker side (south pole) facing the students.

B. Ask students to predict: *"Notice that there are magnets attached to this wheelchair. I have another magnet in my hand. What do you think will happen to this wheelchair if I hold this magnet an inch away from it? Why do you think that?"* Record student ideas.

C. Hold the handheld magnet one inch from the magnet attached to the wheelchair, with south poles facing each other. Ask students: *"What did you notice?"* and *"Why do you think that happened?"*



NOTE: The wheelchair should move away from your hand as its magnet feels a repulsive force from the magnet in your hand. The wheelchair will stop moving once the wheelchair's magnet is too far away for the repulsive magnetic force to overcome the friction force between the chair and the table surface.

2. Make an exploration plan (small groups, 5 min)

A. Ask students, *"I am going to give each group a miniature wheelchair with two magnets attached to it. You'll also get 6 ring magnets. What do you think are some other ways you could use magnets in your hands to change the motion of the wheelchair?"*

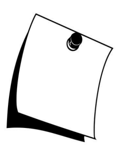
B. Record a few student ideas.

C. Before distributing materials, have students write or draw an exploration plan for their group. Each group should come up with at least three ways they could try to influence the wheelchair's motion with handheld magnets. Have them make a plan for how they will work together to try out their ideas. Will they take turns trying the same thing, and then all try another thing? Or will they each try a different strategy in turn? For example, one group member might hold the stickered side of a magnet near one of the wheelchair magnets and keep their hand very still. Another student might hold the stickered side of the magnet near a wheelchair magnet, but move their hand quickly toward the wheelchair as it starts to move. Another student might try holding three ring magnets in her hand and slowly moving her hand toward a wheelchair magnet.

3. Explore how magnets can change wheelchair motion (small groups, 10 min)

A. Distribute materials to groups.

B. Circulate as students work in their groups to explore how the *location*, *pole orientation*, and *number* of ring magnets in their hand impact the motion of the wheelchair (with magnets attached). Ask for their observations and then prompt them to try to explain WHY they think things are happening. Help students pay attention to the difference in interactions between “stickered” sides of magnets and non-stickered sides.



NOTE: This activity focuses on magnetic fields. Changes in the motion of the wheelchair are due to the forces of attraction and repulsion between the wheelchair’s magnets and the handheld magnets. By flipping the handheld magnets, the magnetic force can be toggled between attraction and repulsion. If like poles are aligned, the wheelchair will be pushed away from the handheld magnet. If opposite poles are aligned, the wheelchair will be drawn towards the handheld magnet. By participating, students will explore and play around with magnetic attraction and repulsion, and learn how these forces result in changes in motion. They will discover that the strength of the magnetic field can be changed by adding or removing additional magnets to the initial handheld magnet and will be able to see the effects in the movement of the wheelchair.

4. De-brief and sense-make as a whole class (10 min)

A. Gather the class and ask students what they observed.
   - Were you able to move the wheelchair without touching it? How?
   - What happened when you added more magnets to your hand? Why?
   - WHY did the wheelchair move towards certain areas? Why do more magnets make a difference?

B. During the whole-class discussion, the goal is to build shared knowledge about magnets that students can use in their design. Record ideas about magnets on chart paper. Start from the students' ideas and press for evidence from their explorations to help refine their ideas.

C. If students aren't sharing much in the whole group, you could try think-pair-share, having design groups share what they learned and others question them, or having groups make their own lists of ideas about magnets that they then share with the group.

D. Some additional questions to consolidate knowledge about magnets:
   - Are all objects magnetic? How can we distinguish non-magnetic objects from magnetic objects?
   - How do we know if a magnet is weak or strong? How can we increase or decrease a magnetic force?

   Some ideas students may begin to grapple with:
   - Magnets have two poles.
   - Like poles repel each other.
   - Unlike poles attract each other. (opposites attract)
   - Only magnetic objects are affected by magnets. Non-magnetic objects like foam are not affected.
   - Magnetic force can be attractive or repulsive. These forces can be made stronger (or weaker) by adding (or reducing) number of magnets or by bringing magnets closer together (or farther apart)
   - Magnets affect magnetic objects in a certain area around them (a magnetic field)
   - Magnetic objects get affected when they come near magnets and their fields.

5. Brainstorm design ideas (5 min, in design teams)

A. Have students gather with their design teams and use what they figured out today about magnets to discuss and record more ideas about what to build for their element of an accessible playground structure. Encourage students to think about how they could incorporate magnets into their designs. Students may ask to handle the magnets while they ideate, and this might be helpful for their brainstorming.

Lesson 6: Design: Plan

Lesson 6 Overview

Activities

1. Plan for fair testing (15 min)
2. Design a first prototype (20 min)
3. Share and refine design ideas (10 min)

Focus Questions & Objectives

How can we use engineering design and ideas about motion and forces to solve the accessible playground design problem?

Revisit the design problem, generate design ideas, and explore available materials and tools

NGSS Alignment

3.3-5-ETS1-1. Define a simple design problem that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost that a potential solution must meet.
3.3-5-ETS1-4(MA). Gather information using various informational resources on possible solutions to a design problem. Present different representations of a design solution.

Materials

For each team

- MIniature wheelchair
- 12” x 12” square of cardboard or chipboard
- Student notebooks
- Design planning handouts (included at the end of this guide)

Preparation

For each student design team, set out one miniature wheelchair and a cardboard square to use as a building platform for their playground structure element. Having these materials available to look at and hold in their hands will help students plan prototypes of an appropriate size.

Lesson Sequence

1. Plan for fair testing (whole class, 15 min)

A. Have student teams use their notebooks to review their team’s design problem statement, which should already state their design goal, criteria, and constraints. Now it is time to think about the ways that they will “test” their playground element prototypes.

B. Pose questions about testing playground designs and record student responses:

"If you were trying to convince your school to build this playground, HOW would we show that these elements of the playground structure work? (WITHOUT building a full size one)? If it was a bridge we were building, we'd test it with weights and show that it didn't collapse. How can we test the playground structures?"

- Students might answer "weight," which is great—magnets or other heavy things in the classroom can be used to mimic the weight of children using the playground.
- Students can also test that the model wheelchairs fit on their structures.

"Another way to think about the test is, How can we show that it works or know what to change?"

"From what everyone is saying, I think one useful way to break it down is to plan for two parts of testing: that it physically works and that it's accessible"

For 1: to ensure it physically works, we have to think about forces:

- What are the pushes and pulls on your playground element?
- How can we test that?

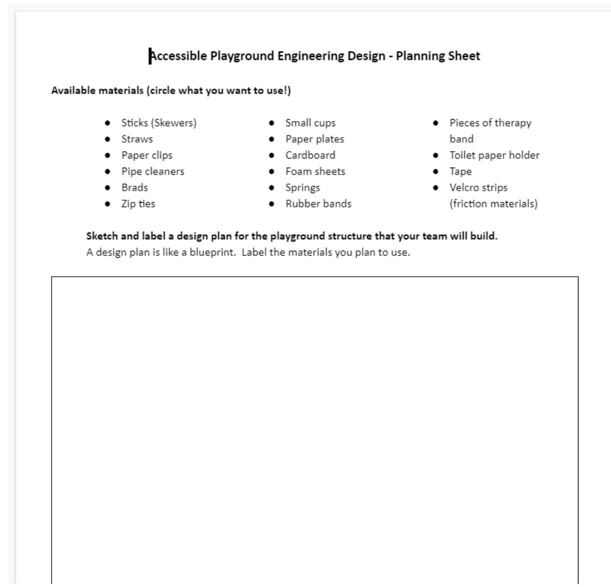
For 2: to ensure accessibility, we have to think about the person using the wheelchair:

- Does the wheelchair fit?
- Can we role-play how a wheelchair user would use the playground element that we have prototyped?

C. Once the whole class has discussed testing, have each group write down and draw in their notebooks how they will test their playground structure element. If they already have a clear idea for the type of playground element they will design (like a slide, swing, or merry-go-round), they might have specific testing protocols to write down. Or, they might just write, "Use weight. Test with wheelchair"

2. Design a first prototype (20 min)

A. Distribute a cardboard square, model wheelchair, and stack of design planning sheets (handouts at the end of this guide) to each student team.
B. Have teams review their design ideas from previous days and look at materials and the size constraint (and time constraint of 3 days) to refine their ideas.
C. Tell students that their playground element prototypes will need to fit on the square, and the wheelchair should fit on their prototype (unless they are designing for a different disability).



Accessible Playground Engineering Design - Planning Sheet

Available materials (circle what you want to use!)

- Sticks (Skewers)
- Straws
- Paper clips
- Pipe cleaners
- Brads
- Zip ties
- Small cups
- Paper plates
- Cardboard
- Foam sheets
- Springs
- Rubber bands
- Pieces of therapy band
- Toilet paper holder
- Tape
- Velcro strips (friction materials)

Sketch and label a design plan for the playground structure that your team will build.
A design plan is like a blueprint. Label the materials you plan to use.

D. Circulate as teams discuss and sketch what to initially build and test. Support teams with strategies for listening and building on each other's ideas, such as using, "I think ___ because ___" sentence frames.
E. Encourage teams to generate multiple design ideas but work toward consensus on which idea they will build first and which ideas they will save as "back up" ideas. Alternatively, you might choose to encourage teams to build multiple prototypes and see which works better. Some teams handle this opportunity well and end up with several working designs or end up deciding between options. In other teams, this opportunity becomes a source of resentment because students don't feel like their teammates are "helping" enough with each different prototype.

3. Share and refine design ideas (whole class, 10 min)

A. Facilitate a whole class discussion to share ideas and inspire further refinement. Consider whether to encourage different teams to make different playground elements so that across the whole class, an entire playground will be prototyped.
B. It might be useful or necessary to remind students that people who use wheelchairs often need assistance to move out of the chair, or to move the chair onto an element of a playground structure. You can show the class or individual teams a video of a wheelchair user transferring to show how hard it is: https://www.youtube.com/watch?v=9MKGOOWUMIk

Lesson 7: Design: Build and Test

Lesson 7 Overview

Activities

1. Build and test (45 min)
2. Discuss student progress and struggles (ongoing)
3. Press for reasoning (ongoing)

Focus Questions & Objectives

How can we build our ideas for accessible playground structures?

Build, test, and iterate on design solutions

NGSS Alignment

3.3-5-ETS1-2. Generate several possible solutions to a given design problem. Compare each solution based on how well each is likely to meet the criteria and constraints of the design problem.

Materials

For each team

- MIniature wheelchair
- 12” x 12” square of cardboard or chipboard
- Student notebooks

For the class

- Assortment of building supplies**:** Wooden skewers, drinking straws, paper clips, chenille sticks, brads, zip ties, small paper or plastic cups, paper plates, cardboard, foam sheets, springs, rubber bands, toilet paper holders, tape, velcro strips, magnets

Preparation

1. Prepare materials in a supply station or otherwise set up a system for students to obtain building supplies.

Lesson Sequence

1. Build and test (45 min)

A. Tell students that in the next lesson, they will be giving each other feedback, so they need to have something built by the end of this day. It does NOT have to be perfect/finished, but they need to be ready to ask for feedback about something.
   - Encourage teams to document their designs and the results of their tests.
   - Push students to think about forces, magnets, and other ideas from the inquiry lessons.

2. Discuss student progress and struggles (ongoing)

- If you notice common struggles with building, or you see exemplary teamwork or notebooking, consider pulling the class together to collaboratively troubleshoot or learn from exemplary work. This can be a great way to highlight work done by students who are often overlooked.
- Look for opportunities to highlight good documentation practices. Encourage teams to document how their design evolves over time, particularly if something fails. It is important to document design failures and keep notes about attempts to improve. Then you can push other teams to think about their own designs and how they will test them and improve them.

3. Press for reasoning (ongoing)

- When talking to students, try to push for students to go beyond showing that something works and instead engage in cause-and-effect reasoning about WHY their prototypes are working or not working. Ask them about the forces acting on their design that affect its performance.

Lesson 8: Design: Peer Feedback

<table>
<tr><th colspan="2">Lesson 8 Overview</th></tr>
<tr><td colspan="2">Activities
1. Discuss feedback strategies (10 min)
2. Generate questions for feedback (5 min)
3. Peer-to-peer feedback (20 min)
4. Build, test, and iterate (10 min)</td></tr>
<tr><td>Focus Questions & Objectives
How can we improve our ideas for accessible playground structures?

Request and provide feedback on playground designs and notebooks.</td><td>NGSS Alignment
4.3-5-ETS1-5(MA). Evaluate relevant design features that must be considered in building a model or prototype of a solution to a given design problem.</td></tr>
<tr><td colspan="2">Materials
<u>For each team</u>
• MIniature wheelchair
• Playground element prototype on 12” x 12” square of cardboard or chipboard
• Student notebooks
<u>For the class</u>
• Assortment of building supplies as in Lesson 7</td></tr>
</table>

Preparation

Determine how you will pair up student teams for the peer-to-peer feedback session. We recommend pairing teams who are approaching the problem in similar ways (i.e. if two teams decided to build merry-go-rounds, they should give each other feedback).

Lesson Sequence

1. Discuss strategies for requesting and providing feedback (10 min)

A. Tell students that today they will be asking for feedback on a problem they’re having and giving feedback to another team on a struggle they are facing. This is something engineers do frequently. Sometimes engineers work so hard on their design that they need help from other people to take a step back and think about problems from a different perspective. Today, each student team will come up with at least one question to ask another team -- something they want advice on.
   - One benefit of asking for feedback on a student-specified issue is that it allows the team receiving feedback to steer the conversation. Instead of hearing a

critique of something they may already be proud of, the feedback-receiving team can direct the other team to an aspect of their design on which they truly would like help.

B. Ask students why we get feedback. "*What do we hope to get out of asking for feedback?"*
    - A new perspective on…
    - A new idea for…
    - Help with…
    - Note: participating in face-to-face peer feedback can often generate positive emotions! It's useful to hear that other people have struggled with similar problems (and how they overcame them).
C. Ask students why we give feedback. "*What do we hope to get out of giving feedback to others?"*
    - Share what we've learned…
    - Help my classmates succeed…
    - See other approaches to the same problem...
    - Note: similarly, positive emotions can be fostered by giving feedback. Students who may be struggling with their own design have the opportunity to help another team with something they're struggling with in a useful or clever way.
D. Ask students to give examples of non-useful and useful feedback (such as, "I don't like the color of your swing" vs. "The slide seems unsafe because …")

2. Generate questions for feedback (5 min)

A. Circulate as students work with their teams to generate a question about their playground design prototype for feedback from peers.

3. Peer-to-peer feedback (in mega-groups, 20 min total)

A. Before class, decide which design teams you will pair into "mega-groups." We recommend pairing teams who are approaching the problem in similar ways (i.e. if two teams decide to build merry-go-rounds, they should give each other feedback).
B. Have teams pair off, bringing their notebooks and their prototypes.
C. One team should go first, asking the question(s) they came up with and listening to the ideas of the other team. After 5 to 10 minutes, repeat with the other team asking their question(s).

4. Build, test, iterate (10 min)

A. Support design teams to continue building and testing their designs. Students may choose to incorporate the feedback they received, or continue on with any of their own ideas.

Lesson 9: Design: Iterate and Document

<table>
<tr><th colspan="2">Lesson 9 Overview</th></tr>
<tr><td colspan="2">Activities
1. Test and iterate (35 min)
2. Generate playground design recommendations (10 min)</td></tr>
<tr><td>Focus Questions & Objectives
How can we improve and document our ideas for accessible playground structures?

Make final changes to design and finish notebooks to prepare for the Design Expo</td><td>NGSS Alignment
4.3-5-ETS1-3. Plan and carry out tests of one or more design features of a given model or prototype in which <s>variables are controlled and </s>failure points are considered to identify which features need to be improved. Apply the results of tests to redesign a model or prototype.</td></tr>
<tr><td colspan="2">Materials
<u>For each team</u>
● Miniature wheelchair
● Playground element prototype on 12” x 12” square of cardboard or chipboard
● Student notebooks
<u>For the class</u>
● Assortment of building supplies as in Lessons 7 and 8</td></tr>
</table>

Preparation

Prepare materials in a supply station or otherwise set up a system for students to obtain building supplies.

Lesson Sequence

1. Test and iterate on playground element prototypes (35 min)

A. Support students in cycles of testing and iterating on their prototypes. As appropriate, encourage them to incorporate the peer feedback they received. By the end of this session, teams should have prototypes and notebooks ready to share at the Design Expo.

B. Encourage students to add detail to previous notebook entries to better capture the evolution of their playground design ideas.

2. Begin list of accessible playground design recommendations (10 min)

A. As a midpoint or closing discussion for this testing and iteration session, gather students for a whole-class discussion about their big takeaways for accessible playground design. Ask students and record their ideas:
   - "*Based on everything you have tried so far with your prototypes, what can you say about what works and what doesn't work for accessible playground structure design?*
   - *Looking across all the teams' prototypes, what recommendations can our class make to others who are interested in accessible playground design?"*

B. Let students know that this list of "Design Recommendations" will be shared with visitors during the Design Expo.

Lesson 10: Design Expo

Lesson 10 Overview	
Activities 1. Anticipate Design Expo questions (10 min) 2. Design Expo (20 min) 3. Complete final design reflection (15 min)	
Focus Questions & Objectives *How can we share what we have learned about the accessible playground design problem?* Share with an external audience about designs, notebooks, and recommendations for accessible playground design	**NGSS Alignment** **4.3-5-ETS1-5(MA).** Evaluate relevant design features that must be considered in building a model or prototype of a solution to a given design problem.
Materials For each team • Miniature wheelchair • Playground element prototype on 12" x 12" square of cardboard or chipboard • Student notebooks	

Preparation

Arrange for visitors to join you for a Design Expo lasting roughly 30 minutes. Visitors might include other students, teachers, administrators, families, or community members. Set up the classroom so that each team can stand or sit with their playground element prototype and notebook and so that visitors can circulate freely among the student teams.

Lesson Sequence

1. Anticipate Design Expo questions (10 min)

With turn-and-talk discussions or individual writing time, prepare students to answer questions that visitors might have about their prototypes, notebooks, and design process. Questions to post include:

- How did you decide on this design?
- What are the strengths and weaknesses of this design?
- How did you make sure the design was accessible?
- How did you make sure the design was safe?
- What changes did you make from the original design?
- What was the hardest part of making the design?

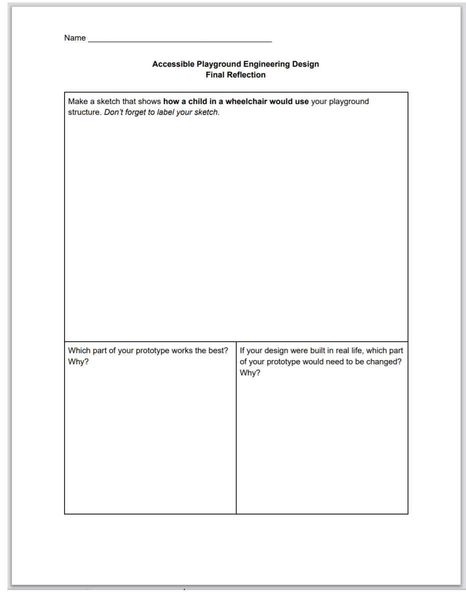
- What do you think is the most important part of your design?
- What part of your design are you most proud of?
- What would you continue to improve if you had more time?

2. Design Expo (30 min)

Circulate and encourage visitors to test out the playground element designs, look through the notebooks, and ask students about their process in addition to their final design.

3. Complete Final Design Reflection (15 min)

As a final individual work product for the unit, have students complete the Design Reflection individually. Conversations during the Design Expo will help prepare students for this drawing and writing task.



Name ______________________________

Accessible Playground Engineering Design
Final Reflection

Make a sketch that shows **how a child in a wheelchair would use** your playground structure. *Don't forget to label your sketch.*

Which part of your prototype works the best? Why?	If your design were built in real life, which part of your prototype would need to be changed? Why?

STUDENT HANDOUTS

Engineering Design Problem:
Accessible Playground Structure

You are working as engineers to design one element (like a slide, swing, or merry-go-round) of a playground structure that would be fun and safe for all children, including children who use wheelchairs.

Criteria for your playground structure:
(Criteria are like a checklist for solving an engineering design problem.)

- ❏ **Is it accessible?** (Can kids in wheelchairs use it?)
- ❏ **Does a wheelchair fit on it?** (Can you show a miniature wheelchair on it?)
- ❏ **Is it stable?** (Does it stand up on its own, even when the weight of a wheelchair is on it?)
- ❏ **Is it functional?** (Can you show it really moving or working?)
- ❏ **Is it fun?** (Would real kids enjoy playing on a life-size version of it?)

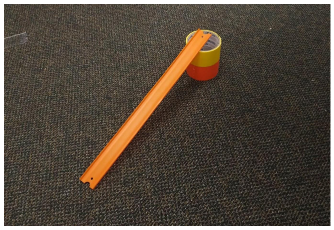
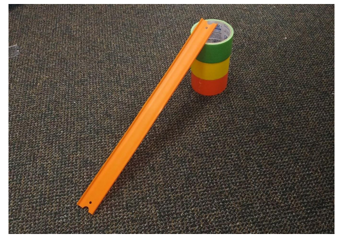
Constraints for your playground structure:
(Constraints are like limits, or things that your engineering design can't do.)

- ❏ It can only use materials from the list.
- ❏ It must fit on the cardboard square.
- ❏ It must be a single element (like a slide, swing, or merry-go-round), not an entire playground.
- ❏ You only have a limited amount of time to build it.

How will you test your playground structure?

You should be able to show it working with a miniature wheelchair.

Varying-Height Ramp Station

1. Set the ramp at different heights and roll your car down each different ramp height.

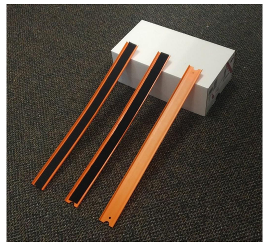
2. Make a sketch or take a picture of each different ramp set-up.

3. For each different ramp set-up, record observations and ideas to answer these questions:
    a. What happened when the car rolled down the ramp?
    b. Did the car go faster or slower than the other set-ups?
    c. Why do you think that happened?

4. Talk to your team and others at the station to figure out:

How does ramp height affect how fast your car travels?

Varying-Surface Ramp Station



1. Set up the three different material ramps (plain ramp, fuzzy side of Velcro, bumpy side of Velcro) and roll your car down each of them.

2. Make a sketch or take a picture of each different ramp set-up.

3. For each different ramp set-up, record observations and ideas to answer these questions:
    a. What happened when the car rolled down the ramp?
    b. Did the car go faster or slower than the other set-ups?
    c. Why do you think that happened?

4. Talk to your team and others at the station to figure out:

How do the different surfaces affect how fast your car travels?

Falling Weight Station

1. Add some weight to the cup and make sure the string is attached to your car. Then release the cup and observe what happens to the car. Repeat for different amounts of weight or different lengths of string.

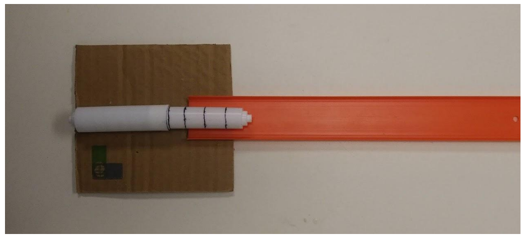
2. Make a sketch or take a picture of each different set-up.

3. For each different set-up, record observations and ideas to answer these questions:
   a. What happened when you tested the car with this set-up?
   b. Did the car go faster or slower than the other set-ups?
   c. Why do you think that happened?

4. Talk to your team and others at the station to figure out:

How does the amount of weight or length of string affect how fast your car travels?

Stretch Station: Spring



1. Push your car back into the spring, release it, and observe what happens. Try pushing the spring back different amounts.

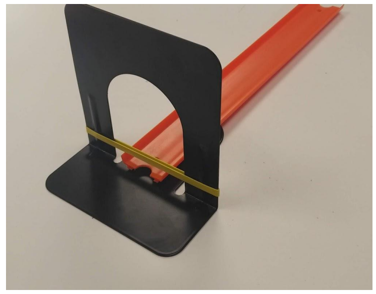
2. Make a sketch or take a picture of each different spring set-up.

3. For each different set-up, record observations and ideas to answer these questions:
    a. What happened when you tested the car with this set-up?
    b. Did the car go faster or slower than the other set-ups?
    c. Why do you think that happened?

4. Talk to your team and others at the station to figure out:

How does how far you push back the spring affect how fast your car travels or how fast it slows down?

Stretch Station: Rubber Band



1. Pull back the rubber band then put your car and the edge of the track. Let go of the rubber band so it hits your car and makes the car move. Try pulling back different distances. Then, try rolling your car into the rubber band.

2. Make a sketch or take a picture of each different rubber band set-up.

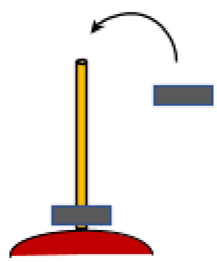
3. For each different set-up, record observations and ideas to answer these questions:
   a. What happened when you tested the car with this set-up?
   b. Did the car go faster or slower than the other set-ups?
   c. Why do you think that happened?

4. Talk to your team and others at the station to figure out:

What affects how fast your car travels or how fast it slows down?

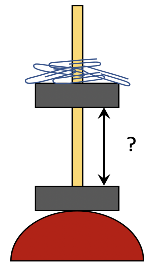
Floating Magnets: Part 1

1. Push your pencil into the clay, then place two ring magnets over the pencil. What happens?
2. Flip one of the magnets over. What happens now?
3. Make a sketch or take a picture of the magnets both ways.
4. Record your observations about **what** is happening.
5. Jot down some notes about **why** you think that is happening.



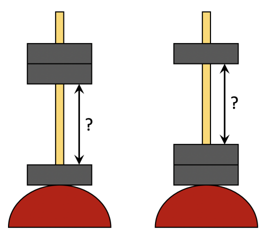
Floating Magnets: Part 2

1. Add 20 paper clips to the top magnet to make it heavier. What happens?



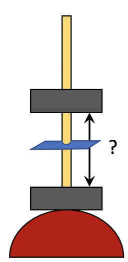
2. Make a sketch and record your observations and ideas about what happens.

3. Stick two ring magnets together and levitate them on top of one ring magnet. Is the gap between the magnets the same? Bigger? Smaller? Now put the two magnets on the bottom. Is the gap the same now? Bigger? Smaller?



4. Make a sketch and record your observations and ideas about what happens.

5. Place a square of paper or cardboard between the two magnets. What happens to the gap between the magnets? What about if you try with foam?



6. Make a sketch and record your observations and ideas about what happens when you try with paper, cardboard, or foam.

Accessible Playground Engineering Design - Planning Sheet

Available materials (circle what you want to use)

- Sticks (Skewers)
- Straws
- Paper clips
- Pipe cleaners
- Brads
- Zip ties
- Small cups
- Paper plates
- Cardboard
- Foam sheets
- Springs
- Rubber bands
- Toilet paper holder
- Tape
- Magnets
- Velcro strips (friction materials)

Sketch and label a design plan for the playground structure that your team will build.
A design plan is like a blueprint. Label the materials you plan to use.

Accessible Playground Engineering Design
Final Reflection

Make a sketch that shows **how a child in a wheelchair would use** your playground structure. *Don't forget to label your sketch.*	
Which part of your prototype works the best? Why?	If your design were built in real life, which part of your prototype would need to be changed? Why?

MATERIALS LIST

For an online document listing all materials and links to purchase many of them: https://docs.google.com/spreadsheets/d/1dlGw9H_4UYOc80CqGXGmBxoKaXmsBmoCJAHL9_GfYjQ/edit?usp=sharing

	needed per classroom	**#/pack**	**Quantity**	**Price per pack**	**Price (total)**	**Used for...**	**Lesson(s)**	**Notes**
					289.26			
MATERIALS YOU MAY NEED TO PURCHASE								
Hot wheels track	(6,9,12)x12" + (3,6,9)x9" + 3 extra	31x12" + 12x9"	1	19.99	19.99	Inquiry	2,3	Use the same length tracks at the different stations
Toy cars	6-12	12	1	12.99	12.99	Inquiry	2,3	
1.25" adhesive velcro	1 foot + extra for design	16.4ft	1	10.99	10.99	Inquiry + Design	2,6,7,8,9	
Dixie cups	3 + extra for Design	600	1	14.99	14.99	Inquiry + Design	3,6,7,8,9	
String	a few feet x 3	100 yards	1	5.99	5.99	Inquiry	3	
Paper clips	60 + extra for Design	10x100	1	7.87	7.87	Inquiry + Design	3,6,7,8,9	In the inquiry L3, these are used as weight for the falling weight system. Pennies or small washers (or anything else) could be substituted.) These are also used in the design challenge.
Measuring tape	1 for each group (4-8)	12	1	5.99	5.99	Inquiry	2,3	
Toilet paper holder	3 + extra for Design	4	1	5.99	5.99	Inquiry + Design	3,6,7,8,9	One can be taken apart to show the spring inside
Bookend	3	2	2	5.36	10.72	Inquiry	3	It doesn't have to be these exact ones! Anything you can stretch a rubber band between and tape a track to will do.
Bar magnet (labeled)	1	2	1	10.99	10.99	Inquiry	4	
Pencils	2-4	12	1	3.99	3.99	Inquiry	4	Can also just use pencils from the classroom
Play doh	enough for 2-4 pencils	10	1	7.99	7.99	Inquiry	4	
Ring magnets	<32	40	1	15.99	15.99	Inquiry + Design	4,6,7,8,9	
Sticks (skewers)		100	1	5.45	5.45	Design	6,7,8,9	
Straws		200	1	6.99	6.99	Design	6,7,8,9	This link is for biodegradable paper straws, assorted plastic straws work as well!
Pipe cleaners		324	1	8.99	8.99	Design	6,7,8,9	
Paper plates		200	1	12.99	12.99	Design	6,7,8,9	
Cardboard, 12"x12" (for base)	1 per group (6-8)	25	1	12.49	12.49	Design	6,7,8,9	Can also use reused corrugated cardboard or cereal boxes
Foam sheets		80	1	14.99	14.99	Design	6,7,8,9	

Rubber bands		0.5 lb	1	5.43	5.43	Design	6,7,8,9	
Duct tape		12	1	16.99	16.99	Design	6,7,8,9	
Masking tape		9	1	16.49	16.49	Design	6,7,8,9	
Miniature wheelchairs	1 per group, or share 2-3 per class	1	3	17.99	53.97	Design	6,7,8,9,10	
Springs		*-*	*-*	*-*	*-*	*Design*	*6,7,8,9*	*OPTIONAL. Can also use extra toilet paper holders as springs*
Therapy band	*~6 feet + extra for Design*	*75 ft*	*1*	*19.99*	*19.99*	*Inquiry + Design*	*3,6,7,8,9*	*OPTIONAL. Get the very light resistance! (teal)*
MATERIALS YOU PROBABLY HAVE ON HAND								
Design notebooks	1 per group	-	-	-	-	Inquiry + Design	1,2,3,4,5,6,7,8,9,10	
Books/buckets/rolls of tape	different heights for 2-4 stations	-	-	-	-	Inquiry	2	to prop up ramps for inquiry
Needle	1	-	-	-	-	Inquiry	4	
Stickers	1 per magnet (~32)	-	-	-	-	Inquiry	4	
Cardstock (e.g., manila folder, index cards)	1 of each for 2-4 stations	-	-	-	-	Inquiry	4	
Rulers	2-4	-	-	-	-	Inquiry	4	
Bubble wrap	two small (4"x4") pieces	-	-	-	-	Inquiry	4	
Zip ties, brads	*optional*					Design	6,7,8,9	optional for design challenge
Cardboard (for building)		-	-	-	-	Design	6,7,8,9	You can start gathering this beforehand, cereal boxes work great and are easier to cut and bend than corrugated cardboard.