**Lesson Plan: Solving Hard-to-Reach Problems with ROVs**

**Learning Overview:** Remotely operated vehicles, or ROVs, are often used in environments that would be unsafe or difficult for people to enter to explore. In this activity, students will think critically about how engineering practices can be used to monitor environmental issues or solve real-world problems before designing and modeling an ROV that could be used to investigate a real-world problem impacting their local environment.

**NGSS-DCI:** HS-ESS3; HS-ETS1.

**Paired Article:**

*Science News:*“[See the wonders of two newfound deep-sea coral reefs off the Galápagos](https://www.sciencenews.org/article/two-new-deep-sea-coral-reefs-galapagos)”

Readability Score:11.2

**Directions**: Prior to starting the activity in class, students will read the *Science News* article “[See the wonders of two newfound deep-sea coral reefs off the Galápagos](https://www.sciencenews.org/article/two-new-deep-sea-coral-reefs-galapagos)” and answer the associated questions for homework. In class, students will review the answers to the homework questions in groups before identifying a hard-to-reach local environment that can be investigated using a remotely operated vehicle. In groups, students will use the activity prompts to design their ROV to collect data or samples to monitor one or more aspects of the environmental problem. Then, they will make an illustration and, finally, a model. Each group will then present their model to the class and test their model to ensure it meets the required specifications.

Teachers should read through the first section of the activity to brainstorm hard-to-reach local environments that students may investigate using an ROV. Storm drains, a universally hard-to-reach environment, is provided as a possible location in the second section of the activity. If using storm drains, identify any that may be easily accessible on school grounds and investigated with students. Ensure that paper and markers or colored pencils are accessible for students to use in drawing their designs.

Prior to the second day of the activity, have materials for building models available for student use.

**Approximate class time:** 2 class periods

**Supplies:**

* Computers
* Student Worksheets
* Rulers / Tape measure
* Paper
* Markers / Colored pencils
* Popsicle sticks / Straws / Wooden dowels
* Wire / Pipe cleaners
* Cardboard / Foamboard
* Pool noodles / Foam
* String or rope
* Scissors
* Bottle caps
* Glue
* Tape

**ROVs in the Galápagos Islands**

For homework, students should read the *Science News* article “[See the wonders of two newfound deep-sea coral reefs off the Galápagos](https://www.sciencenews.org/article/two-new-deep-sea-coral-reefs-galapagos)” and answer the following questions.

1. What is the importance of the discovery made in the article?

*Scientists discovered deep sea reefs in the Galápagos. These reefs have been sheltered from the direct impact of humans and climate change, such as warming seas, to a larger degree than reefs near the surface.*

2. What device was used to make this discovery?

*Scientists discovered the reef using a remotely operated robot named SuBastian. This robot was in use for 30 days and explored part of the Galápagos Islands Marine Reserve.*

3. What is a potential scientific question that scientists may have used for this investigation?

*Scientists may have used SuBastian to investigate the following question: What type of environments and ecosystems are located at depths that are hard for humans to explore in the Galápagos Islands Marine Reserve?*

4. Based on the article, what information or data did this device collect? What other kinds of information or data could this type of device collect?

*SuBastian recorded video, which the scientists used in real-time to explore the ocean. Remotely operated robots could also potentially collect samples for scientists or perform tests or analyses in the environment that scientists cannot.*

5. Give three examples of environments or places where remotely operated vehicles might be useful. Explain how ROVs would be useful in each of these environments.

*Remotely operated vehicles would be useful in exploring places like the deep sea, space, and caves. Deep sea reefs are dangerous to explore in person due to the massive pressure exerted by the water. Space is difficult to explore in person due to the massive amounts of resources needed to support life and the difficulty, dangers and unpredictability of space exploration. Cave exploration can be dangerous due to tight passages that may be prone to collapse, which could trap explorers or divers inside. In all of these cases, using a remotely operated vehicle for exploration uses fewer resources than sending humans into these environments and reduces the level of risk associated with exploration.*

6. What technology or resources do you think this device may require?

*Student answers may vary. Remotely operated vehicles must be able to send and receive signals to and from the operating scientists. This could either be through a cable connecting the two parties or through radio waves. The remotely operated vehicle would also require circuitry and a power source. This power source could either be a portable, rechargeable battery pack or could be supplied through a cable. If using a rechargeable battery pack, the remotely operated vehicle may also use solar panels to provide energy to the ROV.*

7. What kind of planning, knowledge or skills may be required to create this type of device?

*You would need to understand the task that the remotely operated vehicle will undertake before starting to design the ROV. Designing the ROV itself probably requires knowledge of electronics and materials and would require the use of engineering practices.*

8. Think of a place that might be difficult for scientists to access and study in your local area. Why might scientists want to study this place?

*Student answers may vary. There are some fast-moving, low-visibility rivers nearby that are difficult to investigate. It can be dangerous for divers to enter these waters to evaluate river health, as the current and low visibility can make it dangerous and difficult for divers to maneuver.*

**Determining the ROV’s purpose**

For this part of the activity, students will be designing an ROV that can be used to investigate a self-identified scientific question about a hard-to-reach local environment. Assign students into groups of no more than four individuals. Once students are in their groups, ask students to share the answers to their homework with each other.

After students have shared their answers, let them know that they will be working in their group to design an ROV. This ROV will investigate a hard-to-reach local environment defined by the group. Or assign all groups within the class to design an ROV that investigates the same hard-to-reach local environment that you have chosen. While students may design an ROV that investigates any hard-to-reach local environment, the following location can be used by any classroom:

Storm drains carry excess water and runoff from urban areas into local streams or rivers. This water and runoff can carry trash or chemicals that pollute local waterways.

Give students approximately 10 minutes to research storm drains in their group before taking students outside to observe a storm drain on school grounds. While the students are outside, have them measure the opening of the storm drain. During the next section of the activity, students will build models of their ROV that fit within the storm drain opening.

Students may use computers to answer the following questions. Once students have answered the first set of questions, provide paper and drawing tools so that students may illustrate their model design. Make sure that their illustrations include clear labels and identify measurements and the location of the power source and other components, such as sensors or cameras. Students can use the second set of questions to guide them in their design.

1. Use at least three reputable sources to learn about the hard-to-reach local environment. What aspects of this location would make it difficult to monitor in person?

*Student answers may vary. Storm drains are a hard-to-reach environment due to the size of the storm drain opening and the sometimes small-diameter pipes used within the drain. While a person could open the grate covering the storm drain and enter, they would be unable to enter the pipes that carry storm water. Storm drains also rapidly fill with water after storms, making it dangerous to be inside them.*

2. Why would scientists need to monitor this environment?

*Student answers may vary. Scientists may need to test for pollutants, such as pesticides, at multiple points within the storm drain. Testing for pollutants at multiple locations in the storm drain would allow scientists to identify where pesticides are entering it. Testing for pesticides is important because any pesticides that enter the storm drain would eventually reach a local stream or river, where it could then harm wildlife.*

3. Develop a scientific question about this hard-to-reach environment that scientists could investigate using a ROV.

*Student answers may vary. Where are pesticides entering storm drains?*

4. Design an investigation that uses an ROV to focus on one aspect of the problem. What will the ROV do in this investigation?

*Student answers may vary. An ROV could be sent into a storm drain to collect water samples at different locations. These samples could then be brought back to the surface where scientists could test them for pesticides.*

5. What type of data would the ROV collect?

*Student answers may vary. The ROV will collect video and water samples from within the storm drain.*

6. How does the ROV record this data or collect this sample? Be as detailed as possible.

*Student answers may vary. The ROV can collect video using a remotely operated camera that streams a live feed to a mobile phone or other device. To see the inside of the storm drain with the camera, the ROV will also be equipped with a light. To collect water samples, the ROV will carry a clamshell device that can be opened remotely. The clamshell should be watertight so that when the two sides close together, the water sample cannot leak out.*

**Developing a design for your ROV**

When building an ROV, there are many factors to keep in mind. Use the following questions to guide you in building your model.

1. How is the ROV powered? Will all electronic components use the same power source? Be as detailed as possible.

*Student answers may vary. The ROV will have a rechargeable battery pack that powers the camera and light and will have a separate rechargeable battery pack that powers ROV movement. This is because the ROV camera may use a significant amount of power. A second battery would allow the ROV to take a sample and serve as back-up for retrieval of the ROV even if the camera’s battery were to run out.*

2. Do any components need to be watertight? If so, how will you keep the water out?

*Student answers may vary. The battery packs and other exposed electrical elements will need to be watertight to prevent a short out of the ROV’s circuits.*

3. How will you retrieve the ROV if it malfunctions?

*Student answers may vary. A rope will be tied to the end of the ROV so that if the ROV malfunctions or loses power entirely, it can be hauled up to the surface manually.*

4. Are there any size limitations? If so, what are the size limitations? How will this affect your design?

*Student answers may vary. The ROV will have to fit through the 3 x 20-inch storm drain opening. Because of the opening’s size, the vehicle will have to be relatively flat.*

6. Are there any weight limitations? If so, what are they? What could happen if your ROV is too light or too heavy?

*Student answers may vary. While there are no weight limitations, having an ROV that is very heavy may make it difficult to slowly lower it into or raise it out of the storm drain. It’s important that the ROV isn’t so heavy that it falls and breaks at the bottom of the storm drain, and it needs to be light enough that it can be hauled back out. The ROV should also be heavy enough that it isn’t swept away by water within the storm drain.*

7. Does your ROV need to be buoyant? If so, how will you make the ROV buoyant?

*Student answers may vary. The ROV does not need to be buoyant.*

8. Are there any additional design features that you feel are important to ensure that the ROV is successful in completing its task?

*Student answers may vary. The ROV should have some cushioning or padding on its exterior to reduce the chance of it breaking when being lowered into or raised out of the storm drain.*

**Modeling your ROV**

On the following day, provide students with materials such as popsicle sticks, straws, wooden dowels, wire, cardboard and foam to create a model of their ROV. The materials listed for this part of the activity are the bare minimum required to create a rudimentary model. It is highly encouraged to provide students with additional building materials. Students may also use bottle caps as wheels or other components for their ROV model. If possible, provide each group with a motor and circuitry kit. While multiple motor and circuitry kits are available for purchase online, the Lego SPIKE Education Prime and Essentials kits allow for students to create battery-powered vehicles with sensors that do not require coding to function. If students do not have access to motors and circuitry kits, the model will not be expected to have any powered functions. However, the models will still be expected to absorb an impact when dropped, should be mobile when pushed or pulled and able to turn, should have each component labeled and should fit within the size constraints that students previously identified. Let students know that each of these parameters will be observed, tested and measured upon completion of their models. To help guide students in creating their ROV models, the student worksheet includes a checklist of model requirements.

Once students have completed their models, have groups present their models to the class. The presentations should address each of the questions students answered in the “Developing a design for your ROV” section of the activity. At the end of each presentation, students should measure the dimensions of their vehicle to show that it met the size parameters they set the previous day. Then, they will demonstrate the model’s range of movement and, finally, demonstrate their model’s durability. To measure models’ durability, models should be dropped from at least 3 feet above the ground. If student ROV models have motors and circuitry, have students demonstrate their model’s capability prior to the durability test. It is important that all aspects of the model have been tested, observed, and measured prior to the durability test, as this test may damage the model’s functionality. If a model has a structural failure during the durability test, make sure students understand that this does not determine whether their model was a success or failure, as a true ROV would be made from different materials.

If using the storm drain environment scenario, prepare an open box with the same dimensions as the observed storm drain. The box should be open on two sides and should be placed on the edge of a table to simulate the opening of the storm drain. After students have given their presentations and demonstrated model mobility, students should approach the testing area and lower or drop their model through the open box onto the floor. All models should have a rope attached for model retrieval. Once the model is on the floor, students should attempt to pull their model back up through the box.