TOOLKIT FOR SCIENTISTS WORKING WITH YOUTH

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Produced by

PROJECT EXPLORATION
Changing the Face of Science®

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About This Toolkit

Bringing scientists together with students to work alongside one another is at the core of Project Exploration's work to provide meaningful access to science. We know that practicing scientists are often looking for ways to share their expertise and passion for the natural world with young people. Educational outreach is a personal and meaningful way to inspire a young person, while also re-energizing one's own practice and commitment to science.

This toolkit is designed to help scientists in the endeavor to provide authentic and high-caliber experiences for youth. We provide advice on a variety of aspects of the outreach experience: preparing for the event, designing an activity, promoting youth confidence, developing scientific inquiry skills, and teaching so that students actually learn. Our goal is to make the outreach experience as meaningful as possible—for both you and the students.

If you would like to share suggestions for this toolkit or provide a testimonial of your outreach experience with Project Exploration, please email us at **scientists@projectexploration.org**. We'd love to hear from you!

About Project Exploration

Project Exploration is a nonprofit science education organization that works to ensure communities traditionally overlooked by science—particularly minority youth and girls—have access to personalized experiences with science and scientists. Our youth programs impact the lives of hundreds of students each year by fostering a long-term involvement in science, and are supported by public programs that provide a window into science in action through exhibits, online initiatives, and contributions to the field of science in out-of-school time.

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www.projectexploration.org/connect

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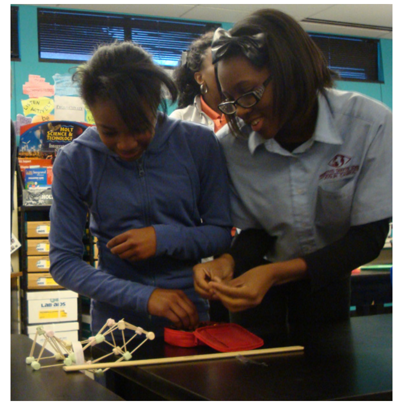
Engaging in Educational Outreach with Youth: A Checklist for Scientists

The following are some points to keep in mind as you participate in an educational outreach activity or program with youth. This advice will help you plan the outreach, develop a youth-centered activity, and facilitate a meaningful experience for both yourself and the students.



1.) Communication and Location

- Obtain contact numbers for both the teacher and the school.
- If visiting a classroom, try to schedule a visit so that you can observe the space and resources, and have an opportunity to speak to the teacher about the presentation.
- Verify how much time you will have for your presentation.
- Verify the school address, parking information, and room number.
- Determine how materials from your car will be transported to the room.
- Provide your cell phone number to the teacher in case of last minute changes.
- Make sure to give yourself extra time to sign-in at the Main Office, if applicable.
- Learn how the teacher normally gets the students' attention and use this method when needed.
- Ask if the desks and chairs can be rearranged to facilitate intended interactions with you and between students.

2.) Developmental Appropriateness

- Determine the grade(s) of the students.
- Determine the age range of students.
- Ask the instructor what the students have already covered in previous lessons and what they will be covering in upcoming lessons.
- Check the National Science Education Standards (www.nap.edu/html/nses) and the Illinois Learning Science Standards (www.isbe.state.il.us/ils/science/capd.htm) to determine what is developmentally appropriate for students.
- Review your lesson for any technical terms and vocabulary. Ensure that you have developmentally appropriate definitions for the terms.

3.) Planning Your Activity

- Use the 5E model (p. 14) to plan the activity.
- Determine what props, materials, and resources you will bring.
- Consider what skills you want the students to practice or develop.
- Consider what specific tasks students need to accomplish during the activity.
- Connect the activity to students' everyday lives by thinking of a big idea and making it relevant.

- Determine how you will tap into students' prior knowledge and experiences about the subject.
- Make a list of materials and resources you will need.
- Consider how you want the room to be set up to facilitate student interactions, discussion, and group work.
- Plan an activity where students are doing meaningful and productive work. In other words, ask yourself, "Are the students doing real science?"
- Determine how you will have the students reflect on their learning experience. How will you know what the students have learned from the lesson?
- Make sure to leave enough time for reflection, questions, and any necessary clean-up.

4.) Materials

- Ask what resources and materials are available for the lesson.
- Ask if there is budget for purchasing materials.
- Determine if resources or materials can be borrowed or donated in-kind from your institution.
- If using technology, determine availability of a projector, Wi-Fi, and an extension cord for plugging into an outlet.

5.) Follow-Up

- Ask the teacher or other observers for feedback on both the activity and your instruction.
- Ask the students what they enjoyed and what could be improved.
- Evaluate and reflect on your experience by considering how you might change the activity and your instruction for the next time you present.
- Share your experience with colleagues and your institution to encourage local educational outreach.
- Share your reflections and experience with the teacher and the school principal.
- Write a thank you note to the students for welcoming and inviting you into their classroom.

Best Practices and Techniques for Scientists Working with Youth

1. **Establish a personal connection with the students.**

   - Begin by sharing a personal story, such as where you grew up, your hobbies, or interests or how you became interested in science.
   - Ask students a question about their interests or something they are curious about.
   - Provide some background about your professional work and why it is an important field of science.
   - Tell students why you pursued your profession and what you enjoy most about being a scientist.
   - Make eye contact with the students.
   - Address students by their names as much as possible. If you can't recall, ask students to repeat their names to you.

2. **Provide an engaging and meaningful session.**

   - Make connections between the topic and students' everyday lives to establish the relevancy and importance of science.
   - Include a hands-on activity in which all students can participate. Avoid a formal presentation or lecture for longer than 10 – 15 minutes.
   - Have the students be physically active as early in the session as possible to help maintain their attention.
   - Explain and define any technical words that you use. Visuals, such as pictures and models, are particularly effective ways of communicating abstract or technical terms.

3. **Promote confidence and self-efficacy.**

   - Encourage students to ask questions throughout the session.
   - Verbally reinforce that the students are scientists and are engaging in the scientific process. Remind them that the goal is not to be "right" or "wrong," but to learn something new through the process of questioning and testing.
   - Tell students that you, and all scientists, are always learning and asking new questions.
   - Compliment students when they model scientific habits, such as when they ask questions, say "I don't know" or "I'm not sure," or make an evidence-based observation.

4. Discuss careers in science.

- Encourage girls to pursue a career in science and inform them of the need for female representation in your particular field.
- Advise students about the educational avenues relevant to your profession. Frame this by sharing your personal academic background.
- Discuss the variety of options that are available to college graduates with science degrees.
- Share both the rewards and challenges of working as a scientist in your profession. When discussing challenges that you have personally experienced, such as sexism and/or racism, share the ways that these obstacles can be overcome.
- Don’t be afraid to describe salary ranges of scientists in your profession.

Designing and Teaching Meaningful Science Outreach Activities

Scientists engaged in educational outreach with youth often work with a wide variety of students. Given differing levels of literacy or academic success, how does a scientist facilitate a meaningful and engaging experience for all students?

Science instruction is effective when it allows students to interact and participate fully. Regardless of whether the students are academically successful or not, research shows that learning science is guided by certain principles:

1. Students have preconceived notions about how the world works.
2. Learning science is an active, not passive process.
3. Learning is based in relationships, both with caring adults and meaningful experiences.

Making science accessible to all students means that science instruction and educational outreach is based in these principles. Identifying a great activity to share with youth is one aspect of a meaningful outreach experience. The second aspect is engaging the students through an inquiry-based approach that recognizes how students learn science.

The 5Es is a useful and effective model for meaningful science instruction that can be used with any activity and all students. Through the 5E approach, the scientist facilitates an experience for students that mirrors their learning cycle: engage, explore, explain, elaborate, and evaluate.

Briefly, the stages can be described in the following way:

Engage	The initial activity that gets students engaged and excited about the topic and program.
Explore	Opportunities for students to investigate a problem, ask questions, and interact with the topic.
Explain	Students develop an understanding about a particular concept, skill, or process based on their initial engagement and exploration.
Elaborate	Students apply and refine their understanding in a new context or through a novel challenge.
Evaluate	The facilitator assesses student learning and their own teaching.

In practice, the stages of the 5E model are not necessarily linear and there is typically overlap and cross-over between stages. However, in designing an activity for educational outreach, it is helpful to think about how one will move the students from one phase to another. By intentionally facilitating educational outreach opportunities in ways that recognize how students learn, the activity becomes meaningful, personal, and accessible for all students.

The following provides examples of six 45-minute lessons from Sisters4Science, Project Exploration's after-school program for middle school girls. Each lesson is described through the stages of the 5E model and therefore focuses not just on the hands-on activity, but also on the instruction. An additional blank template is provided to help you design your own activities with youth.

Sample Lessons from Sisters4Science

Designing and Building Structures

Engagement:

Structural engineer Annie Bridge introduces herself to the girls. She discusses how she first became interested in science and the challenges and victories with science during her school years. Annie asks the girls if they have ever traveled across a bridge and if they have felt safe while crossing it. Annie explains that her job as a structural engineer is to ensure that bridges safely hold the weight that passes over them. Annie asks the girls if they've ever built or created something and informs them that they have already been engineers!

Exploration:

Annie poses the girls with a question that she often faces at work. As an engineer, one has to create things that are strong, secure and enduring. Using various Lego pieces, the girls will construct, in groups, the strongest cube they can build. The girls set to work. Annie walks around the room asking the girls what their thoughts are. "Don't forget to write down your observations!" The girls are reminded that recording data is critical in science and that the observations will come in handy in the future. After five minutes the girls share with the other groups what made their cubes strong.

Explanation:

Annie takes the girls' observations of what made the cubes strong and uses them to introduce her main structural concepts for the lesson. Group #1 used a Lego piece across all the corners, this is called a bracing technique, and it allows corners to become more stable. Group #2 had a good idea going with doubling the sides to make it stronger, but that also makes it heavier. So what are some good ways to add support without making something heavier? The girls have some ideas. It's time to put them to the test.

Elaboration:

Given the girls' new understanding of structural techniques, it is now time to build something more challenging. Annie explains that the main job of an engineer is to come across a challenge and design ways to overcome it. If you were to design a product for safety, like a bicycle helmet, it would have to withstand impact. The girls are to take their cubes and build one that can survive a fall from four feet. The girls work in groups to build a sturdy cube.

Evaluation:

The cubes are dropped one at a time. Some survive the fall and others break. Each group now presents the unique structure of their cube, why they chose to build it that way, and what aspects they would modify in the future. The girls then discuss how Annie could use these structures to make safe bridges. Annie concludes the activity by reflecting with the girls on what they used to think about engineering and discussing how their opinions have changed. As the session wraps up, Annie shares some statistics about women in engineering today and future demand for structural engineers in Chicago. The girls go home with an informational booklet about women in engineering, donated from Annie's workplace.

Using Fingerprints as Clues to Solve Mysteries

Engagement:

Latent print examiner Tracy Print introduces herself to the girls. She shares how she was always interested in solving mysteries and taking things apart when she was younger, but always had a difficult time in math and science in school. Tracy explains that when she went to college, she wasn't sure what she would major in or what career path to pursue. One day, she accompanied her friend to a recruitment event in college where she had the opportunity to attend a presentation by the state forensic science center. She immediately became interested in forensic science and knew it was for her! Tracy asks the girls, "What do you know about forensic science?" She writes their comments on the board under a category called, "What we know about forensics."

Exploration:

A number of the students share that forensic science is used to solve crimes. Tracy follows-up that comment by posing the following question: "What types of clues are left at a crime scene?" Tracey writes down their responses on the board and reviews them in categories. The girls mention that fingerprints are a type of clue that are often left at crime scenes. Tracy tells the girls that she studies fingerprints at the state forensic science center. She provides each girl a document with six pictures of different fingerprints. Tracy asks the girls to group the fingerprints into categories. Which ones are similar to one another? After five minutes, the students share their thoughts.

Explanation:

Tracy introduces the girls to the terms loops, arches, and whorls. The girls are amazed when Tracy says that all fingerprint patterns fall into these three basic categories. Returning to the images, Tracy asks girls to find loops, arches, and whorls. They take a few minutes working together as a group before Tracy goes through each picture. What type of fingerprint pattern do we see in picture 1? Pictures 2 through 6?

Elaboration:

It's time to look at our own fingerprints and see what patterns we have! Tracy has brought an inkpad from work and gives each student a white index card. The students write their name and date on the index card. Going through each student one-by-one, Tracy has the girls roll and print the four fingers of their right hand. She gives each girl a magnifying glass. What types of pattern do you have on each finger? The girls are ready to work on their own prints!

Evaluation:

What fingerprint pattern is the most common? To answer this question, the girls decide to choose to compare the pattern of their index fingers. Each girl shares and Tracy writes their responses on the board. It turns out that most of the students have loops. Can we say that loops are the most common in the entire human population? Do you think there is a difference between genders? What about ethnicities? The girls have lots of ideas and Tracy encourages the girls to think about how they could design an experiment to find the answer to one of these questions. A few of the girls tell Tracy that they want to do a science fair project to determine the most common fingerprint pattern for their 7th grade class. Where do they start? Tracy gives them her card and points out her email and phone number. "Get in touch with me for advice!"

Making Observations to Understand Animal Diets

Engagement:

Francine Fishman, an icthyologist from the local natural history museum, introduces herself to the girls. She discusses how she did not think science was for her until the end of high school. That's when she began to work with animals and has done that ever since. Francine asks the girls to think about the tools they use to eat. What is the function of a fork? A spoon? A knife? Together they discuss how each tool has its own function; one is used for grabbing the food, one for scooping, and one for cutting. Now, Francine has the girls think of way in which animals can scoop, cut, and grab food without using tools. Many girls mention teeth and mouths. This sounds great! Let's explore it further.

Exploration:

Francine talks a little about her own work, where she catches fish all over the world to learn how their mouths and teeth work! As an ichthyologist, Francine makes observations of the mouth and comes up with hypotheses for the type of food that fish eat. She tells the girls that it is now their turn to be ichthyologists and passes out a different fresh fish specimen to each group. Each group will use their powers of observation to make detailed notes on the specimen. The girls take 10 minutes to write down their observations.

Explanation:

Francine asks for groups to share their observations. As the girls share, Francine writes down the information from each group in two columns – quantitative and qualitative – on the board. Some of the girls' observations were about the fish mouth and teeth. She asks, did you know fish have teeth?! As the girls get excited about fish teeth, Francine introduces the terms carnivore, herbivore, and omnivore, making sure to write the terms on the board and have the girls repeat the vocabulary together. As a group, the students come up with a few animals that they know of that fit each category. Francine gets the girls to think about what carnivore mouths have in common? How about herbivore mouths? Omnivores?

Elaboration:

The girls now return to their specimen to apply this new information. In groups, the girls work to figure out what type of food their fish eats. This time, Francine asks girls to make three quantitative and three qualitative observations about their fish specimen, its mouth, and its teeth. She goes over the difference between the two types of observations with examples. Each group then puts their heads together to come up with an educated guess as to what their fish eats.

Evaluation:

Each group takes a turn presenting to the rest of the students. They show everyone their fish and share their guess on what type of food it eats. Francine encourages the girls and adds any observations that the students might have missed. After every research group has presented, Francine pulls out two mammal skulls. She asks the girls to use their tooth knowledge and guess what these animals eat. Success!

Observing and Studying the Behavior of Animals

Engagement:

Biology graduate student Susie Slytherin introduces herself to the girls. She tells the girls about her work at the university where she has had the opportunity to travel the globe observing and studying animals. Her current work focuses on studying nature in Chicago. There is so much animal activity right here in and around the city! Susie asks for a show of hands of girls who have ever had a pet. What are some examples of animals that the girls have seen in the city? She asks if they ever took some time to notice animal behavior. What are some things your pet animals do? What about city animals? Susie explains how scientists who observe animals take note of the behaviors they see. The next step is always to ask: Why is the animal behaving that way?

Exploration:

It is the girls' turn to study animal behavior. Susie introduces the girls to earthworms. She shows the girls how to handle them with care, and then asks them to work in pairs to take a few notes. On a side table, Susie has placed some coloring pencils, rulers, and a scale. Susie asks the girls to draw the worm, measure its length and width, determine its weight, and take note of how the worm feels. She tells the girls that it is very important to have accurate descriptions of the animals they are observing because sometimes animals interact with each other and you need to be able to tell them apart.

Explanation:

Susie asks the girls to share some of their observations. The girls proudly share their colorful drawings and some of them have drawn the worms to scale! As the girls share their observations, some questions come up. Where are the eyes? How do we know if the worm is male or female? How do worms breathe? Susie answers each of the questions, writing some notes on the board. One of the girls asks, do worms have a skeleton? Susie asks the girls if any of them felt a backbone on the worm. She points to her own backbone saying that humans are considered vertebrates, but earthworms do not have a backbone and are invertebrates. Whether an animal has a spine or not can really determine their movement and behavior. Now it is time to experiment on the type of environments our worms prefer!

Elaboration:

The girls work in pairs to set up an experiment to test if worms prefer light or dark places and to test whether worms prefer wet or dry environments. Susie asks the girls to use what they know about worms to make a hypothesis before they begin testing. The girls use wet and dry paper towels to see where the worms decide to stay. Then they use a dark corner and a flashlight to observe which area the worms move to. Susie reminds the girls to try the experiment more than once to make sure their observations are accurate.

Evaluation:

The girls come back together to share their hypotheses and experiments with the group. What type of environment did the worms prefer? Susie chats with the girls about experiences they have had with worms in nature. When do they typically see the worms above ground? What type of environment do worms prefer below ground? The girls use the knowledge gained from their experiments to further their knowledge about worms and to help explain worm behavior.

Discovering the Chemistry of Everyday Liquids

Engagement:

Pharmacologist Nancy Atom introduces herself to the girls. She shares with them that she was always curious and asking a lot of questions in middle school, just like them! Nancy talks about pursuing science in college and admits to the girls that she had several classes that were a challenge, but she really learned to seek out help and that has been a skill she has used ever since. Nancy tells them that if they have ever cooked, they have absolutely done chemistry. Why is cooking just like chemistry? The girls share their ideas: using different ingredients, turning up the heat, mixing things together, and trying out new combinations. Nancy follows-up the girls' comments and shares that the final product of cooking is not the same as the ingredients. A change has occurred! She writes the term chemistry on the board and tells the girls it's all about change occurring. In a chemical reaction, one substance or ingredient interacts with another and a change happens. Nancy shows the girls a quick demonstration with an antacid tablet and water. As the girls observe the fizzing, she reminds them that one substance is interacting with another to produce a change.

Exploration:

What is an acid anyway? What is the opposite of an acid? Nancy writes down "acid" and "base" on the board. What do you think of when you hear the word of acid or acidic? What are some examples of an acid? Nancy shares that acids and bases can be distinguished using a pH indicator. She writes the term on the board and describes how by changing color, it can tell you if something is an acid or a base. Nancy shares with the girls a pH indicator that she has created and tells them that they will be using it to test several household liquids, such as shampoo, conditioner, oil, and soda pop. Before they test the items, everyone writes down a hypothesis for what they predict will be the results. They work in pairs to test their liquids and write down their observations in their journals.

Explanation:

The girls come back together to share their results. Together, they make a chart on the board of each household liquid, and its color before and after adding the indicator. Based on the results, which ones are acidic? Which ones are basic? Nancy asks the girls if they were surprised by any of the liquids. Nancy talks with the girls about what they usually think of when they think of something acidic. Together the class discusses that juices like lemon and orange juices are acidic. Nancy agrees that fruit juices are definitely acidic.

Elaboration:

Nancy asks the girls if they have ever heard of stomach acid or heartburn. Let's go back to our antacid! Why do you think it's called an antacid? Do you think the antacid is a base or acid? Why? Nancy shares how pharmacologists use magnesium to make antacids. She provides each group with some milk of magnesium and asks them to predict if it is a base or acid. Let's try it out!

Evaluation:

Nancy gives the girls a list of liquids and asks the girls to suggest to someone with stomach acid the best ones to drink and to avoid. The girls all decide that lemonade should be avoided but that milk might be helpful.

Uncovering the Inner Workings of Computers

Engagement:

Computer scientist Mariah C. Drive introduces herself to the girls and asks them to share their name and favorite websites. Mariah then shares with the girls the world in which she grew up, where technology was brand new. She asks the girls to imagine a world without cell phones or internet, and a place where computers were just starting to become popular. "What are some things that people might do differently without cell phones or internet?" Mariah tells the girls that she was fascinated by the first computer her family ever owned, and when it was finally too old to work, she was given permission to take it apart. At that time she was in high school and she was so surprised to open it up that she immediately wanted to learn more! It was such a great experience and she wants to share it with the students today!

Exploration:

Mariah asks the girls, "Who has ever taken something apart?" A few of the girls raise their hands. "Have you ever opened up your cell phone to take out the battery?" All the girls raise their hands! A cell phone is just like a mini-computer, Mariah tells them. Taking things apart is one of Mariah's favorite things to do. She reminds the girls that before taking something apart, they should have permission and take notes so that they can put it all back together again. Mariah explains that as a group they are going to open up a computer and look at two pieces. The girls will have 10 minutes to make three observations of the two pieces of the computer. Then the group will come back together and share it out!

Explanation:

Mariah asks a few of the girls to share the piece they found the most interesting. As the girls share each piece, Mariah reveals the appropriate name for the piece and writes down that part's role is in the computer. Mariah hands out a diagram with all of the pieces labeled for the girls to keep and take notes on. With diagram in hand, Mariah walks the girls through what happens when a computer is turned on and how it keeps running throughout the day.

Elaboration:

"All of these pieces look very complicated, but they all work because of one simple thing: a circuit! Has anyone here ever heard of a circuit?" Mariah writes down the girls' ideas. She tells them that circuits are everywhere in our lives. "Circuits are what help carry power to our beloved technologies! A circuit is similar to a train track. The electricity can move along the tracks, but if tracks are missing, the electricity cannot continue. This is how we do things like turn our room light on and off. When we turn it on, we add the missing track and electricity can move. When we turn it off, we take that track away, and the electricity cannot get there". Mariah hands out a simple circuit, attached to a light bulb, to every group. She allows the girls to experiment with every piece of the circuit.

Evaluation:

Mariah makes her way to each group and asks them if they can show her how electricity is moving through their circuits. Then she asks them what will happen if she takes out a part of their circuit. What if she adds a bigger battery? The groups use their new knowledge to make great hypotheses and test out various scenarios!

Template for Designing Your Activity

This 5E model is a tool for helping you guide students through their learning experiences while they're doing the activity you have planned. The model has been adapted from the Biological Sciences Curriculum Study (BSCS) 5E Instructional Model (www.bscs.org).

Engage

Get your students excited about both the topic and the program that will follow. Use a demonstration, an opening activity, or a discussion centered on what the students already know about the topic. The idea is to "engage" student curiosity. Use this mode to also test for prior knowledge and misconceptions.

Explore

During the "explore" mode, students have a chance to experience some of the concepts involved in the program. Through exploration, students begin to develop a preliminary understanding of the concepts involved in the program and get a sense of the variables or key characteristics that matter.

Explain

In an “explain” mode you begin to fill in more complete information about the concepts and help students make connections. Since your students have already been engaged and have had ample opportunity to explore, they will be more interested in the explanations and will have questions they are trying to figure out.

Elaborate

The “elaborate” mode unfolds when students begin to apply their knowledge in new and possible different contexts. During this phase students refine and deepen their understanding of the big ideas. You can try to find a way for students to apply specific principles to more general circumstances. You can also pose scenarios for them to consider and ask them to discuss “what might happen if…”

Evaluate

You evaluate to assess student learning – and your own teaching. Consider using an “authentic” assessment strategy that puts student knowledge on display through a creative activity. Recognize the value of having students evaluate their own knowledge by assessing how well they can apply their learning to real-world situations. Think about how evaluation information can help you refine your curriculum (what you’re teaching) and instruction (how you teach).

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