WORK IT WITH CIRCUITS | EDUCATOR

Links to Next Generations Science Standards |

4-PS3-2: Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

4-PS3-4: Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

3-5-ETS1-2: Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

HS-PS3-5: Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to its interactions.

S T E M

Pacing | 1-3 class periods

Background Needed | Electricity basics and safety precautions

Assessment | Rubric provided

Materials/Resources |

- The following materials were used for the basic circuit building examples included in this lesson:
  - Aluminum foil
  - Low voltage flashlight bulbs (such as 1.5v or 4.5v)
  - Batteries to power the bulbs (1.5v D cell or 9v)
  - Masking or electrical tape

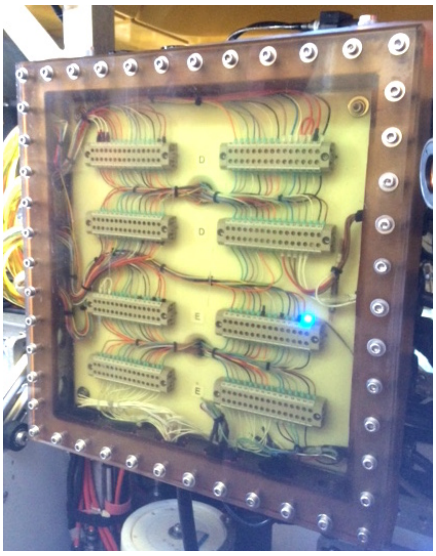
- The following materials are additional suggestions for circuit building. You can mix and match as it suits your budget and learning environment.
  - Insulated wire
  - Wire clippers
  - Alligator clips
  - Arduino Uno, breadboard, LEDs, resistors, wires
  - Multimeter for measuring voltage (http://nautl.us/2y8Qh41)

Overview

In this inquiry-based module, students will research the basic components of how electricity works, build a basic circuit, draw diagrams of electric circuits, and use models to explain when the path of an electric circuit is complete. For an extra challenge, students can build series and parallel circuits and define differences between them.

Objectives & Learning Outcomes

- Students will understand the basics of electricity.
- Students will use models to learn the basic components of a simple circuit and explain the difference between an open and closed circuit.
- Students will build a circuit to light a bulb.
- Students will learn how to diagram a simple circuit.
- Students will learn how electric components are used in ocean exploration, such as the circuit board mounted to Remotely Operated Vehicle (ROV) *Hercules* shown at right.



Links to Common Core Standards | CCSS.ELA-LITERACY.RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context.

Set The Stage! Use two images of a city scene at night with power and lights turned on, versus one that has lost power. Ask students to think about the differences between the two pictures to begin a conversation on electricity, its uses, and how the planet utilizes this resource.

Extensions & Adaptations

Introductory |

- No wire circuits with LEDs: https://www.youtube.com/watch?v=O2wYZzZlQt8
- Have students build and design their own conductivity tester (Digital Resource Library Link: http://nautl.us/2xMlNmW) to see what materials conduct electricity and which ones do not.
- Lead students through the guiding questions as a whole group discussion.

Guiding Questions

1. What creates electricity?
   - ✓ **Possible answers:** Magnets - in the 1800's Michael Faraday discovered that when a magnet moves through a loop of wire, the wire becomes electrified. Today, much of the world obtains electricity via power plants in which big magnets rotate around a wire to produce an electric current. Learn more about this process here: https://www.eia.gov/energyexplained/index.cfm?page=electricity_generating.

2. Define electrical current.
   - ✓ **Possible answers:** Flow of electric charge. In electric circuits the charge is often carried by moving electrons in a wire. The current (I) in a circuit can be determined if the quantity of charge (Q) passing through a cross section of a wire in a time (t) can be measured. I = Q/t. The standard metric unit for current is ampere, shortened to Amp, abbreviated by the unit symbol A. A current of 1 ampere means that there is 1 coulomb of charge passing through a cross section of a wire every 1 second. The ammeter is an instrument used to measure this.

3. What is an electric circuit and what are the main components?
   - ✓ **Possible answers:** A path in which electrons from a voltage or current source flow. A circuit has to be closed, joined at both ends, in order for current to flow through. A simple circuit has the following main parts:
     - Conductors: Often non-insulated copper wires; Make the path through which electricity flows. One piece of the wire connects the current from the power source (cell) to the load. The other piece connects the load back to the power source.
     - Switch: Small gap in the conductor where the circuit can be open or closed. When the switch is closed (Ex: turning a light switch ON), electricity flows.

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Extensions & Adaptations

- Primary Energy Infobook: https://issuu.com/theneedproject/docs/primaryenergyinfobook
- Elementary Energy Infobook: https://issuu.com/theneedproject/docs/elementaryenergyinfobook

Advanced |

- Students familiar with Arduino can practice building their own simple circuits without looking at a diagram using an Arduino microcontroller, breadboard, a power source, connector wires and an LED.
- Don't provide students a materials list but have them come up with their own supplies. Students can compare designs and circuit formations.
- Encourage the class to create a circuit that runs the perimeter of the classroom or specified area.
- Learn more about circuitry aboard the (E/V) *Nautilus* here: (http://nautl.us/2yobN4d)

- The Load: A small light bulb or buzzer that lights when the circuit is turned on, or closed. Also known as a resistor.
- Cell: The power source. A battery is multiple cells put together. All batteries have a positive end and a negative end. Batteries convert chemicals stored inside it into electrical energy. Electrons will build up at the negative end and flow through a circuit from (-) to positive (+) http://www.explainthatstuff.com/batteries.html.

4. What is conductivity?
   - ✓ **Possible answers:** The ability of some materials to allow electric current to flow through them due to the make up of the materials' atoms.

5. What makes some materials better conductors over others?
   - ✓ **Possible answers:** In a conductor, electrons can freely move through the material when an electric charge is applied. Metals such as copper make excellent conductors. Water is also conductive. Materials that do not easily allow electrons to flow through them are called insulators. Common insulators include glass, plastic and rubber.

6. Discuss the differences between a series circuit and a parallel circuit.
   - ✓ **Possible answers:** In a series circuit, multiple components are connected within the same circuit without any branches of wires. The wires connect the components one after the other. Tree string lights are often series circuits, which is why when one bulb goes out, they all go out due to the circuit being broken, or "open". Parallel circuits are set up in branches, so if one component is not working, the others still can. Most houses are set up using this type of circuitry. Parallel circuits are also frequently used on the Remotely Operated Vehicles (ROVs) operated from Nautilus.

Activity/Tasks

Students will:

- Read the lesson introduction and use their available resources to answer the guiding questions.
- Perform the kinesthetic circuit model activity.
- Work through the all parts of the procedure and complete all associated tasks.

✓ **LESSON SET-UP |** It is suggested that students work in pairs to complete this module.

☐ Helpful tips:

- ✓ Students can be led through the introductory questions as a whole group.
- ✓ Review electricity safety tips and warnings with students prior to beginning this lesson.
- ✓ Review with students how they can determine how many batteries they will need to power their circuit based on the voltage of the batteries and components provided. Example, a 1.5v D cell battery will work well with 1.5v light bulbs. Multiple batteries can be connected together to provide more voltage if needed. Be cautious of using too high of a voltage battery with much lower voltage bulbs. This can destroy the bulb.
- ✓ Inform students that connections have to be very secure in a circuit in order for the current to flow through it properly. Use masking or electrical tape to help secure the circuit.

☐ Use this kinesthetic activity and electron printable (http://nautl.us/2xAojNX) to have students think about open vs. closed electric circuits:

1. Hand each student an electron cut out from the printable sheet.
   - ✓ *Tip: Laminate a class set of electrons to have available each year.*
2. Have students form a circle and choose one person to represent the "battery" with their right hand representing (-) and left hand representing (+). The circle will represent a wired circuit through which electrons can flow.
3. The battery will pass their electron to their right.
4. The student who receives the electron will in turn pass their electron to their right. Electrons share the same negative charge which repels one another, which keeps them moving in the same direction. The flow of electrons through the circuit is the current.
5. Students will continue to pass the electrons to the right to complete the circuit.
   - ✓ *Tip: Add another component to this by choosing a student to be the "load" and hold a flashlight. When that student receives their electron, they can turn on the light.*
   - ✓ *Inform students that since electrons are so tiny (smaller than protons & neutrons), the conductors in a circuit have to be in close proximity to each other in order for the electrons to pass through. This represents a "closed" circuit.*
6. Have a student move away from the circle to represent an "open" circuit. Students should be able to conclude that electrons can not flow through the circuit because it is too far of a gap for the electrons to travel.

☐ Student Safety Warnings:

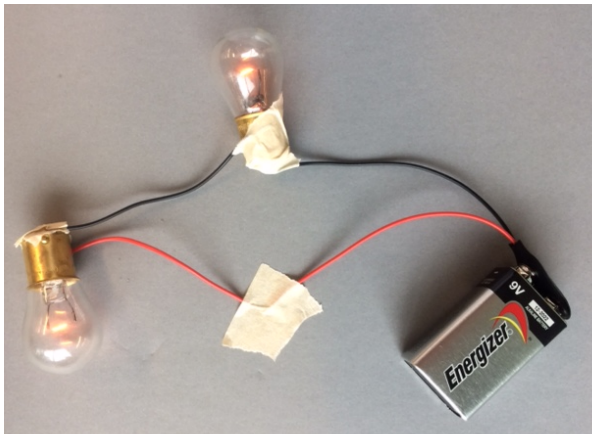
- ✓ You are using low voltage batteries and components for this lesson. NEVER connect a conductive material between the (+) and (-) ends of a battery. The material will get hot and could potentially burn you and the battery will quickly lose its energy, creating a short circuit.

- ✓ NEVER experiment with wall outlets. These are operating at much higher voltages and pose a safety hazard or even death if not used correctly.

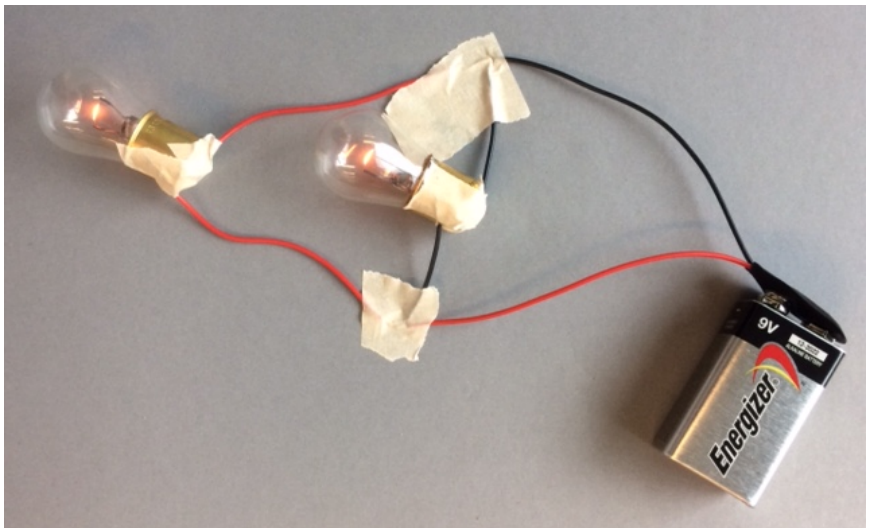
☐ Example circuit setups:

- ✓ This circuit was created with aluminum foil "wires", masking tape, 3 (D-cell) batteries and 1 (4.5 v) bulb.

- ✓ This series circuit was created with insulated wires (remove insulation from ends with wire strippers), masking tape, 1 (9v) battery and 2 (4.5 v) bulbs. Students will notice that based on the voltage of the battery and bulbs they may appear dimmer if they are connected to a lower voltage battery.

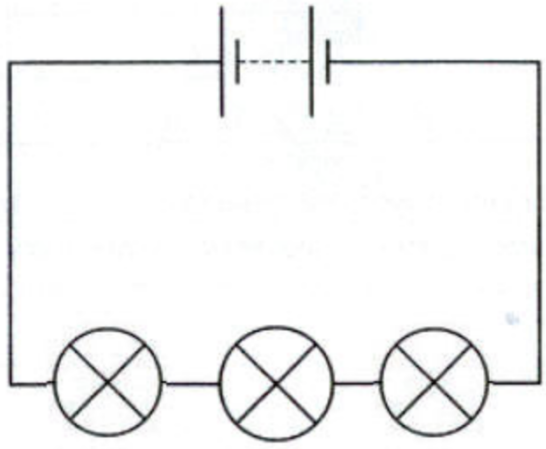


- [ ] Example circuit setups:
  - ✓ Parallel circuit. Additional insulated wires were used to make this circuit.



- [ ] Extra Circuit Challenge Answers:
  - ✓ Example series circuit diagram:
    - ✓ *Tip: Wires are always drawn using right angles and straight lines to make following complex circuitry diagrams less cumbersome.*

Battery (each set of lines represents 1 cell)

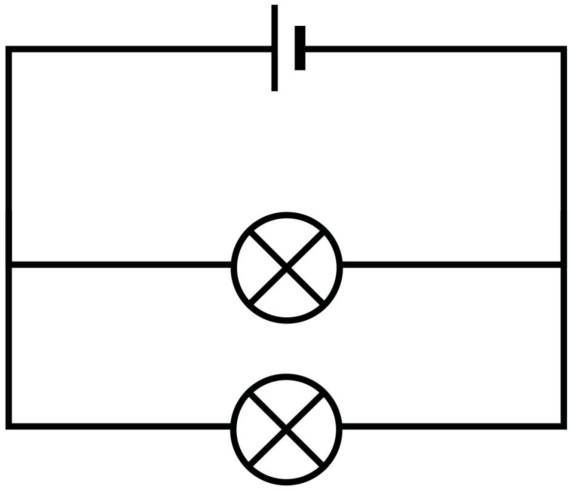


Wire

Lightbulbs

☐ Extra Circuit Challenge Answers:

✓ Example parallel circuit diagram:



a. Which circuit produced the brightest bulbs? Why do you think this is so?

✓ Students should observe that parallel circuits produced brighter bulbs. In circuits, bulbs can also be considered types of resistors. In a series circuit, the current passes consecutively through each bulb, and the more bulbs/resistors that are added the current will gradually decrease. Since bulbs are placed on separate branching lines in a parallel circuit, there are more pathways for the current to travel, and it therefore does not limit the current as much as a series circuit does. An analogy for this is to think about a city tollbooth. A tollbooth is a "resistor" slowing down the traffic (flow of charge/current through wires). If there is only one tollbooth, imagine the slow-down that would occur. If the tollbooths are all on the same path, it would continue the slowdown (series circuit). If the tollbooths are added in multiple lanes next to one another, it allows more cars to flow through at a faster rate (parallel circuit).

b. What are some advantages and disadvantages of each type of circuit?

✓ Series: Pros- less wires, do not easily overheat, all components carry the same current. Cons- if one component goes out they all do because the circuit will be open, the more components added the greater the resistance.

✓ Parallel: Pros- every component gets equal amount of voltage, if one component stops working the others will stay functional, easy to connect or disconnect a new element. Cons- energy from the power source is split across the circuit so can't be used in a situation that requires constant current, requires more wires and more complex design.

WORK IT WITH CIRCUITS | STUDENT

Learning Goals

- Understand the basic principles of electricity.
- Use models to learn the basic components of a simple circuit and explain the difference between an open and closed circuit.
- Build a circuit to light a bulb.
- Use proper diagrams to illustrate the components of your circuit.

Nautilus Knowledge

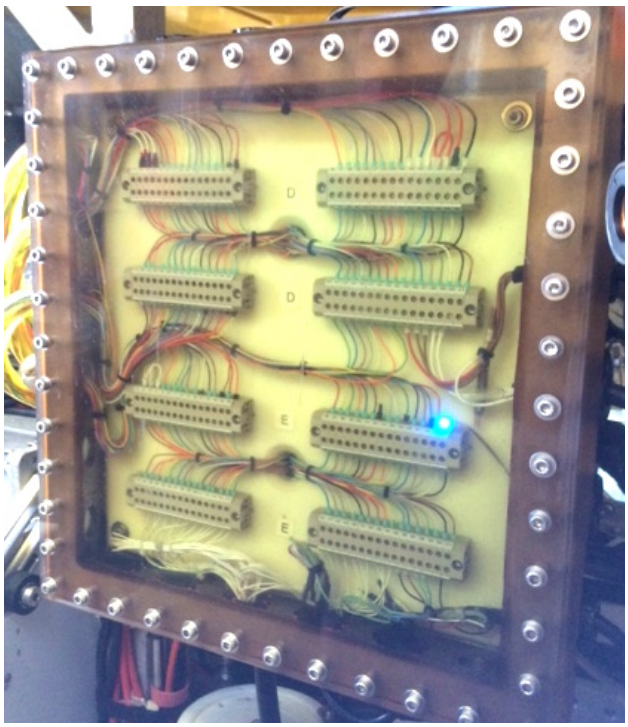
The word "circuit" comes from Latin *circuitus* which means "to go around".

Think About It!

Why do electronics need to be protected from seawater? What would happen if they weren't?

Introduction | Have you ever wondered what actually occurs to allow you to turn on a light, use a cellular phone or use batteries to power a device? Electricity is all around us and we rely upon it every day, yet few people understand the basic principles of this important energy source. Exploration Vessel (E/V) *Nautilus* uses two large generators to supply the electricity and circuits that run a wide variety of equipment on the ship. Circuits powered by the generators keep Remotely Operated Vehicles (ROVs) *Argus* and *Hercules* operating underwater, powering all the computers and network systems in the onboard data lab, making sure the crew has well lit areas and outlets to plug in equipment, and running unique sensor and scientific sampling tools. Almost all of Nautilus' operations requires the use of electricity. The ship is staffed with electricians and engineers who make sure everything is working properly and who assist the science team in making sure electronics are ready to go on the ROVs and sampling equipment during expedition dives.

In this module, you will learn the basic components of how electricity works, build a basic circuit, draw diagrams of electric circuits, and use models to explain when the path of an electric circuit is complete.



This circuit board panel mounted to the side of ROV *Hercule* powers equipment such as lights, cameras, and sensor tools utilized during dives deep beneath the ocean's surface. The conductive wires and elements are protected from the seawater by being encased in non-conductive and environmentally friendly mineral oil. As the pressure increases and some oil leaks out of the casing, more oil is pumped in via a backup supply kept on the robot.

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Helpful Resources:

- https://learn.sparkfun.com/tutorials/what-is-electricity
- https://www.eia.gov/energyexplained/index.cfm?page=electricity_generating
- https://www.tigoe.com/pcomp/code/circuits/understanding-electricity/
- http://science.howstuffworks.com/environmental/energy/circuit1.htm
- Video - Electricity & Circuit Basics: https://www.youtube.com/watch?v=D2monVkCkX4
- Video - Series and Parallel Circuits for Kids: https://www.youtube.com/watch?v=js7Q-r7G9ug

Background | Electricity is an invisible force caused by microscopic particles called electrons moving through a substance. This can happen naturally in the atmosphere, such as in the event of lightning, or can be harnessed in currents flowing through wires to power all of the gadgets, equipment and power sources we use as humans on our planet. Use your available resources to find the answers to the guiding questions below, and learn more about the basics of electricity and circuits.

Guiding Questions | Using your resources including those in the margin space, answer the following questions thoroughly. You may need to use additional paper.

1. What creates electricity?

2. Define electrical current.

3. What is an electric circuit and what are the main components?

4. What is conductivity?

5. What makes some materials better conductors over others?

6. Discuss the difference between a parallel circuit vs. a series circuit

WORK IT WITH CIRCUITS | STUDENT

Human Circuit Analogy!

Hand each person in your group a small object to represent an "electron". Form a circle. Choose one student to represent the "battery", with the right hand representing the negative end and left hand representing positive. The battery will pass their electron to their right. The student receiving the electron will in turn hold on to that one and pass their electron to the right. Since electrons share the same negative charge, they repel one another and move in the same direction through a circuit. The flow of electrons represents the current. Answer the following questions:

1. What do the students holding the electrons represent?
2. What would happen to the flow of electrons if there's a break in the circle?
3. Why do circuits need to be "closed" to allow electrical components to run or turn on?

Build a Circuit!

Materials | Your teacher will provide you with materials to build a simple circuit with. Record these materials below:

Procedure |

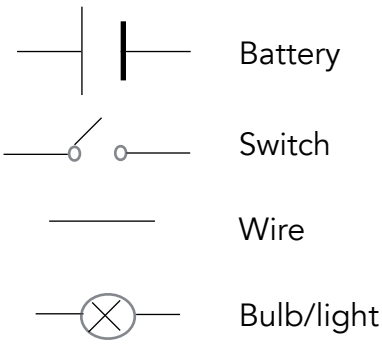
1. Build a simple circuit to get your light to turn on with the materials provided.

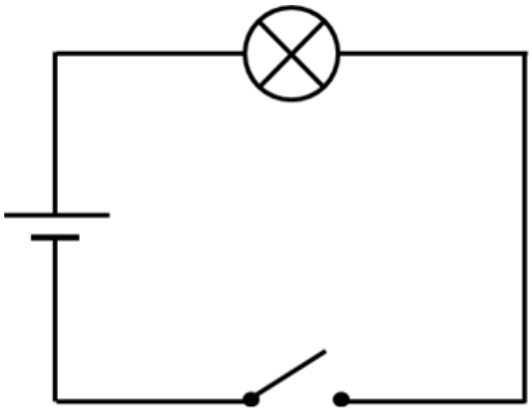
SAFETY WARNING!!

You are using low voltage batteries and components for this lesson. NEVER connect a conductive material between the (+) and (-) ends of a battery. The material will get hot and could potentially burn you and the battery will quickly lose its energy, creating a short circuit.

NEVER experiment with wall outlets. These are operating at much higher voltages and pose a safety hazard or even death if not used correctly.

2. Use the following symbols and example diagram to draw your circuit on the next page. Label the following: conductors, switch, load, battery, wire





3. Diagram your circuit below:

4. **Extra Circuit Challenge!** Use your materials to build a series and parallel circuit. Diagram both circuits in the boxes below and answer the questions that follow.

Series Circuit	Parallel Circuit

a. Which circuit produced the brightest bulbs? Why do you think this is so?

b. What are some advantages and disadvantages of each type of circuit?

WORK IT WITH CIRCUITS | ASSESSMENT

Scientific Modeling & Communication Rubric

OBJECTIVE	CRITERIA			
	4 Exemplary	3 Commended	2 Emerging	1 Developing
Evidence of Planning and Research |	Student submits thoroughly completed and accurate worksheets, documents, outlines, drafts, etc. of preliminary planning and research on topic.	Student submits completed and mostly accurate worksheets, documents, outlines, drafts, etc. of preliminary planning and research on topic.	Student submits partially completed worksheets, documents, outlines, drafts, etc. of preliminary planning and research on topic. Some information may be inaccurate.	Student submits minimally completed worksheets, documents, outlines, drafts, etc. of preliminary planning and research on topic. Information may be inaccurate.
Student Model or Product |	Adheres to all guidelines and expectations set forth. Model or product exhibits neatness, creativity and thoughtfulness in design.	Adheres to most guidelines and expectations set forth. Model or product exhibits neatness, some creativity and thoughtfulness in design.	Adheres to some guidelines and expectations set forth. Model or product exhibits some neatness, creativity and thoughtfulness in design, or these may be inconsistent.	Adheres to few guidelines and expectations set forth. Model or product does not exhibit neatness, creativity or thoughtfulness in design.
Communication of Content |	Student is able to thoroughly discuss content through use of their model/ product. Student thoroughly completes all associated follow-up worksheets, questions, reports, etc. with no content errors. Student can answer questions about their ideas using examples from what they learned.	Student is able to discuss content through use of their model/product. Student completes follow-up worksheets, questions, reports, etc. with few content errors. Student can answer questions about their ideas using examples from what they learned.	Student is able to weakly discuss content through use of their model/ product. Student completes some associated follow-up worksheets, questions, reports, etc. There may be some content errors. Student can answer rudimentary questions about their ideas.	Student is able to minimally discuss content through use of their model/ product. Student minimally completes associated follow-up worksheets, questions, reports, etc. Student has difficulty answering questions about their ideas.
Total Score: _____	**Comments:**			

How Large is Nautilus Nation?

Tracking the reach of Ocean Exploration Trust's education programs is essential in ensuring we are funded to continue making discoveries and inspiring the next generation of explorers.

Name: **My Community (City, State):**

Email Address:

School's Name:

Instruction date: **Grade level instructed:**

Subject area:

My education space is a...

- ❑ Classroom
- ❑ After school program / Club meeting
- ❑ Fair / Festival / Event
- ❑ Museum / Science Center
- ❑ Other. Tell us more:

Who did you engage in your teaching?

Students

Community Members

Select all the OET materials you used in your instruction:

- ❑ STEM Learning Modules. Which ones? _____
- ❑ Digital Resource Library materials. Which ones? _____
- ❑ Nautilus Live website: photo albums ❑ highlight videos ❑ live stream
- ❑ Meet the Team STEM mentor profiles
- ❑ Facebook (NautilusLive) ❑ Twitter (@EVNautilus) ❑ Instagram (@nautiluslive)
- ❑ Other. Tell us more: _____

_____

What made working with OET resources valuable to your instruction (select all that apply)?

- ❑ Hands-on activities ❑ STEM career connections
- ❑ Easy to use lessons ❑ Standards-based lessons
- ❑ Website resource access ❑ Real world application of curricula topics
- ❑ Excitement of cutting-edge discoveries / Unfamiliarity of deep ocean
- ❑ Another reason. Tell us more: _____

_____

Using OET resources increased my confidence in teaching my science, technology, engineering, or math subjects.	❑ Yes	❑ No
OET provided me with helpful and relevant teaching resources.	❑ Yes	❑ No
Using OET resources increased my awareness of STEM careers.	❑ Yes	❑ No
If yes, how so? How can we improve?		

Please scan this document or snap a picture of it with your phone. Email the feedback or questions to education@oet.org. You can also submit feedback online: http://nautl.us/2cp3PNu

Thank You For All You Do!