THINKING AND ACTING LIKE A SCIENTIST

TEACHER'S GUIDE

Let's Pull Together

How does mass affect the gravitational force between two objects?

GRADES 6–8

Physical Science

VAN ANDEL EDUCATION INSTITUTE
VAEI.ORG

INQUIRY-BASED SCIENCE

Physical

Let's Pull Together

Grade Level/Content	6–8/Physical Science
Lesson Summary	In this lesson, students use an online simulation to compare the strength of gravitational pull between two objects with varying masses. Students summarize their findings by creating a cartoon dialogue between two original characters following a claim-evidence-reasoning model.
Estimated Time	1, 45-minute class period
Materials (per team)	two objects with different masses, balance or digital scale, Internet access to PhET "Gravity Force Lab" online simulation, white copy paper, drawing materials, Investigation Plan, Observation Form, journal
Secondary Resources	How Stuff Works: Tides YouTube: What Is Gravity? (2:08) Bill Nye: Gravity (22:53)
NGSS Connection	**MS-PS2-4** Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.
Learning Objectives	• Determine that the gravitational force between objects increases as their masses increase and decreases as their masses decrease. • Collect data to show that the gravitational force on objects is the same, even when one of the objects has a greater mass than the other. • Use evidence to support the idea that gravitational interactions are attractive and depend on the masses of the interacting objects.

How does mass affect the gravitational force between two objects?

Everything on Earth is affected by gravity. It pulls matter down so that nothing goes flying off into space! Students have learned about this invisible force in earlier grades. What they may not realize is that every object exerts a gravitational pull on all of the objects around it. Students should be able to grasp the nature of gravity between objects as they consider how massive objects in space pull on each other. For example, just as Earth is pulling the moon toward it, as evidenced by the moon's orbit, the moon is pulling on Earth. We witness this as large bodies of water shift and move with the pull of the moon—otherwise known as tides.

The concept of all matter having gravity is difficult to fathom since here on Earth, the pull between objects is immeasurably less than Earth's pull on us. In this lesson, students develop an understanding of gravitational interactions between matter through an online simulation, and determine how the objects' combined masses affect the strength of the force between them.

Investigation is based on the Van Andel Education Institute (VAEI) Instructional Model for Inquiry-Based Science. In all investigations:

Students don't know the "answer" they are supposed to get.

Students play a driving role in determining the process for learning.

Teachers and students construct meaning together by journaling.

Students are working as hard as the teacher.

Part 1

INVESTIGATION SETUP

Each student will need the following:

- Two objects with different masses
- Balance or digital scale
- Internet access to the PhET "Gravity Force Lab" online simulation
- White copy paper and drawing materials
- Investigation Plan
- Observation Form
- Journal

Part 2

INVESTIGATION FACILITATION

Question

Introduce the investigation question.

How does mass affect the gravitational force between two objects?

CURIOSITY

Place two objects with different masses (i.e., stapler and pencil) on a table or desk in front of students. Ask what forces are acting on the objects. Explain to students that the two objects are interacting. Ask students to predict how this may be the case since neither of them is moving. Then introduce the investigation question.

Personal Knowledge

Students capture what they already know about gravitational forces.

- Have students reflect on what they already know about gravitational forces.
- Create a class list of ideas. *(Suggestions may include: It pulls objects toward Earth. Weight is a function of gravity. It is less on the moon than on Earth.)*

RISK-TAKING

Add all ideas, even misconceptions, to the class list. If something is questionable, circle it and explain that the class will revisit it later. Tell students that if their personal knowledge is incorrect, they can make changes to their ideas at any time. Address misconceptions at the appropriate time in the investigation, perhaps during data analysis and explanation.

Prediction

Students communicate an expected outcome, based on prior knowledge.

Based on what they know about gravity, ask students to predict what will happen to the gravitational pull between two objects as the mass of each object changes. Identify three options: the force will increase, decrease, or stay the same. Pose these situations, and have students show their predictions by using a thumbs up (increase), thumbs down (decrease), or thumbs sideways (stay the same).

- Situation 1: The mass of object one increases, and the mass of object two stays the same.
- Situation 2: The mass of object two increases, and the mass of object one stays the same.
- Situation 3: The mass of both objects increases.
- Situation 4: The mass of both objects decreases.

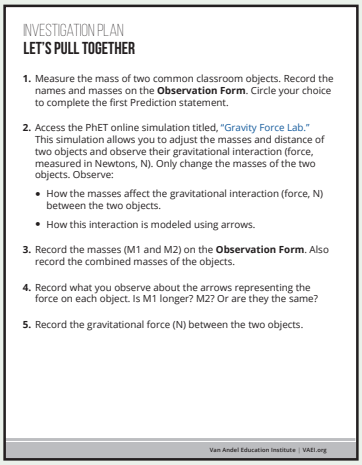
Make a chart on the board to record the number of predictions in each case. Then, ask students to explain why they made the predictions they did. Revisit the chart after the investigation, and have students discuss whether their predictions were correct.

Investigation Plan

Students conduct trials to determine how the mass of two objects affects the gravitational force between them.

- Review the materials as a whole class.
- Divide the class into pairs. Distribute the Investigation Plan and review it with students.
- Distribute the Observation Form to each pair.
- Review **Part 1** of the **Observation Form**. Have students complete the "Materials" and "Prediction" sections. Have each pair of students choose two objects to measure and record, and make their prediction. Advise students to complete the "Outcome" section following the online simulation.
- Demonstrate the online simulation for the class. Explain that the simulation is provided by the University of Colorado, a reputable source for valid math and science data.
- Model how to complete **Part 2** of the **Observation Form**. Explain that this simulation also includes the variable of distance, but students should only change the mass of the objects as they conduct their investigation and record their data.
- Instruct students to observe the strength of the force as the objects pull on each other. Be sure students understand that this interaction is modeled using congruent arrows pointing from one object toward the other object.
- Have students access the online simulation and conduct their trials. Encourage students to increase and decrease the mass of object one, of object two, and of both objects.

Note: If students do not have individual access to the online simulation, conduct a class investigation. In this situation, all students will record the same data as it is displayed for the class.



INVESTIGATION PLAN

LET'S PULL TOGETHER

1. Measure the mass of two common classroom objects. Record the names and masses on the **Observation Form**. Circle your choice to complete the first Prediction statement.
2. Access the PhET online simulation titled, "Gravity Force Lab." This simulation allows you to adjust the masses and distance of two objects and observe their gravitational interaction (force, measured in Newtons, N). Only change the masses of the two objects. Observe:
   - How the masses affect the gravitational interaction (force, N) between the two objects.
   - How this interaction is modeled using arrows.
3. Record the masses (M1 and M2) on the **Observation Form**. Also record the combined masses of the objects.
4. Record what you observe about the arrows representing the force on each object. Is M1 longer? M2? Or are they the same?
5. Record the gravitational force (N) between the two objects.

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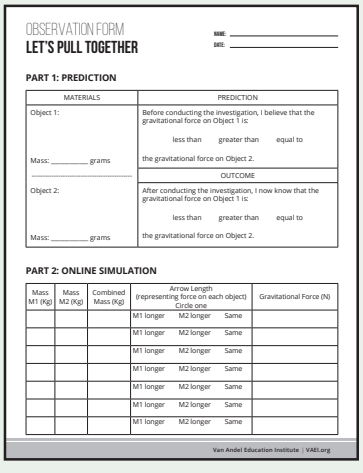
Investigation Plan



OBSERVATION FORM

LET'S PULL TOGETHER

NAME: _____

DATE: _____

PART 1: PREDICTION

MATERIALS	PREDICTION
Object 1: Mass: _____ grams	Before conducting the investigation, I believe that the gravitational force on Object 1 is: less than greater than equal to the gravitational force on Object 2.
	OUTCOME
Object 2: Mass: _____ grams	After conducting the investigation, I now know that the gravitational force on Object 1 is: less than greater than equal to the gravitational force on Object 2.

PART 2: ONLINE SIMULATION

Mass M1 (Kg)	Mass M2 (Kg)	Combined Mass (Kg)	Arrow Length (representing force on each object) Circle one	Gravitational Force (N)
			M1 longer M2 longer Same	
			M1 longer M2 longer Same	
			M1 longer M2 longer Same	
			M1 longer M2 longer Same	
			M1 longer M2 longer Same	
			M1 longer M2 longer Same	
			M1 longer M2 longer Same	

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Observation Form

Continued

OPENNESS TO NEW IDEAS

Ask students how they will feel if their data does not support their predictions. Encourage them to find joy in learning something new. If students struggle, share a time when your openness to new ideas allowed you to learn something new.

CRITICAL THINKING

Use the Fair Test checklist to help students think critically about the investigation plan. Help them understand that a good investigation plan must include a test that is repeatable, generates quality data, and minimizes error. The more critically students think about their investigation plan, the more confident they can be in their results.

Observation

Students record the strength of the gravitational force between two objects as the mass of each object changes.

- Remind students to record data for each trial on the **Observation Form**. They may complete up to seven trials.
- Have students join with another team to compare and combine observations.

SHARED CONTROL

Having students direct their learning with the online simulation allows them to own their learning process, leading to higher retention and more engagement.

Part 3

INVESTIGATION ANALYSIS AND DEVELOPMENT OF CLAIM

Data Analysis

Students make sense of their data by organizing it and representing it visually.

Have students analyze their data. They may wish to use the Data Analysis prompt as a guide.

- Have students **evaluate** their data for trustworthiness.
- Then, have them analyze their data to find patterns and trends. They may **organize** the data and/or **represent** it visually to construct meaning.
    - You may want to have students order the total masses of M1 and M2 from least to greatest to help them compare the strengths of the force and identify trends. They may also want to graph their findings to help make sense of them.
- Have students **interpret** what the identified patterns or trends mean. They should see that the greater the combined mass, the greater the gravitational force.
- Ensure they have enough data that it can be used as evidence to support a claim.
- Remind students to complete the "Outcome" section of the **Observation Form**.

CRITICAL THINKING

Ask students to find unusual patterns in the data. For example, if the masses of the two objects are doubled, is the force also doubled? Is there a pattern between the combined mass and the gravitational force? Challenge students to graph the data on a coordinate grid to illustrate this relationship.

Secondary Knowledge

Students use secondary sources to understand that gravitational interactions are attractive and depend on the masses of the interacting objects.

- Use these resources (or your own) to develop students' understanding of gravitational interactions between objects with different masses.
  How Stuff Works: Tides
  YouTube: What Is Gravity? (2:08)
  Bill Nye: Gravity (22:53)
- After reviewing these resources, students should understand the concept of gravitational interaction (attraction) between objects. They should understand that this interaction is the same on each object, regardless of how the masses of the objects compare, and that as their combined mass increases, the gravitational force also increases.

RISK-TAKING

Have students reflect on their predictions before the investigation. Allow students to talk with a partner about how their predictions were either confirmed or denied, and what they learned by conducting the investigation and reviewing the secondary resources. Praise students who use evidence to disprove their initial predictions to foster a culture of risk-taking.

Explanation

Students write a claim and provide evidence and reasoning to support it.

- Have students use what they've discovered from their analyzed data to write an explanation that answers the investigation question. Students may wish to use the Explanation prompt as a guide. Have them write their summary on a sheet of white paper which they divide into four cartoon frames. They can add the cartoon to their lab journal.
- Have students create two cartoon characters who are talking about the gravitational interaction between objects. The first character should develop a **Claim** to answer the question: How does mass affect the gravitational force between two objects?
- Then, have students add **Evidence** (the analyzed data) presented by the second character to support the claim.
- Finally, have them add **Reasoning** to their claim shared between the two characters. Reasoning should include the information obtained from this investigation as well as science principles they have learned.

Claim

Character One: Did you know that every object in the universe has a gravitational pull on all the other objects around it?

Character Two: Yes, but do you know how mass affects the gravitational force between two objects?

Character One: I do! The greater the combined mass of two objects, the greater the gravitational force is between them!

Evidence

Character Two: Yes! My simulations showed that as I increased the combined mass of the objects, the gravitational force increased as well. But, the interaction between objects is the same no matter what their

Continued

masses. I showed this in my simulation, too. Even when the masses of two objects were different, the gravitational pull on each of them was the same.

Character Two: So, now we know that all objects have a gravitational interaction between them. They are attracted to each other! And our simulation gave us evidence to prove it.

Reasoning

Investigation

Character One: The mass of each individual object does not affect the pull between them. It is the same force no matter what the mass is of each object. When one object is 1 kilogram and the second is 1,000 kilograms, the force between them is the same! Just 0.000 000 004 171 N.

Character Two: And, as the combined mass of the objects increases, the force between them increases. When their combined mass is 250 kilograms, the force is only 0.000 000 010 011 N. When I increase their combined mass to 500 kilograms, the force increases to 0.000 000 250 269 N.

Character One: That must also mean that as the combined mass of the objects decreases, the force between them decreases.

Character Two: But, how do you know this simulation is accurate?

Character One: The online simulation is from the University of Colorado, a reputable institution with a whole website dedicated to online simulations for math and science. Universities are generally reliable sources of valid data that we can use as evidence.

Science

Character Two: And, we learned from readings and class discussion that gravitational interactions are attractive, and the force between them depends on the combined masses of the interacting objects.

- Once the explanation is written, have students discuss their results using a Present and Defend.

DISCOURSE

Have students conduct a Present and Defend to develop presentation skills as well as audience participation. Each team presents their cartoon to the class. The class analyzes the information presented and asks clarifying questions, challenges and/or supports the arguments made, and presents alternative explanations as appropriate. Research teams defend their explanation with evidence and reasoning. If students are doing the same investigation plan, choose 1 or 2 groups to share.

Evaluation

Students reflect on the investigation.

- Ask students how the outcome of the online simulation compared to their original prediction before the investigation.
- Create a class list of additional questions students would like to investigate based on the online simulation or data collection. Students may wish to investigate the additional variable of distance between objects and its effects on the gravitational force between them.

Part 4

INVESTIGATION ASSESSMENT AND EXTENSION

Application

Students demonstrate understanding of objects having a gravitational attraction to each other, and how mass affects the gravitational force between them by devising an original system to model that objects are attracted to each other.

- Have students apply their learning by answering the question: How can you model the gravitational interaction between two objects? *(measure the mass of two objects, draw and label their masses, show the force between them with two congruent arrows pointing toward each other)*
- Now that students understand the concept of gravitational interaction between objects, they can use this knowledge to design a system that demonstrates that objects have an attraction to each other. This series of "Prove Your World: Gravity" video segments provides students with ideas on how to set up a system to demonstrate this interaction: Episode 1 "Things Fall Down"; Episode 2 "Everything Pulls on Everything Else"; Episode 3 "How Can We Be Sure?"; Episode 4 "Even In Space?" *Suggested materials: washers, meter sticks or rulers, brass fasteners, medium rocks, large books or heavy objects, chair, table or desk, rope or yarn, clay, straight pins, tape, or other materials the students deem appropriate and necessary, with teacher approval.*

SELF-DIRECTION

Encourage students to conduct additional research to create an original system to demonstrate this phenomenon. Students can use round or suspended objects, or place objects in water to minimize friction.

Assessment

- To assess understanding, revisit the activity conducted during the "Prediction" component of the lesson. Restate the situations, and have students use a thumbs up, thumbs down, or thumbs sideways to explain the outcomes. Use evidence to support the idea that gravitational interactions are attractive and depend on the masses of the interacting objects.
- You can also assess student cartoons for how well they demonstrate students' understanding that:
  - the gravitational force between objects increases as their masses increase and decreases as their masses decrease.
  - the gravitational force on objects is the same, even when one of the objects has a greater mass than the other.
  - the gravitational interactions are attractive and depend on the masses of the interacting objects.
- You can also assess with the following situational questions. For each situation, ask students to draw a diagram to illustrate the gravitational interaction between the two objects. They should draw each object and label its mass. Then they should use arrows to show the forces between them.

Situation 1: A rock has a mass of 74 grams. A bottle of glue also has a mass of 74 grams.

(Students should draw a rock and a bottle of glue each with mass labeled 74 grams. Two congruent arrows should point from the rock to the glue, and from the glue to the rock to indicate that the force between them is the same strength.)

Situation 2: A stack of nickels has a mass of 50 grams. A stack of quarters has a mass of 66 grams.

(Students should draw a stack of nickels with mass labeled 50 grams, and a stack of quarters with mass labeled 66 grams. Two congruent arrows should point from the nickels to the quarters, and from the quarters to the nickels to indicate that the force between them is the same strength.)

Continued

Situation 3: A book has a mass of 2,180 grams. A pencil has a mass of 5 grams.

(Students should draw a book with mass labeled 2,180 grams, and a pencil with mass labeled 5 grams. Two congruent arrows should point from the book to the pencil, and from the pencil to the book to indicate that the force between them is the same strength.)

In Situation 3, what will happen to the gravitational force if the book is replaced by a heavier book, with a mass of 5,000 grams?

(If a heavier book is added to the system in Situation 3, the combined mass of the system will increase, and the gravitational force on the objects will also increase.)

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