Rainwater Harvesting

Lesson 3: Rainwater Harvesting and Engineering Design Introduction

INTRODUCTION

Students will use the Engineering Design Process (EDP) to ensure that they design the very best rainwater harvesting system to meet all criteria and constraints.

OBJECTIVES

- **DISTINGUISH**: Make distinctions about what the Engineering Design Process is and is not.
- **BUILD THE SYSTEM:** Identify the parts of a rainwater harvesting system and categorize them by function.
- **RELATE** the parts of the rainwater harvesting system to the functions that they serve.
- **TAKE A PERSPECTIVE**: From the perspective of an engineer, identify criteria and constraints for the problem to be solved by the rainwater harvesting system.

MATERIALS & EQUIPMENT

- Diagram: *Eight Steps of the Engineering Design Process*
- Handout: *Principles of Rainwater Harvesting - Stacking Function*

Teaching Strategies

If your students are familiar with the Engineering Design Process (EDP), then jump right into the challenge. If engineering is new to your students, introduce them to the process using the *Eight Steps of an idealized Engineering Design Process* diagram.

EDP is also an effective way to bring in cross-cutting concepts. As students think through the EDP, encourage them to think about how rain and snowfall patterns in their area might affect their design. How might the energy of a strong storm need to be accounted for in their model? How might large storms influence the proportion or scale of their rainwater harvesting system?

Note: In this lesson, students will be identifying criteria and constraints to their engineering design challenge that will help them design the optimal solution. Be sure to keep these two lists available for use in later lessons.

LESSON SUMMARY

In this lesson, students will apply the first step of the Engineering Design Process (*Ask*) to the rainwater harvesting system design project. If students are not familiar with engineering design, introduce them to the process using the *Eight Steps of the Engineering Design Process* background diagram. Students will develop a list of criteria and constraints and ensure that metrics are part of their problem statement.

The Rainwater Harvesting Unit is adapted with permission from the Arizona Project WET, Rainwater Harvesting Aqua STEM Program.

PRESENTATION GUIDE

Connect to the Unit

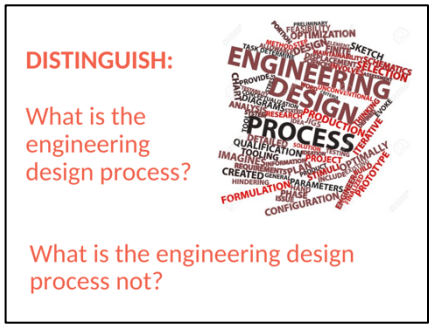
In Lesson 2, students explored the structure and function of simple rainwater harvesting systems. They learned about the major physical components of a passive system and the four main processes involved in all rainwater harvesting systems: **Collection, Conveyance, Infiltration, and Storage**. Students also investigated Stormwater Best Management Practices (BMPs) to better understand how stormwater can be effectively managed. In addition, they analyzed and compared the key features of permeable and impermeable surfaces.

Launch the lesson

In this lesson, students will:

- Apply the Engineering Design Process to help construct an explanation for the best rainwater harvesting design.
- Ask questions that define problems in which new technology may provide solutions for saving drinking water.
- Develop a model to manage stormwater runoff in the schoolyard watershed.
- Analyze and interpret data to support decision-making and planning.

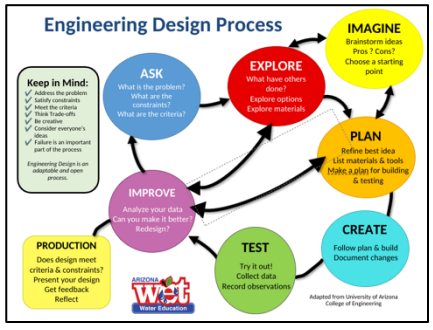
We will start to apply the Engineering Design Process (EDP) to design our rainwater harvesting system.



DISTINGUISH

• What is the Engineering Design Process?

Students might say building something or making something, to which you might ask, "How do they build something or make something?" Record students' ideas. We will work towards this definition: *The Engineering Design Process is a way to think through a problem to find the best solution given measurable criteria and constraints.*



• What is the Engineering Design Process not?

The scientific process, theory, boring, hard to use. Only produces one solution.

This is a diagram of the Engineering Design Process (EDP).

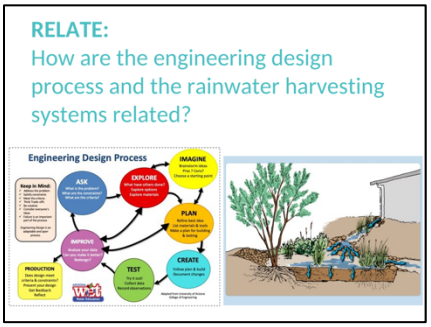
BUILD THE SYSTEM

• What are the parts of the Engineering Design Process?

Ask students: "What do you think the EDP is used for?" Encourage them to share their thoughts. They may say things like, "to figure something out," "to make something well," or "to solve a problem." Record their ideas to revisit later.

Clarify for students: The EDP is a structured to ask questions, define problems, and find solutions. It involves multiple steps and can take time—sometimes several weeks—to complete.

Using the EDP helps people create well-thought-out designs that meet specific **criteria** (what the design should do) and **constraints** (limits like time, materials, or cost). Unlike designs that are rushed or improvised, the EDP supports ongoing improvement to make sure the solution is effective and efficient.

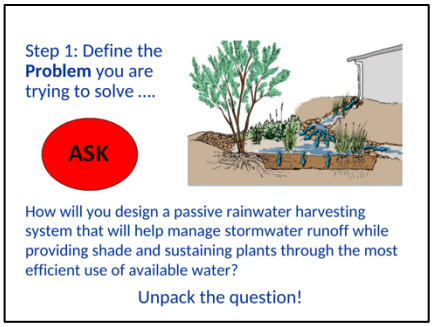


RELATE

• How are the Engineering Design Process and rainwater harvesting systems related?

Students may already recognize that they could use the EDP to design an effective rainwater harvesting system. Rainwater harvesting is a **simple system with interacting parts**, and the EDP is also a system — one made up of clear, logical steps to follow when solving a problem.

In this project, students will use steps of the EDP—**Ask, Explore, Imagine, Plan, Create, Test, and Improve**–to design a passive rainwater harvesting system that fits a specific area at school.



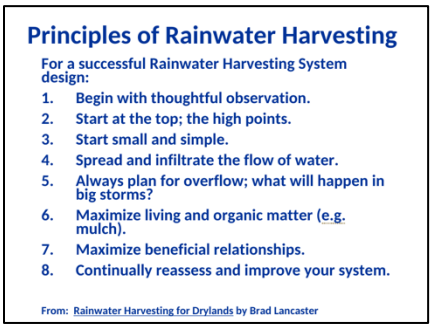
Students will begin by focusing on the "**Ask**" step of the EDP. When we're solving problems using engineering, we need to have a clear idea of WHAT the problem is. We do this by asking questions and identifying:

- The **physical structures** and surroundings (e.g., part of the school landscape)
- The **needs** of the people or environment affected by the system and involved in designing the solution
- The **constraints** (e.g., space, time, budget, or available materials) that may limit the kind of solution that you can develop.

Explore with students what this question is really asking them to do: *How will you design a passive rainwater harvesting system that will help manage stormwater runoff while providing shade and sustaining plants through the most efficient use of available water?*

Work with students to unpack key terms: What is the importance of **managing stormwater runoff**? What does **sustain** mean? What does

efficient use mean? Etc. Help students see how this question ties into both environmental challenges and design opportunities.



Your students will create an integrated design using the *Principles of Rainwater Harvesting* to devise a rainwater harvesting system that will meet the water demands of the plants and provide shade at your school by capturing stormwater runoff.

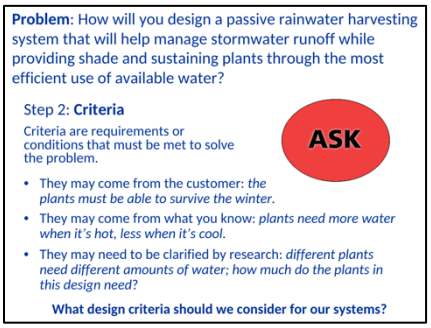
DISTINGUISH

- **What is meant by integrated design?**
  - How does it affect plants that are chosen?
  - What functions do the parts of my design serve?

These will become quantifiable criteria as the students work through the Engineering Design Process.

Post a list for brainstorming ***criteria*** somewhere in the room where you can refer to it throughout the next several lessons. Have students work in small groups to ask questions and begin identifying criteria for this problem. Criteria are requirements that your design must meet.

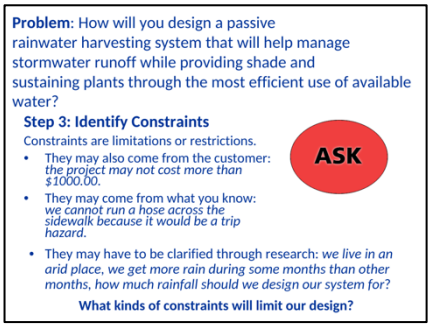
Prompt students to ask: What do we already know about stormwater runoff, shade, and sustaining plants? What do we still need to learn or clarify? What must our system *definitely* do? There will be opportunities throughout the exploration phase to refine these.



Criteria might include:

- Plants must have enough water to survive. How much?
- If it doesn't rain often, how does that affect plant choice?
- Which plants provide shade? Are other plants included in the design? What function do they serve?
- Location? Where is shade needed? What is proximity to water source or runoff?
- How much water do we need? How much water is available?

Note that that all these criteria become questions that must be answered. Many will be answered during the exploration phase of the design process. All must be answered for the design to be successful.



Also post a list of ***constraints*** in the room. Have students work in small groups again. Constraints must be satisfied. In the real world, we can't design just anything; there are limitations to what we can and cannot do. These limitations might be natural, i.e., we have no choice but to work with the soil type that our school has. Other limitations are imposed by the customer, i.e., the project cost cannot exceed a given dollar amount.

What constraints come to mind when you think about this project?

Write questions for constraints that you will want to clarify during exploration. There will be opportunities to expand the list of constraints and to clarify them as the exploration phase happens. Some examples of constraints might be:

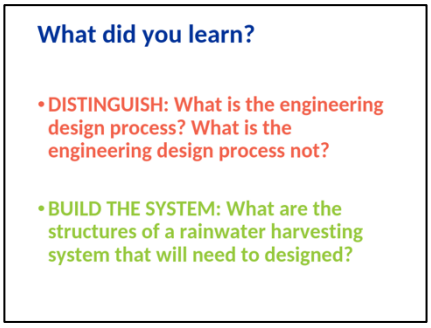
- Budget: we are not going to specify a specific dollar constraint, but the system should be as simple as possible.
- Location of plants: Where do you want to place trees, grasses, and other plants?
- Variability in rainfall patterns: how much rain do we get? When do we get it? When do we not get it?
- How much rain is in a 100-year flood event in your area?
- Local regulations: how much time is water allowed to sit in a basin before infiltrating? (In New Mexico this is 96 hours.)
- How do we determine the infiltration or percolation rate for soil?
- What are components we can add to the system to help infiltrate the water?
- Storage capacity (quantity and scale): How big does my basin need to be? Is it more than one basin?
- Space (structure as well as scale)
    - How much water can we store in the space we have?
    - What other structures or barriers do we have to work around?
    - Are there underground utility lines in this area?
- Overflow: What will we do about unusual rainfall events (patterns)?
- Safety (cause and effect):
    - What are the rules and regulations of the site and what kinds of limitations will they place on the project?
    - How deep are my basins?

Engineering Design Process

Just like with criteria, each **constraint** can be turned into a **question**—and these questions will guide students' investigations. In the end, every constraint must be addressed for the design to be successful.

Remember to keep both the criteria and constraint list posted or available to refer to in later lessons. You will likely be adding to both lists as you work through the EDP.

This video is an overview of the Engineering Design Process. As students watch it, have them try to define the **Problem**, **Criteria**, and **Constraints** in this scenario.



Conclusion

DISTINGUISH

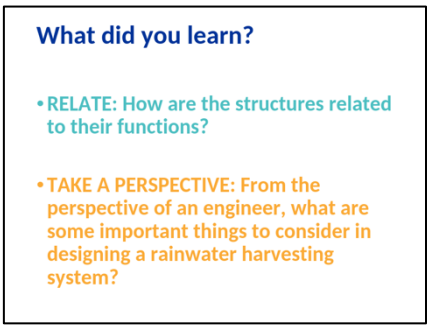
• What is the Engineering Design Process?
• What is the Engineering Design Process not?

The Engineering Design Process is several steps that help you find the best solution to a problem. It involves thinking carefully about the problem and improving your design after testing. It is more than building, designing, or creating.

BUILD THE SYSTEM

• What are the structures of a rainwater harvesting system that must be designed?

See if students have ideas about physical structures that can function to support any of the four processes involved in rainwater harvesting (collection, conveyance, infiltration, storage).



RELATE

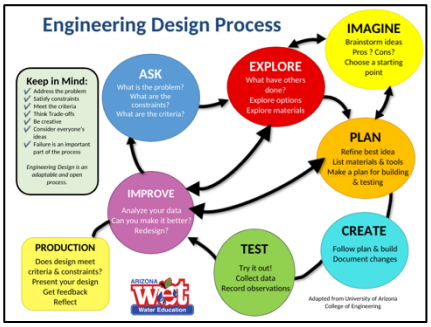
• How are the structures related to their functions?

Collection areas: Rooftops have the advantage of being higher than the landscape, but a parking lot, patio, or road could be a collection area too.

Conveyance: Gutters and downspouts are easy ways to convey water. Rock structures slow the water and decrease erosion. Berms and swales direct water.

Infiltration: Plants and mulch assist in infiltrating the water.

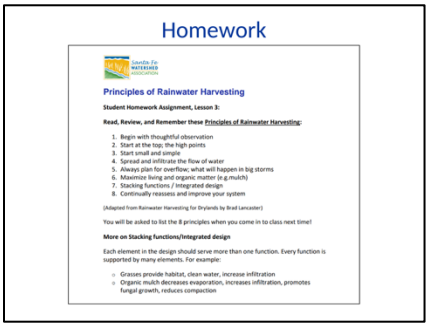
Storage: Plants store water or water is stored in the ground.



TAKE A PERSPECTIVE

• From the perspective of an engineer, what are some important things to consider in designing a rainwater harvesting system?

The next step in the Engineering Design Process is **EXPLORE.** Now that we have asked questions and clearly defined the problem, we can explore our physical site to learn more about what we have to work with. We'll begin our school yard explorations in the next lesson.



Homework Assignment

Have students read, review, and try to remember the *Principles of Rainwater Harvesting – Stacking Function* document. Do these principles add anything to your lists of criteria or constraints?