Investigate and Innovate with CSIRO

Robot Responders

CSIRO National Science Experiment

Community guide

Before You Begin

To help the activity run smoothly, consider the following:

Time required:

- Flexible delivery options are provided. Activities can be completed as a single session or spread across multiple sessions depending on available time.
- Allow additional time if participants will be building physical robot prototypes.

Materials:

- Optional: PowerPoint presentation
- Optional: internet-enabled devices for the Robot Responders HTML game
- Optional: Robot Responders mission cards – 2 missions **Note:** *Adult to decide whether both missions are explored in each environment.*
- Optional: Robot Responders card game
- Optional: craft and construction materials for physical robot prototypes (e.g. cardboard, recycled materials, tape, scissors, markers) **Note:** *the craft and construction materials resources will need to be sourced prior to conducting the activity.*

Prior knowledge and skills

- No prior robotics experience is required.
- Participants will benefit from basic problem-solving, teamwork and communication skills.
- The PowerPoint presentation is available as an optional resource to support the introduction of key robotics concepts and background knowledge.

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Learning environment

- A classroom, library, community space or workshop setting is suitable.
- If building physical prototypes, ensure participants have adequate workspace and access to materials.

Small groups of 2–4 participants are recommended to encourage collaboration and discussion.

Flexible Delivery

The plugged and unplugged resources can be used independently or combined to create a blended learning experience. Facilitators are encouraged to select the pathway that best suits their participants, available technology and learning environment.

How to use this resource

Recommended exploration of resources:

Plugged (Internet access)

PowerPoint presentation, activity workbook Robot Responders HTML game

Participants will explore robotics concepts through a combination of real-world examples (PowerPoint), workbook activities and an interactive digital game. The HTML game allows participants to design and customise robots, test solutions and apply problem-solving skills in realistic cave and lava tube, marine and space exploration scenarios.

Unplugged (No internet required)

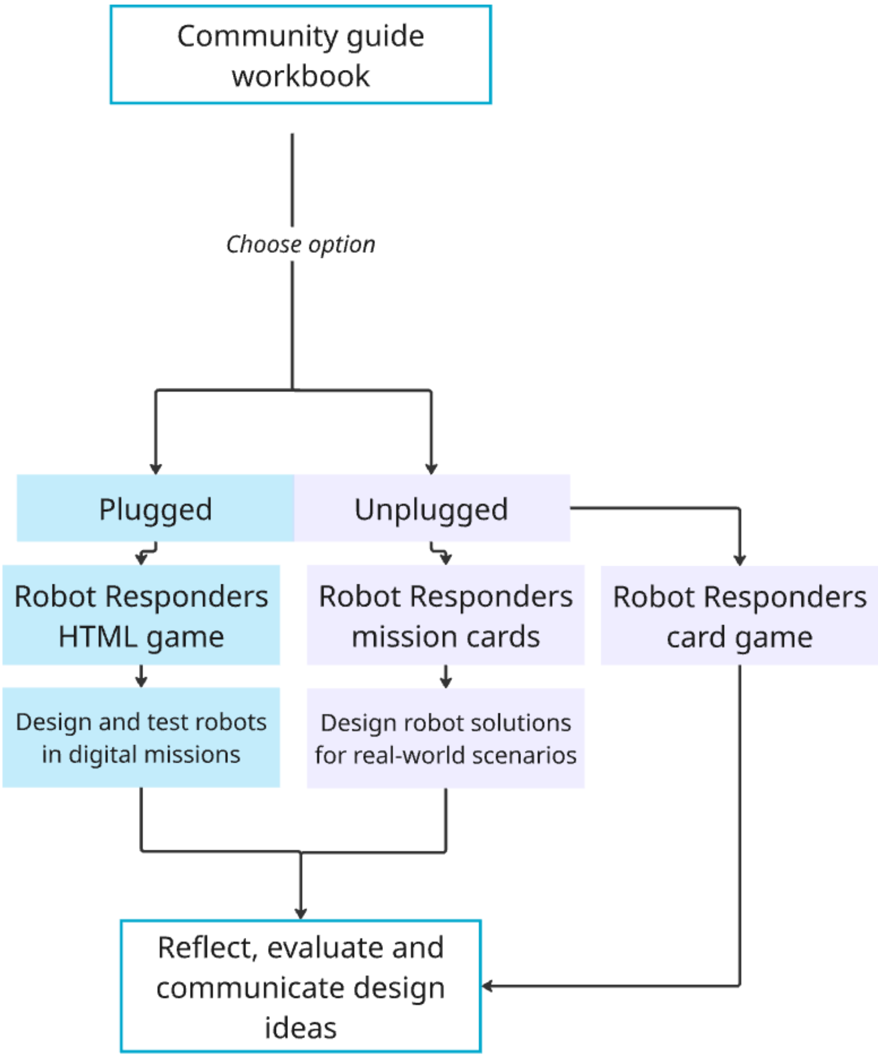
PowerPoint presentation, activity workbook and Robot Responders mission cards (2 missions per environment), building physical prototype OR Robot Responders card game.

Participants will investigate robotics concepts through adult-guided activities, design challenges and scenario-based problem solving.

Using the mission cards, participants will design and communicate solutions before creating a physical robot prototype using available classroom materials.

In addition to the mission cards and robot prototyping, participants can also test their design skills with the Robot Responders card game to strategically collect and combine robot components while overcoming challenges to design a robot that successfully completes a mission.

Community resources:



Example session run sheet (60-90mins)

Activity	Suggested time
Introduce the three environments (page 4), the design challenge and read the mission scenarios (workbook page 8-16)	5–10 min
Discuss the problem, mission requirements and environmental challenges	5–10 min
Participants work individually, in pairs or small groups to design their robot solution	20–30 min
Build a physical robot prototype or complete the HTML game mission or play Robot Responders card game	20–30 min
Gather participants to share, test or present their robot designs	10–15 min
Reflection and discussion: What worked well? What challenges did you encounter? What would you improve next time?	5–10 min

Background information

Robot Responders by Smriti Daniel

For further exploration of robotics concepts and real-world robot applications, educators may wish to obtain a copy of Robot Responders by Smriti Daniel, available through CSIRO Publishing.

CSIRO research:

Caves and lava tubes:

- CSIRO Blog: From Earth to space: Testing tech in lava tubes for future space exploration.
- CSIRO YouTube: CSIRO's Multi-Robot Navigation Stack.
- CSIRO website: CSIRO-Japan collaboration advances lunar cave robotics.
- CSIRO Data Access Portal: Jenolan Caves: 3D Data Collection.

Marine environments:

- CSIRO YouTube - How Google and CSIRO are helping protect the Great Barrier Reef with AI.
- CSIRO News article- World-first robotic hand to help cultivate baby corals for reef restoration.
- CSIRO Research – Bio-sensors: Discovering the secret life of oysters.
- CSIRO News article - The promise of seagrass pastures.

Space:

- CSIRO website: multi-resolution scanning.
- CSIRO Research: multi-resolution scanner.
- CSIRO and ISS National Laboratory: Testing novel 3D mapping technology to transform space exploration and benefit industries on Earth.
- CSIRO News article: CSIRO 3D mapping tech blasts off for International Space Station.

Investigation: Robot Responders

Read below to find out about the three dirty, dangerous and/or dull environments explored in this investigation:

Dirty, dangerous and/or dull environments
Caves and lava tubes environments
Caves and lava tubes are some of the most exciting and mysterious places on Earth! Imagine exploring deep underground where it's dark, twisty, and full of surprises around every corner. These environments can be narrow, bumpy, and uneven, with sharp rocks, steep drops, and even hidden pools of water. Lava tubes are tunnels made by flowing lava during volcanic eruptions! Inside, you might find rough floors, delicate ceilings, and unexpected changes in the ground. Some areas can be tricky or unsafe for people to explore, which makes them perfect places for scientists to investigate in new and creative ways to access them.
Marine environments
Oceans cover most of our planet, but so much of them is still a mystery like an uncharted world waiting to be explored! As you go deeper underwater, it becomes darker, colder, and the pressure increases, creating conditions very different from anything we experience on land. Beneath the waves, the seafloor can be rocky and uneven, with strong currents moving everything around. In some places, it's so dark that you can't see your hand in front of you! There are also extreme areas, such as the deepest parts of the ocean or regions trapped beneath thick ice, where humans can't safely go. That's why finding innovative ways to successfully explore these environments so fascinating.
Space environment
Space environments are some of the most extreme and challenging places humans can explore. They are vast, airless and exposed to extreme temperatures, radiation and microgravity, making them dangerous and difficult for humans to access. These environments may include the surface of planets and moons, as well as space itself, where there is no oxygen and very little protection from harmful radiation. Surfaces can be rocky, dusty and uneven, with craters, steep slopes and unknown hazards. Because these environments are so harsh and unpredictable, it's often too risky for humans to explore them directly.

Get ready for a robot rescue mission!

Explore caves and lava tubes, then design, build, and test a robot that can tackle the challenge. Play online or with cards — can your robot complete the mission?

Designing robots for complex environments requires engineers to consider factors such as movement, stability, durability, sensors, tools and materials. Engineers continuously test, evaluate and improve their designs to ensure the robots can successfully complete their missions in difficult conditions.

CSIRO engineering design process:

1. Identify the problem – What's going wrong? Who needs help? Where will the robot be used?
2. *Optional:* Research and learn – How other robots do similar jobs? What environment will the robot work in?
3. Imagine possible solutions – What shape will it be? Should it have wheels, legs or tracks?
4. Plan the best idea – Which idea solves the problem? Is it safe?
5. Build a prototype – What do I need to build? 3D printed parts? Household materials? Lego?
6. Test and improve – Does it do the job? Is it breaking? What do I need to fix on the robot for it to work?
7. Share and reflect - What worked? What didn't work? What we'd improve next time?

Aim:

To design, build and test a robot that can successfully explore a dirty, dangerous and/or dull environment where humans cannot.

Focus question:

How can we design a robot that can successfully explore a dirty, dangerous and/or dull environments that are too dangerous or difficult for humans to access?

Robot Responders game instructions

Option 1: Plugged

Access **https://www.csiro.au/en/education/Resource-Library/Resource-Library/Robot-Responders-HTML-game** and build your prototype in the game

Access the Robot Responders Game

Open the *Robot Responders* HTML game on your device using the link provided by your adult. Use your design plan to select robot components and build your digital robot.

Test your robot

Launch your robot into the mission environment and observe how it performs. Pay attention to how well it navigates obstacles, completes tasks and manages the challenges presented.

Review, refine and retry

Failure is an important part of the engineering design process. If your robot does not successfully complete the mission:

- Review your robot design
- Identify which features were successful and which were not
- Modify your design and component choices
- Test your robot again

Continue improving and testing your robot until it successfully completes the mission or performs more effectively.

Option 2: Unplugged

Print and cut cards on pages 9 – 16.

How to complete the unplugged Robot Responders mission

1. **Read the mission brief**

   Carefully read the scenario and identify the problem the robot needs to solve. Consider the environmental challenges, mission goals and design requirements.

2. **Follow the CSIRO engineering design process**

   Use the engineering design process to:

   - define the problem
   - research and learn
   - brainstorm possible solutions
   - plan and sketch your robot design
   - create a prototype
   - test and improve your design
   - share and reflect.

3.

Construct a prototype	Play Robot Responders card game
Build a physical prototype using everyday materials such as cardboard, paper, recycled materials, craft supplies or classroom construction materials.	Go to **https://www.csiro.au/en/education/Resource-Library/Resource-Library/Robot-Responders-HTML-game**. Players work together or compete to design a robot that can complete an important mission. Each turn, you collect and swap cards to build your robot, making sure it includes all the essential components. The winner is the first player or team to complete the robot and successfully meet the mission requirements while staying within budget.

4. **Test and refine your design**

   Evaluate how effectively your prototype meets the mission requirements. Make improvements based on any challenges or limitations you identify.

5. **Present your solution**

   Present your robot design to the class, explaining:

   - The problem your robot solves.
   - Key design features.
   - Any improvements you made during the design process

Robot Responders scenario card: Caves and lava tubes

Mission card #1: The cave mapping

A team of scientists have discovered a large underground lava tube system beneath an ancient volcanic region. The caves may contain important geological information about past volcanic eruptions, underground water movement and rare cave ecosystems. However, the tunnels are too dangerous for humans to fully explore.

The cave environment contains:

- Unstable rocks
- Steep & uneven terrain
- Narrow passages
- Complete darkness
- Deep drop-offs
- Thick dust blocking visibility

Your engineering team has been asked to design a robotic explorer that can safely travel through the cave and help create a map of the underground system.

Your task

Mission #1: The cave mapping

Your robot must be able to:

- Move across rough terrain
- Navigate in darkness
- Avoid obstacles & drop-offs
- Collect & return information
- Survive dust & rocky conditions

As you design your robot, think about:

- What movement system would work best?
- How will the robot "see" in the dark?
- How will it avoid obstacles?
- How can the robot communicate underground?
- What features will help it stay stable on uneven surfaces?

Using the engineering design process, your team will:

- Define the problem
- Optional: Research and learn
- Brainstorm possible solutions
- Sketch and label your robot design
- Build a physical prototype using everyday materials
- Test and improve your design based on feedback and failures
- Share and reflect

At the end of the challenge, your team will present how your robot design could help scientists safely explore dangerous cave systems.

Robot Responders scenario card: Caves and lava tubes

Mission card #2: The deep cave search

A group of cave researchers entered a remote lava tube system to investigate unusual rock formations deep underground. During the expedition, part of the cave became blocked by fallen rocks, preventing the team from continuing safely.

The cave system is extremely dangerous because:

- Large piles of rubble block pathways
- Visibility is almost zero
- The ground is uneven & slippery
- Some tunnels are too small for humans to enter
- Communication with the surface is unreliable

Your engineering team has been asked to design a robotic explorer that can safely travel through the cave and help create a map of the underground system.

Your task

Mission #2: The deep cave search

Your engineering team must design a robot that can:

- Explore tight underground tunnels
- Move safely over rocks & rubble
- Search for safe pathways
- Carry equipment or emergency supplies
- Communicate information back to the rescue team

As you design your robot, think about:

- What movement system would work best?
- How will the robot "see" in the dark?
- How will it avoid obstacles?
- How can the robot communicate underground?
- What features will help it stay stable on uneven surfaces?

Using the engineering design process, your team will:

- Define the problem
- Optional: Research and learn
- Brainstorm possible solutions
- Sketch and label your robot design
- Build a physical prototype using everyday materials
- Test and improve your design based on feedback and failures
- Share and reflect

At the end of the challenge, your team will present how your robot design could help scientists safely explore dangerous cave systems.

Robot Responders cost card: Caves and lava tubes

Budget: 100 credits

Body (base)	Compact core – 10 credits	Standard frame – 15 credits	Heavy platform – 20 credits	Basic thermal insulation – 25 credits	Active cooling and heating insulation – 30 credits
Wheel (locomotion)	Standard wheels – 10 credits	Rubber tracks – 15 credits	Single thruster – 20 credits		
Arm (manipulation)	Basic gripper – 10 credits	Drill – 15 credits	Arm – 20 credits	Precision arm – 25 credits	Laser arm – 30 credits
Motor	Brushed motor – 10 credits		Brushless motor – 20 credits		High torque motor – 30 credits
Head (camera)	Single grayscale – 10 credits	HD colour – 15 credits	Humanoid – 20 credits	Stereo vision – 25 credits	Thermal camera – 30 credits
Battery	Small capacity – 10 credits	Solar array – 15 credits	Solar panel – 20 credits	Medium capacity – 25 credits	Large capacity – 30 credits
LiDAR/ SLAM		2D LiDAR/SLAM – 15 credits		3D LiDAR/SLAM – 25 credits	

Robot Responders scenario card: Marine

Mission card #1: Crown-of-thorns starfish reef rescue

Marine scientists working on the CSIRO Great Barrier Reef monitoring program have discovered a large outbreak of crown-of-thorns starfish (CoTS) damaging sections of coral reef. Crown-of-thorns starfish are native marine animals covered in long toxic spines that feed on living coral. When too many starfish gather in one area, they can rapidly destroy large sections of reef habitat.

The reef environment is difficult and dangerous for divers to manage alone because:

- The starfish have toxic spines
- Underwater visibility can be poor
- Large areas of reef need to be monitored quickly
- Some reefs are deep or difficult to access
- Repeated surveys are needed to track outbreaks

Scientists are now investigating how robotic technologies can help monitor reef health, detect crown-of-thorns starfish outbreaks and assist with reef protection efforts. Some robotic systems can use cameras, sensors and artificial intelligence to identify starfish underwater.

Your engineering team has been asked to design an underwater robot that can help scientists protect coral reefs.

Your task

Mission #1: Crown-of-thorns starfish reef rescue

Your robot must be able to:

- Detect or locate Crown-of-Thorns starfish
- Help scientists monitor reef health
- Operate in low-visibility conditions
- Navigate around coral without causing damage
- Travel safely underwater
- Collect reef data or images

As you design your robot, think about:

- How will your robot move underwater?
- What sensors or cameras might it need?
- How will it avoid damaging coral?
- How can it detect crown-of-thorns starfish?
- How will information be sent back to scientists?

Using the engineering design process, your team will:

- Define the problem
- Optional: Research and learn
- Brainstorm possible solutions
- Sketch and label your robot design
- Build a physical prototype using everyday materials
- Test and improve your design based on feedback and failures
- Share and reflect

At the end of the challenge, your team will present how your robot design could help scientists safely explore dangerous cave systems.

Robot Responders scenario card: Marine

Mission card #2: Coral recruitment and reef restoration

Marine scientists are working to restore damaged coral reef ecosystems after coral bleaching events, storms and crown-of-thorns starfish outbreaks have reduced large areas of healthy coral. Coral reefs are important habitats that support thousands of marine species and help protect coastlines from erosion and strong waves.

One of the biggest challenges facing scientists is helping baby corals survive long enough to grow and rebuild damaged reefs. Baby corals are extremely small and fragile, making them difficult to move, monitor and plant safely by hand. Researchers from CSIRO have developed a soft robotic "hand" that can gently handle and transfer baby corals during reef restoration projects.

Your engineering team has been asked to design an underwater robot that can assist scientists with coral recruitment and reef restoration.

Your robot must be able to:

- safely transport delicate baby corals
- operate underwater without damaging coral reefs
- identify suitable locations for coral growth
- navigate around rocks and coral structures
- collect reef data or images
- support reef restoration efforts in challenging ocean conditions

The reef environment presents several challenges:

- baby corals are fragile and easily damaged
- underwater visibility can be poor
- waves and currents can affect movement
- coral reefs have uneven and delicate surfaces
- scientists need to restore large reef areas efficiently

Your task

Mission #2: Coral recruitment and reef restoration

As you design your robot, think about:

How will your robot move underwater?

How can it gently carry or place baby corals?

What features will help avoid damaging the reef?

How will your robot identify safe coral planting areas?

What tools or sensors might scientists need?

As you design your robot, think about:

How will your robot move underwater?

- What sensors or cameras might it need?
- How can it gently carry or place baby corals?
- What features will help avoid damaging the reef?
- What tools or sensors might scientists need?

Using the engineering design process, your team will:

- Define the problem
- Optional: Research and learn
- Brainstorm possible solutions
- Sketch and label your robot design
- Build a physical prototype using everyday materials
- Test and improve your design based on feedback and failures
- Share and reflect

At the end of the mission, your team will present how your robot design could help scientists restore and protect coral reef ecosystems for the future.

Robot Responders cost card: Marine

Budget: 100 credits

Body (base)	Compact core – 10 credits	Standard frame – 15 credits	Heavy platform – 20 credits	Pressure housing – 25 credits	
Wheel (locomotion)	Standard wheels – 10 credits	Rubber tracks – 15 credits	Single thruster – 20 credits	Omni-thruster – 25 credits	Multi-thruster – 30 credits
Arm (manipulation)	Basic gripper – 10 credits	Drill – 15 credits	Arm – 20 credits	Precision arm – 25 credits	Laser arm – 30 credits
Motor	Brushed motor – 10 credits		Brushless motor – 20 credits		High torque motor – 30 credits
Head (camera)	Single grayscale – 10 credits	HD colour – 15 credits	Humanoid – 20 credits	Stereo vision – 25 credits	Thermal camera – 30 credits
Battery	Small capacity – 10 credits	Solar array – 15 credits	Solar panel – 20 credits	Medium capacity – 25 credits	Large capacity – 30 credits
LiDAR/ SLAM		2D LiDAR/SLAM – 15 credits		3D LiDAR/SLAM – 25 credits	

Robot Responders scenario card: Space

Mission card #1: Lunar sample collection

Scientists have identified several locations on the Moon that may contain valuable geological samples. By studying rocks and soil from these locations, researchers hope to learn more about the Moon's history, how planets form and whether resources can support future human exploration.

The collection zone is located near a rugged canyon system containing steep slopes, rocky outcrops and deep shadowed areas. Engineers need a specialised robotic rover capable of travelling safely through the environment while collecting and transporting samples back to a central base station.

The mission presents several challenges:

- Some collection sites are difficult to reach
- Rocky terrain can damage equipment
- The robot has limited energy available
- Lunar dust can interfere with moving parts
- Samples must be handled carefully to avoid contamination

Your engineering team has been selected to design a robotic sample collection rover for the mission.

Your task

Mission #1: Lunar sample collection

Your robot must be able to:

- Navigate around obstacles & steep slopes
- Locate & collect rock or soil samples
- Safely transport samples
- Travel across challenging terrain
- Operate in dusty conditions
- Return collected samples to the base station

As you design your robot, think about:

- How will your robot collect and store samples?
- What type of robotic arm or gripper will it need?
- How will it travel safely across rough terrain?
- How can the robot conserve energy throughout the mission?
- What design features will help protect the samples?

Using the engineering design process, your team will:

- Define the problem
- Optional: Research and learn
- Brainstorm possible solutions
- Sketch and label your robot design
- Build a physical prototype using everyday materials
- Test and improve your design based on feedback and failures
- Share and reflect

At the end of the mission, your team will present how your robot design could help scientists collect and transport valuable lunar samples while overcoming the challenges of the environment.

Robot Responders cost card: Space

Budget: 100 credits

Body (base)	Compact core 10 credits	Standard frame 15 credits	Heavy platform 20 credits	Basic thermal insulation 25 credits	Active cooling and heating insulation 30 credits
Wheel (locomotion)	Standard wheels 10 credits	Rubber tracks 15 credits	Single thruster 20 credits		
Arm (manipulation)	Basic gripper 10 credits	Drill 15 credits	Arm 20 credits	Precision arm 25 credits	Laser arm 30 credits
Motor	Brushed motor 10 credits		Brushless motor 20 credits		High torque motor 30 credits
Head (camera)	Single grayscale 10 credits	HD colour 15 credits	Humanoid 20 credits	Stereo vision 25 credits	Thermal camera 30 credits
Battery	Small capacity 10 credits	Solar array 15 credits	Solar panel 20 credits	Medium capacity 25 credits	Large capacity 30 credits
LiDAR/ SLAM		2D LiDAR/SLAM 15 credits		3D LiDAR/SLAM 25 credits	

Reflection

Describe the design features that helped your robot successfully complete the mission.

Which robot components (movement, sensors, computing, etc.) were most important for exploring the environment successfully?

What challenges did your robot face during the mission, and how did you improve your design?

As Australia's national science agency, CSIRO is solving the greatest challenges through innovative science and technology.

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