WATER WISE FARMS: GRAVITY IN ACTION

Multi-Week Challenge Guide

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Challenge Rationale

Farmers need water to grow crops, but getting water to the right place isn’t always easy. On sloped land, gravity pulls water downhill. This means some areas can get too much water, while others don’t get enough. When that happens, plants might not grow well, and water can be wasted. In fact, farmers around the world are already working to fix this problem. According to the Food and Agriculture Organization (FAO), about 70% of all freshwater used by humans goes to agriculture. Even small improvements in how we move water on farms can make a big difference for people and the planet.

By learning how gravity affects water flow, we can design better irrigation systems that help farmers use water wisely. Whether it's building small channels, using drip lines, or changing the slope of the land, understanding gravity helps farmers get water exactly where it's needed without wasting a drop.

Source: Food and Agriculture Organization of the United Nations. (2017). Water for Sustainable Food and Agriculture. Retrieved from: https://openknowledge.fao.org/server/api/core/bitstreams/b48cb758-48bc-4dc5-a508-e5a0d61fb365/content

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Establishing The Challenge

Identify a Challenge

How does gravitational force affect water flow on sloped farmland, and how can farmers use this understanding to design better irrigation systems?

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Establishing The Challenge

CHALLENGE QUESTION

How does gravitational force affect water flow on sloped farmland, and how can farmers use this understanding to design better irrigation systems?

THIS SOLUTION MUST ADDRESS THE FOLLOWING NEEDS:

To meet the challenge, students must create a simulation or prototype that allows them to manipulate both mass and distance between objects to observe the effects on gravitational force. They are expected to record, organize, and analyze data from multiple trials to identify and explain patterns in how gravitational force changes. Their findings must be represented visually—through graphs, tables, or other tools—in a way that clearly illustrates the relationships between variables. Importantly, students must apply their observations to a specific agricultural scenario, such as the flow of water on sloped farmland, and explain how an understanding of gravitational interactions can lead to improved irrigation system design. Their solution should reflect an awareness of how scientific knowledge can support responsible and sustainable decision-making in agricultural engineering.

SUCCESS WILL BE DETERMINED BY:

Success in this challenge will be demonstrated by students' ability to generate accurate, evidence-based data from their simulation or prototype that clearly shows how gravitational force varies with changes in mass and distance. Students will use visual tools, such as graphs or charts, to effectively communicate the patterns they observed. In addition, they must explain how gravitational interactions influence water movement in agricultural systems and provide a thoughtful application of their findings to a real-world farming context. Their final product, whether it is a report, poster, video, or presentation, should clearly connect the scientific principles of gravity to agricultural challenges and show how this understanding can guide responsible irrigation decisions that conserve water and support crop health.

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Standards Addressed

Next Generation Science Standards

nextgenscience.org

- MS-PS2-2 Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
- 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.
- MS-ESS2-4 Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.
- MS-ETS1-1 / MS-ETS1-2 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the environment. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- Optional Connection – MS-ESS3-3

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Standards Addressed

COMMON CORE STANDARDS

corestandards.org/mathematics-standards

- EE.B.6 Use variables to represent numbers and write expressions when solving real-world or mathematical problems.
- RP.A.3 Use proportional relationships to solve multistep ratio and percent problems.
- SP.C.5 Summarize numerical data sets in relation to their context.
- SP.B.4 Display numerical data in plots on a number line, including dot plots, histograms, and box plots.

corestandards.org/english-language-arts-standards

- RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.
- RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
- RST.6-8.7 Integrate quantitative or technical information expressed in words with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
- WHST.6-8.1 Write arguments focused on discipline-specific content.
- WHST.6-8.2 Write informative/explanatory texts, including scientific procedures/experiments or technical processes.
- SL.6-8.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details.

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Guiding The Challenge

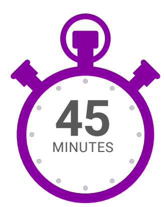
Each Purple Plow Challenge can be implemented in a variety of methods, time frames, and programs. Follow the steps below to help determine how this challenge will best fit the current situation and educational environment.

1. **REVIEW** the Purple Plow “Design Process” (next page) and the “Lesson Packet” documents.
   Note that the lessons are encouraged but not required.
2. **EXAMINE** the suggested timeline to determine ways to integrate the challenge and lessons to fit your needs.
3. With the time frame in mind, **USE THE GUIDANCE PROVIDED** in this section to help students progress through the challenge. This guidance includes suggested student prompts, guiding questions for students, signs of step completion, and journaling opportunities. The student prompts, guiding questions, and journal prompts are found in the “Student Guide.” Facilitators or students may determine the method by which they record their research and discoveries found for these prompts and journal reflection questions.

SUGGESTED TIMELINE

This sample pacing guide is created for a 90-day calendar with a 45-minute class. It is important to remember that timing may vary on student’s pace, as well as how much time you dedicate to each of the steps listed below. Your students may return to certain steps and repeat the process, no journey is the same!

DESIGN PROCESS STEP	TIMELINE
Identify	2 days
Imagine	2 days
Design	2-3 days
Create	3-4 days
Test & Improve	2-3 days
Share	2 days



You may need time beyond the allotted program time estimates above to fulfill the challenge's requirements. Possible options for competing include:
Sending the related materials home with students wishing to compete (participating in regular progress monitoring of the project with the facilitator).
Developing continuation options in an after-school or extracurricular club with the facilitator.
Including parents in the process of continuing the investigation (with an option of providing space at school to keep project materials).

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Guiding The Challenge

Week-by-Week Breakdown

WEEK 1: EXPLORE GRAVITATIONAL INTERACTIONS

- Introduction to gravitational force, mass, and distance.
- Guided simulation using tools like PhET or similar apps.
- Students systematically change values for mass and distance, record gravitational force values, and look for patterns.
- Deliverable: Data tables + draft graphs + initial claim/evidence

WEEK 2: DATA ANALYSIS ADN SCIENTIFIC ARGUMENTATION

- Create clear mathematical representations (line graphs, charts) showing the relationship between mass, distance, and gravitational force.
- Construct scientific explanations using CER (Claim–Evidence–Reasoning) format.
- Deliverable: Complete scientific explanation with visuals

WEEK 3: APPLY TO AGRICULTURE

- Research how farmers use gravity for irrigation (e.g., terracing, gravity-fed drip systems).
- Students brainstorm and sketch an irrigation system for a sloped farm using gravity to assist water flow.
- Begin building physical prototypes or digital models.
- Deliverable: Initial system design + prototype draft

WEEK 4: TEST, IMPROVE, PRESENT

- Test water movement through models (if physical).
- Adjust design based on flow effectiveness, water loss, even distribution.
- Final presentations include:
- Key simulation data + graphs
- Scientific explanation of gravity's role
- Irrigation model and rationale for design

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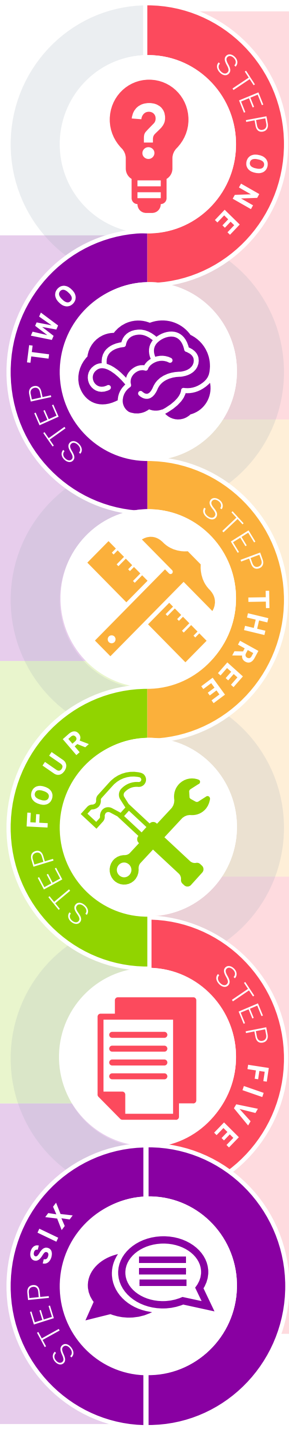
Challenge Design Process



IDENTIFY

Define the problem and how it is affecting life globally, nationally, and locally. Research and consider how others have approached solving the problem. Describe why this problem needs a solution. Determine constraints (e.g., time, space, resources, etc.).

IMAGINE

Brainstorm solutions to the problem. List all ideas – don't hold back! Discuss and select the best possible solution.

DESIGN

Diagram the prototype. Identify the materials needed to build the prototype. Write out the steps to take. Describe the expected outcomes.

CREATE

Follow the design plan and build the prototype.

TEST & IMPROVE

Test the design and collect quantitative and qualitative data. Discuss results and compare with the expected outcomes. Seek areas of improvement and make changes where needed.

SHARE

Communicate what was learned. Share the design, data, and conclusions. Present results.

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Materials List

Suggested Materials List

The items listed below are suggested materials needed to conduct the challenge. Facilitators and students are encouraged to be creative and inventive in acquiring the materials needed to complete the challenge (e.g., purchased, recycled, donated, etc.).

FOR SIMULATIONS:

- Access to gravitational force simulations (e.g., PhET Interactive Simulations: "Gravity Force Lab")
- Computers or tablets with internet access
- Student data sheets or digital forms for recording mass, distance, and force
- Graph paper or digital graphing tools
- Materials for creating a basic model of sloped farmland (cardboard, foam board, or trays)
- Measuring tools (rulers, scales, protractors)
- Water (if modeling flow) and small containers
- Safety equipment (e.g., towels, goggles if water is used indoors)

FOR HANDS-ON PROTOTYPES OR MODELS:

- Cardboard or foam board (for building slopes and models)
- Plastic tubing or straws (to simulate irrigation channels)
- Popsicle sticks, straws, pipe cleaners, aluminum foil (for making barriers or channels)
- Small containers or cups (to hold water)
- Water (colored with food coloring for visibility)
- Soil, sand, or pebbles (to simulate farmland surfaces)
- Modeling clay (to shape terrain features
- Measuring spoons or droppers (to control water flow)
- Toy figures or marbles (to represent mass and simulate gravitational effects)
- Variety of materials - PVC pipes, tubing, plastic bottles, sponges, small pumps, funnels – (for constructing irrigation prototypes)
- Graduated cylinders or droppers (for more precise water measurement)
- Weights - washers, coins, or small containers with variable mass (for exploring gravitational pull)

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Suggested Materials List

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FOR ENHANCED PRESENTATIONS:

- Poster board or trifold boards (for presenting findings)
- Colored paper, glue sticks, scissors (for visuals and models)
- Digital presentation tools (e.g., Canva, Google Slides)
- Stopwatches (for timing water flow if testing physical models)

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STEP ONE

1 IDENTIFY

Purpose of Step

Begin to understand the challenge question, define the problem and explore how it affects life globally, nationally, and locally. Research to build background knowledge on gravitational force and its agricultural applications. Describe why this problem needs a solution. Determine constraints (e.g., time, space, resources, etc.).

Student Prompts and Guiding Questions:

- What is gravitational force, and how does it work?
- How do mass and distance affect gravitational force between objects?
- How could gravity affect water movement on sloped land?
- Why would understanding this help a farmer? What do you already know about irrigation systems?

Signs of Step Completion

Students can explain gravitational force in their own words and explain the factors that affect it. Students can identify the ways gravity and water movement can influence farming practices. They should generate a list of questions they want to investigate and generate a hypothesis about gravity and irrigation.

AT THE COMPLETION OF THIS STEP, DIRECT STUDENTS TO THE REFLECTION QUESTIONS IN THE STUDENT GUIDE.

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STEP TWO

2 | IMAGINE

Purpose of Step

Brainstorm possible solutions, experimental setups, and ways to test gravitational interactions using both simulations and real-world modeling to provide possible solutions to the challenge. Discuss the tools available and how they might be the best solution.

Student Prompts and Guiding Questions:

- How can we use a simulation to explore gravitational force and its variables?
- What kind of physical model might represent water flow on a slope?
- What materials could help us simulate mass, distance, and gravitational pull?
- How might different slopes or weights affect how water moves?
- How might gravity influence how water moves across farmland with different slopes?
- If you were a farmer, what problems might you face with water flow?
- What would happen to water if the mass of water increased or the slow changed?
- What would an ideal irrigation system look like if gravity was used to help water flow?
- What kind of data do you think we'll need to collect to understand the relationship between gravity and water flow?

Signs of Step Completion

Students sketch or describe possible ways to test or simulate gravitational interactions and have proposed at least one simulation or tool to use (e.g., online PhET gravity simulation, simple 3D model of a hill and water flow). They select a focus for their investigation (e.g., data analysis, building a model, both).

AT THE COMPLETION OF THIS STEP, DIRECT STUDENTS TO THE REFLECTION QUESTIONS IN THE STUDENT GUIDE.

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STEP THREE

3 | DESIGN

Purpose of Step

Develop a detailed plan to investigate gravitational interactions using digital simulations and/or physical prototypes. Plan includes variables, controls, data collection, and visual representation of data.

Student Prompts and Guiding Questions:

- What simulation will you use, and what variables will you test (mass, distance)?
- If you're building a model, what slope, container, or materials will simulate farmland?
- How will you collect and organize data?
- What will your data table or graph look like?
- How will you make sure your design can be tested more than once to determine accuracy?
- How can your design connect back to a real-world farming scenario?

Signs of Step Completion

A written plan or blueprint is created for their experiment or model. Students define independent and dependent variables and prepare a data collection system and define success indicators. They also make initial predictions about the expected results.

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STEP FOUR

4 | CREATE

Purpose of Step

Students conduct the investigation, collect and organize data, and begin creating physical prototypes that simulate sloped farmland and irrigation systems.

Student Prompts and Guiding Questions:

- What happens to gravitational force when mass or distance changes?
- What patterns emerge from your simulation?
- How does water behave on your sloped model?
- What role does gravity play in moving water in your setup?
- How does your model or simulation represent a real farm landscape or irrigation system?
- What farming challenge are you simulating (e.g., too much water at the bottom of a hill, erosion, dry patches)?
- If a farmer saw your model, what could they learn about how to manage water on their land?
- How might different crops or soil types be affected by the water movement you observed?
- Are there any real irrigation tools or farming methods your model is like (e.g., terracing, drip irrigation)?

Signs of Step Completion

Physical models are tested and refined, and students have collected and organized data (quantitative and/or qualitative). Initial trends are observed, with annotations or labels on their models/simulations, demonstrating evidence to support or disprove earlier predictions.

AT THE COMPLETION OF THIS STEP, DIRECT STUDENTS TO THE REFLECTION QUESTIONS IN THE STUDENT GUIDE.

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STEP FIVE

5 | TEST & IMPROVE

Purpose of Step

Students review their findings, refine their understanding, improve their model or experiment, and deepen their analysis of gravitational interactions and their agricultural implications.

Student Prompts and Guiding Questions:

- Are your results consistent? What do you think caused unexpected outcomes?
- How can you improve your data collection, simulation setup, or model design?
- How do your findings support your claim about gravity and irrigation?
- If this were a real farm, would your system help conserve water or prevent erosion? Why or why not?
- How would changes in slope, soil type, or crop placement affect the success of your irrigation model?
- What improvements could make your model more helpful for farmers dealing with uneven land?
- If a farmer tested your idea in real life, what feedback might they give?
- What would you change if your farm was in a very dry area? A rainy one?

Signs of Step Completion

Students revise their model or simulation setup and retest, and a second set of data is collected and compared to the first. They begin analyzing results to support a claim with evidence and reasoning and generate mathematical representations (e.g., line graphs, bar charts) to show patterns.

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STEP SIX

6 | SHARE

Purpose of Step

Students communicate their findings, using evidence to explain the relationship between mass, distance, and gravitational force, and their agricultural relevance.

Student Prompts and Guiding Questions:

- What patterns did you find in your data?
- Were your findings what you expected? Why or why not?
- How does gravitational force affect water flow in farming?
- How can farmers use this knowledge to design better irrigation systems?
- What would you recommend to a farmer designing a gravity-fed system?

Signs of Step Completion

Students create a visual representation - a graph/chart with an explanation, a brief report, a poster, a video, or a presentation. Their explanation clearly ties gravitational interactions to agricultural decision-making and explains the impact of using water to move water efficiently across farmland, supporting responsible management practices like reducing runoff, conserving water, and improving crop health.

AT THE COMPLETION OF THIS STEP, DIRECT STUDENTS TO THE REFLECTION QUESTIONS IN THE STUDENT GUIDE.

EXTENSION POSSIBILITIES:

- Compare irrigation systems from around the world that use gravity.
- Build a small-scale gravity irrigation model with tubes, funnels, and water.
- Explore how soil type or plant spacing might interact with water flow patterns.
- Research or interview local farmers or agricultural extension agents to learn how irrigation and slope impact water management in real-world settings.
- Research the costs and benefits of various gravity-based irrigation methods
- Compare solutions that are sustainable for different farm sizes and climates.
- Investigate how farmers in other parts of the world develop innovative solutions in places with limited resources, steep slopes, or rough terrain, and consider how those solutions could be adapted locally.

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