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.

ADDITIONAL RESOURCES

- 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, then 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.

PRESENTATION GUIDE

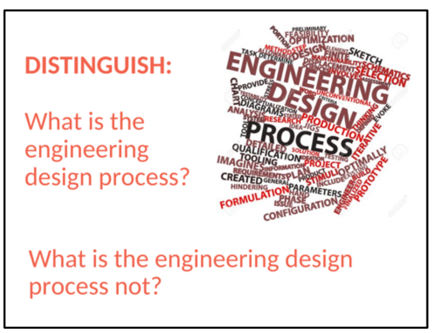
Connect to the Unit

In Lesson 2, students learned about the structure and function of simple systems used to create a rainwater harvesting system; including the major physical components of a passive system and the four processes (Collection, Conveyance, Infiltration, and Storage) involved in all rainwater harvesting systems. Students performed an investigation into Stormwater Best Management Practices (BMPs) to get a better understanding of how stormwater can be managed. They analyzed and made interpretations between permeable and impermeable surfaces.

Launch the 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 answers 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.



In this lesson, we will start to apply the engineering design process (EDP) to design our rainwater harvesting system.

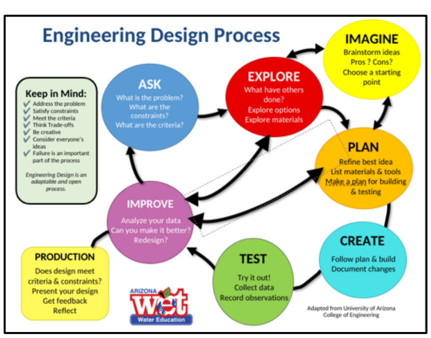
DISTINGUISH:

- **What is the engineering design process?**

Students might say building something, making something, to which you might ask, “How do they build something or make something?” Get only students’ ideas down at this point. 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).

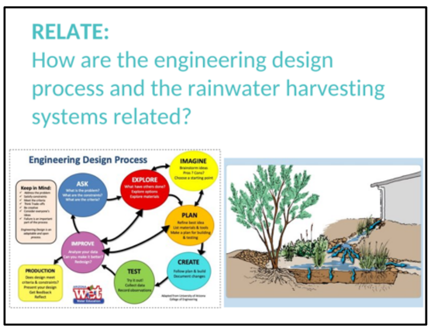
BUILD THE SYSTEM

- **What are the parts of the engineering design process?**

Ask students to add to the distinctions they made on what EDP is and isn't. Ask them, "What do you think the EDP is used for?" They may say things like; to figure something out, to make something well, or to solve a problem.

The EDP is an effective way to ask questions to help define a problem to be solved. EDP has many steps and can take several weeks to complete the entire process leading to the development of a successful design or model.

By using the EDP effective designs that meet the criteria and constraints are developed and produced. Design solutions created on the fly can be costly and ineffective. The EDP provides a mechanism to continually improve a design or model.



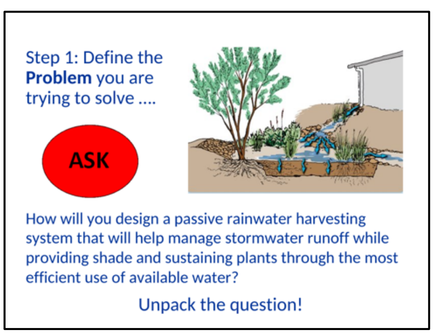
RELATE:

- **How are the engineering design process and rainwater harvesting systems related?**

Students may already see that they could use the EDP to design an effective rainwater system.

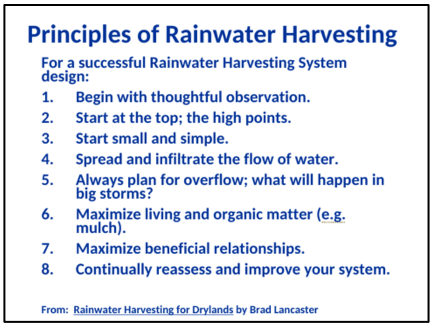
Rainwater harvesting is a simple system with interacting parts. The engineering design process is also a system. They will use the parts of the EDP system as steps or actions to take to build a rainwater harvesting system that fits their landscape area appropriately.

To design a rainwater harvesting system for an area at school, students will ask a question, explore, imagine, plan, create a model, test it, and improve their system based on feedback. Today they will start the project by asking a question.



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. The solution to the problem not only includes the question itself but considers all the parts of a system. This can include physical structures and surroundings, the people affected by the system, and those involved in designing the solution. Defining the problem includes recognizing anything that limits 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?* Unpack the driving question. What is the importance of managing stormwater runoff? What does sustain mean? What does efficient use mean? Etc.



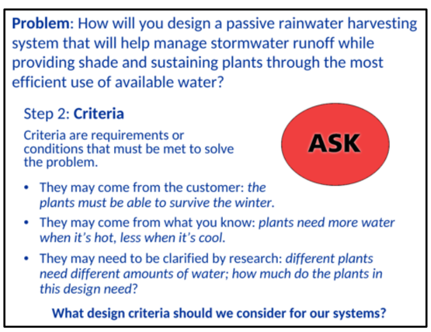
Your students will be creating an integrated design using the *Principles of Rainwater Harvesting* to devise a rainwater harvesting system that will meet the water demands of the plants and provide shade at your school by capturing stormwater runoff.

Distinction

- **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.

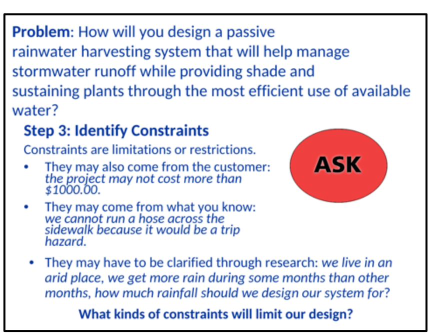
Post a list for brainstorming ***criteria*** somewhere in the room where you can refer to it throughout the next several lessons. Have students work in small groups to ask questions and develop criteria for this problem. Criteria are requirements that your design must meet. What do you know about the things mentioned in the problem statement? Write questions where there are criteria that need to be clarified. 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?
- What 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.



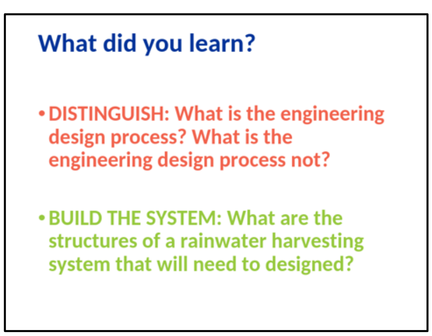
Also post a list of ***constraints*** in the room. Have students work in small groups again. Constraints must be satisfied. In the real world, we can't design just anything; there are limitations to what we can and cannot do. These limitations might be natural, i.e., we have no choice but to work with 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? Where do you want place grasses?
- 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?
- What are regulations in your area for the amount of time that water can sit in a basin before infiltrating? (In New Mexico this is 96 hours.)
- How do we determine the infiltration or percolation rate for my soil?
- What are components I can add to my 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 shall we do about rainfall events (patterns) that are out of the ordinary?
- 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?

As with criteria, every constraint becomes a question that will be answered through exploration and ultimately must be answered in order for the design to be successful. Which of these criteria and constraints can be quantified?

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 will need to be designed?**

See if students have ideas on physical structures which 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?**

What did you learn?

- RELATE: How are the structures related to their functions?
- TAKE A PERSPECTIVE: From the perspective of an engineer, what are some important things to consider in designing a rainwater harvesting system?

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.

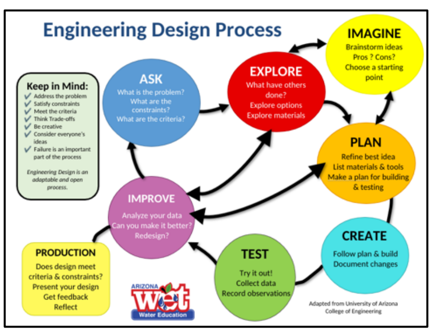
Conveyance: Gutters and downspouts are easy ways to convey water. Rock structures slow the water and decrease erosion. Berms and swales direct water.

Infiltration: Plants and mulch assist in infiltrating the water.

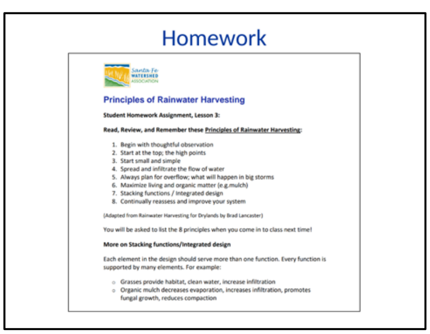
Storage: Plants store water or water is stored in the ground.

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.



Santa Fe Watershed Association

Principles of Rainwater Harvesting

Student Homework Assignment, Lesson 3:

Read, Review, and Remember these Principles of Rainwater Harvesting:

1. Begin with thoughtful observation
2. Start at the top; the high points
3. Start small and simple
4. Spread and infiltrate the flow of water
5. Always plan for overflow; what will happen in big storms
6. Maximize living and organic matter (e.g.mulch)
7. Stacking functions / Integrated design
8. Continually reassess and improve your system

(Adapted from Rainwater Harvesting for Drylands by Brad Lancaster)

You will be asked to list the 8 principles when you come in to class next time!

More on Stacking functions/Integrated design

Each element in the design should serve more than one function. Every function is supported by many elements. For example:

- Grasses provide habitat, clean water, increase infiltration
- Organic mulch decreases evaporation, increases infiltration, promotes fungal growth, reduces compaction

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?