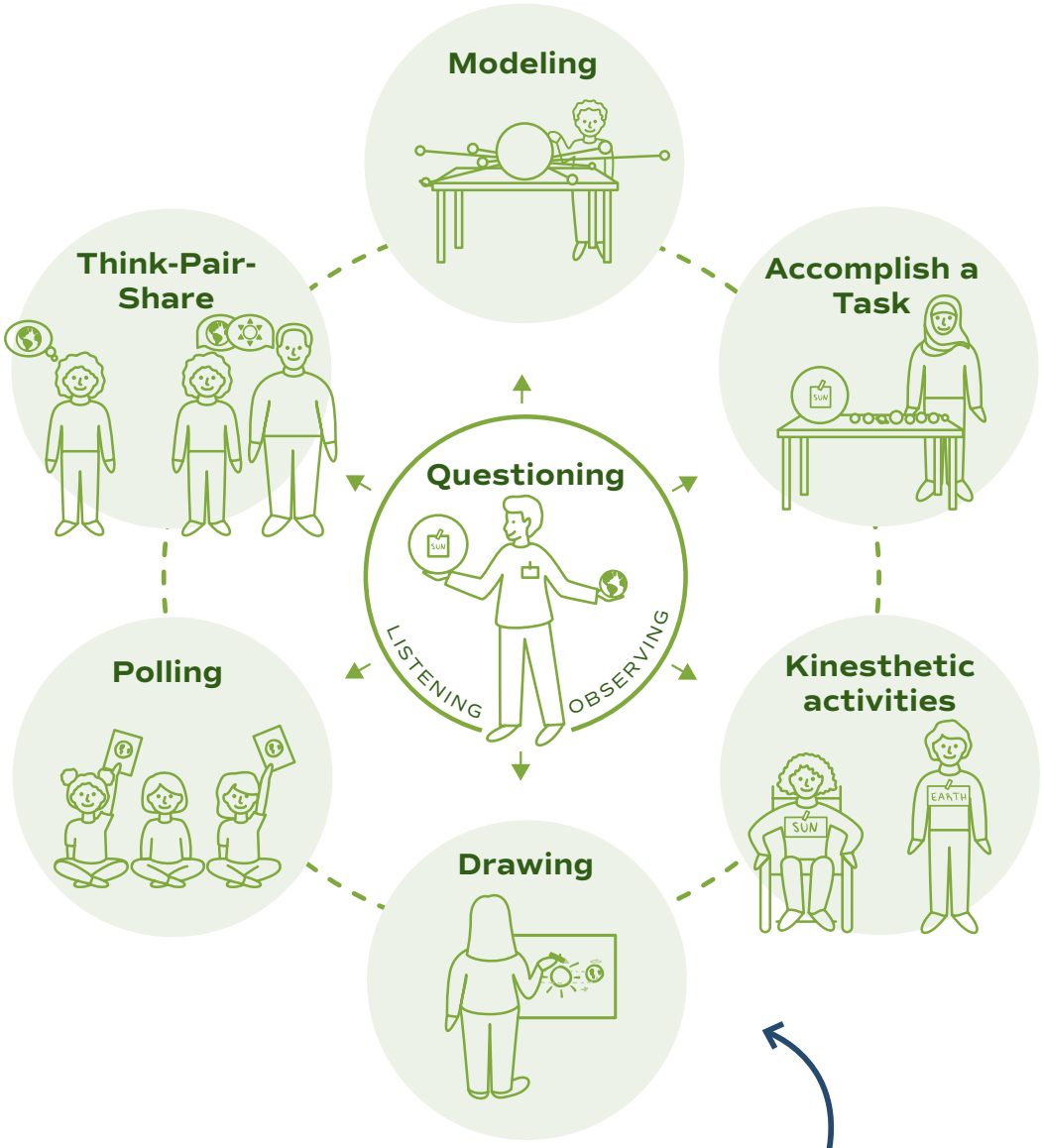

On-the-Spot Feedback

Tactics for Scientists *(and Others!)* to Improve Interactions with Public Audiences

ON THE SPOT FEEDBACK

ABOUT THIS GUIDE

On-the-Spot Feedback

Tactics for Scientists who Engage with the Public

This guide was created by a team of scientists, science educators, and educational researchers from the Astronomical Society of the Pacific, Institute for Learning Innovation, Oregon State University, and National Radio Astronomy Observatory, and is a product of an NSF-funded project *(On-the-Spot Assessment to Improve Scientist Engagement with the Public, NSF DRL 1811022)*.

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Institute for Learning Innovation
Portal to the Public

Oregon State University

Goal of this guide

To support you in collecting, reflecting on, and responding to audience feedback in real time as you facilitate an engagement activity.

Who it's for

Although this guide was developed with scientists in mind, the strategies can be used by anyone (including science hobbyists, museum educators, extension agents, etc.) who communicates ideas to public audiences.

WELCOME TO THE

On-the-Spot Feedback Guide!

Developing opportunities for an exchange of ideas between scientists and nonscientists has never been more important. If you are reading this guide, you are probably interested in improving your skills as a science communicator. Thank you for taking on this task.

Whether you are a novice or an expert in public science engagement, you may have asked yourself these questions:

- **Is my audience understanding me?**
- **Am I understanding my audience? Is this topic relevant to my audience?**
- **Is this activity interesting to them?**
- **Am I connecting to the range of prior experiences and backgrounds of these audience members?**
- **Am I doing a good job?**

After asking yourself these questions, how often do you find that you have insufficient information to meaningfully address them, and instead quickly move on to the next part of your planned presentation?

What if you had tools at your disposal to make audience thinking and feeling visible to you in the moment, during your interactions? The goal of this guide to the **On-the-Spot Feedback approach** is to provide you with information and a set of tools whose application will help reveal any number of things you would like to know about the experience the participants are having.

Using these tools, you'll...

- **Plan your activities with both engagement and feedback in mind**
- **Learn whether participants are enjoying themselves**
- **Learn whether they are successfully integrating the information you are sharing into their current understanding**
- **Better understand the audience in front of you: their interests, experiences, cultures, and how you might use that information to tailor the learning experience you are facilitating**
- **Improve your work with public audiences**

In this guide, you will find descriptions of seven tactics and how they can be used across science disciplines, with a variety of audiences, and in different venues. Many of the tactics described in this guide are well known methods for creating powerful learning opportunites. Here we outline how they can be seamlessly embedded into the learning experience you facilitate to provide actionable feedback.

The guide also includes tips, advice, and concrete examples to help you put these ideas into practice. We encourage you to try these tactics, modifying them as needed to meet your desired outcomes.

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Commit to a reflective process to improve your practice.

highlighted pages indicate worksheets

PRINTING TIP

If you just want to print the worksheets, they are pages 24–29 and 35–36.

Appendix

WHAT IS AN ENGAGEMENT VS FEEDBACK ACTIVITY?

See the next page for definitions

AUDIENCE TIP

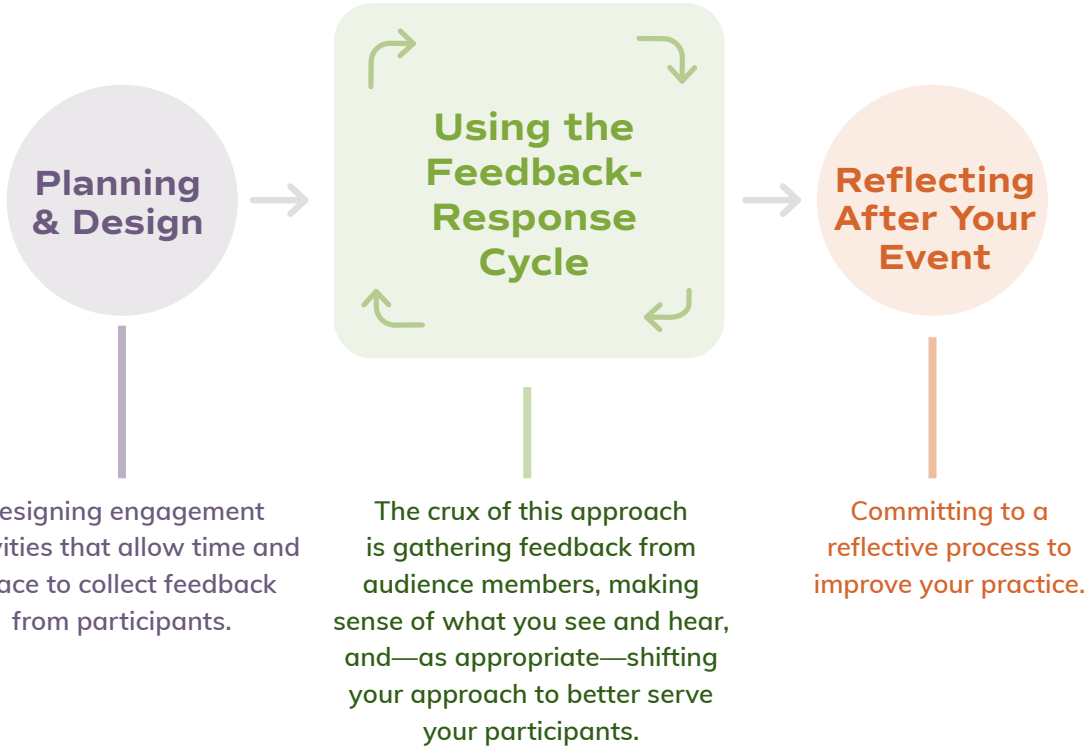
Remember that members of the public are more than just passive recipients of information. Instead, they bring expertise and personal experiences that will inform their own perspective on the topic discussed

INTRODUCTION TO THE

On-the-Spot Feedback Approach

When engaging the public in science, remember that members of the public are more than just passive recipients of information. Instead, they bring expertise and personal experiences that will inform their own perspective on the topic discussed. To be successful in any engagement situation it is important for you, as the facilitator, to focus your attention on the individuals in front of you and to tailor the experience to them. Plan for and respect what participants bring to your science engagement activity, such as their personal experiences, interests, background knowledge, and questions they might have. The choices you make, and how you design and facilitate an activity, can significantly impact how each individual engages with the information you are sharing and what they may learn or get out of the event.

The **On-the-Spot Feedback approach** aims to provide you with some tools to help you tailor each interaction to the individual participants.



USING ACTIVITIES
For Engagement and Feedback

An Engagement Activity

...is meant to be part of a memorable experience. It is driven by a goal. The experience may be designed to capture participants' interest, deepen understanding of a concept, create an enjoyable and safe learning environment, etc.

A Feedback Activity

...is designed to engage and also to elicit information. It is driven by a specific question whose answer will help you improve the overall experience for the participants. The information you collect through the feedback activity can be about the learners (what they know, think, feel, want) or about the experience they are having (are they having fun, are they understanding the concept). This information should help you decide how to change or adjust your approach during the rest of the engagement experience.

An Engagement Activity...	vs. A Feedback Activity
Gets people interested and helps them have fun.	Finds out if people were having fun (or not). With that information, I can change now (or in the future) to make the experience more engaging.
Helps people visualize and understand a concept better than me explaining or describing it.	Finds out if people understood a concept after I led an activity. With that information, I can modify what I do next (or how I change the activity next time) to improve understanding.
Creates opportunities for people to actively participate, rather than just listen.	Finds out what people already know about a fundamental concept. With that information, I can adjust how much introduction I need to do (or skip) in my presentation.
Builds trust and shows people I am listening to them.	Finds out what people are interested in learning. With that information, I can adapt what I cover now or next time.

Collecting feedback on-the-spot and acting on that feedback will help you become a better educator by creating more meaningful and more effective learning experiences for others. It is important to remember that the same activity can be used for engagement and for feedback. In fact, you may have already used some of the tactics presented in this guide to support audience engagement. What is important to remember is that if you can't name what you are trying to learn about the audience, if your activity is not eliciting specific, actionable information, then you are facilitating an engagement activity and not a feedback activity, even if you are using tactics described in the OTSF guide.

Facilitating well-planned engagement activities is important to any learning experience. If you are reading this guide you are likely already working with public audiences and have some experience with designing opportunities for engagement. **The On-the-Spot Feedback approach and this guide will help you move from facilitating activities for engagement to also facilitating activities for feedback.**

TIP

Without designing with inclusion in mind, our carefully planned engagement efforts will not only fall short of our desired outcomes, but could unintentionally discourage participants by reinforcing ideas about who is welcomed and supported in science.

TIP

Planning engagement activities without strong attention to inclusion simply cannot have the kind of impact many of us desire. **This isn't extra work; this is the work.**

Audience Considerations for Inclusion
Getting Started

Across the spectrum of engagement efforts (with varied audiences, venues, and desired outcomes) anyone reading this guide likely shares the desire to facilitate a positive experience for participants and connect public audiences with science and scientists. What we know from studying engagement is that all too often these interactions have unintended negative consequences for reasons not related to the content or the method of delivery.

For example, if an individual from a group historically excluded from the scientific endeavor asks a question that is perceived as being brushed off by a facilitator, this might reinforce her beliefs about who science is for (and not for), and who can be successful in science. The participant may be taking a risk by making an effort to connect and learn in a context that may feel intimidating. What might seem like a small moment to the facilitator with little real consequence might actually be perceived by the individual as another in a long line of discouraging experiences, and could have a big impact on future efforts by the individual to engage with science. The takeaway here is that without designing with inclusion in mind, our carefully planned engagement efforts will not only fall short of our desired outcomes, but could unintentionally close a door for participants by reinforcing ideas about who is welcomed and supported in science.

To help you design with inclusion in mind we share considerations for inclusion at three key moments:

- During a program or Event (page 11)
- Before a program or event (page 23)
- After a program or event (page 34)

Remember that these are not boxes to check, nor is there a "one-size-fits-all" approach to making a program more inclusive. Rather than seeing this as an extra layer of work, consider that planning engagement activities without strong attention to inclusion simply cannot have the kind of impact many of us desire. This isn't extra work; this is the work. The only way to create engagement opportunities that have real impact is to create space for people with a wide range of perspectives, experiences, and worldviews to connect with science. Furthermore, just as in any other industry, science itself is strengthened when it is driven by individuals with diverse perspectives.

These considerations are just a starting point. Many thoughtful people are engaged in making science communication more inclusive. Here are additional resources for further reading:

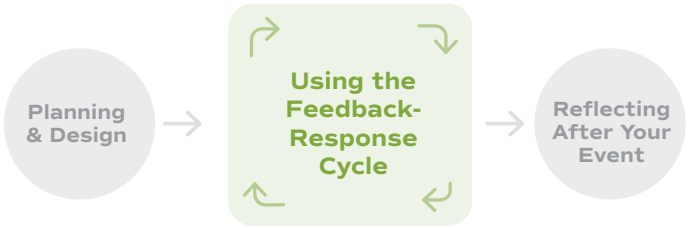
Canfield, K. & Menezes, S. (2020). *The State of Inclusive Science Communication: A Landscape Study.* Metcalf Institute, University of Rhode Island. Kingston, RI. 77 pp.

National Academies of Sciences, Engineering, and Medicine. (2018). *How People Learn II: Learners, Contexts, and Cultures.* Washington, DC: The National Academies Press. See especially ch. 2, pp. 21-33

SECTION

1

The Feedback-Response Cycle



The Feedback-Response Cycle

How to make use of what you learn

TIP

The point of soliciting feedback is to give you the tools to examine your own beliefs about a situation and craft a more relevant response to the participants in front of you.

FOR EXAMPLE

A facilitator might want to gauge the level and direction of her audience's interest so she can decide where to focus her efforts going forward.

At another time, she may want to determine whether the audience is enjoying themselves, and decide to increase (or decrease) the humor she brings to the interaction based on what she learns from the feedback process.

The On-the-Spot Feedback tactics presented in this guide often invite your audience to interact with materials, ideas, or other participants, which can help increase their level of engagement. These same tactics can be thoughtfully used to provide feedback to a question you have about the experience you are facilitating. Information collected with the tactics provides you with an opportunity to learn about what your audience is thinking and feeling. This is information you can use to adjust your facilitation to create an even more meaningful and impactful experience. Remember: the point of soliciting feedback is to give you the tools to examine your own beliefs about a situation and craft a more relevant response to the participants in front of you. A highly-practiced facilitator goes through this process continually during any engagement interaction.

Many facilitators wonder if their audience is understanding the science concepts, and through the feedback cycle can adjust to ensure the audience and facilitator "stay on the same page." Remember that it is through receiving and reflecting on feedback that you will be able to grow in your abilities as an impactful and memorable facilitator.

These steps offer a structure for effectively soliciting and using feedback.

On-the-Spot Feedback Cycle

The Feedback-Response Cycle

Though it can be tricky (and intimidating) to pivot and react "on-the-spot" to new information presented, remember that you planned for and allotted time for this, and this is an opportunity to more deeply and authentically connect with the audience.

You might even respond by departing from your planned outcomes (or activity) to follow the lead of the participants. **Sometimes the most effective interaction can occur when following the learners' lead**.

1 | Use a feedback tactic to solicit feedback.

Key to being an effective science communicator is knowing what audience members are thinking and feeling, what they already know, or what about their lived experiences or culture might make the engagement more successful. Use one or more of the **OTSF tactics** described in this guide to help you better-understand your audience.

2 | Internalize the feedback

Listen to, observe, and reflect on what your audience members are saying or doing. Try to attend to the full range of feedback you receive, and not just the most common response or the response that is easiest to engage with or seems to be the most critical or supportive. Remember that any response can offer you some valuable insights into what each participant is thinking and feeling—even (perhaps especially) any responses that are wholly unexpected.

3 | Share your understanding of the feedback

Reflect their ideas back to the audience. Spend some time discussing their responses; you might use the feedback collected as a starting point to dive into a topic you hadn't planned for. Perhaps the audience members shared an opinion you weren't expecting, or know less or more about a topic than you assumed. **You might say things like:**

- "I heard you say.."
- "I see that some people think..."
- "That's an interesting question..."
- "So you want to know more about..."
- "So from that prior experience you learned..."
- "I see that you're struggling with..."
- "I see some of you still discussing..."
- "What would happen if..."
- "That seemed to work/didn't seem to work..."

4 | Build from the feedback and respond

Building from your audience members' understanding, interests and beliefs, and with your desired outcomes in mind, **you may then respond by**:

- Inviting a conversation about how the topic relates to their life, lived experience, or culture
- Going into more depth about an aspect of the topic that has caught their interest
- Trying a different approach to convey the concept
- Changing your facilitation to better match the energy or goals of your audience
- Slowing down or speeding up a particular portion of your event
- Pivoting, if necessary! Creating a positive experience for your audience is more important than completing the activity as planned. Sometimes the best path forward is to skip a portion of your activity and make more time to pursue another direction.

Audience Considerations for Inclusion

During Your Event

Strive to create a positive and welcoming environment for all.

- Be open-minded and encouraging of all participants, experiences, and questions. Embrace an asset-based mindset, where participants offer value through their own perspectives, expertise, and lived experiences.
- When interpreting feedback, focus on the individual and avoid making assumptions about culture or ability. Also, recognize that not everyone will be comfortable with engaging in the same way. That doesn't mean they're not getting something out of the experience or what they are doing is "wrong". As a responsive educator, think about how you might shift your outreach to accommodate your participants and support their learning.
- Pay attention to who is taking the space to speak: the person who speaks up the most isn't the only one who has something to say. Check that you're not only engaging with participants in the middle of your field of view, for example.
- Consider that sticking to a prescribed agenda or timeline doesn't have to be your top priority. This particularly true if doing so gets in the way of other desired outcomes, like making your audience feel welcome and heard. Additionally, be cognizant that some cultures may have a more fluid sense of time that you are accustomed to and strict time-keeping at the expense of rich, collaborative discussion may be perceived as rude.

Look for opportunities to build connections.

- Listen and identify points of commonality with the audience. (Maybe you grew up in similar communities or have similar interests/hobbies.) Remember that valuing the experiences of your audience is important to developing rapport and creating a welcoming environment.
- You may be asked about a topic in which you do not have expertise. That's ok! It is ok to say that you don't know the answer to a question (and you should not be tempted to make something up). This could be a good opportunity to model scientific thinking: you can express your own curiosity about the question and verbalize your process for thinking it through. Being open about what you know and what you do not know (and what scientists don't yet know) can also make space for participants to share their own ideas and perspectives.
- The rules, culture, and practices that you apply to your scientific research represent one way to come to understand the world around us. It is important to remember that there are rigorous, evidence-based ways of knowing that differ from the organized science many of us are accustomed to. These ways of knowing may also not provide the kinds of credentials we are accustomed to recognizing. For example, Indigenous populations' Traditional Ecological Knowledge is a knowledge base that evolves through distinct, organized practices and often provides a holistic understanding of a specific context or ecosystem.

- Acknowledging your own perspective and expertise (e.g., as a professional trained in western science) is appropriate when identifying the knowledge perspective you represent with audiences. But, do remember that other people will bring their own expertise to the interaction and you might learn from them as well.

Remember that many people have incorrect or incomplete views of science and scientists. Some people may also erroneously believe that science and math are not accessible to them.

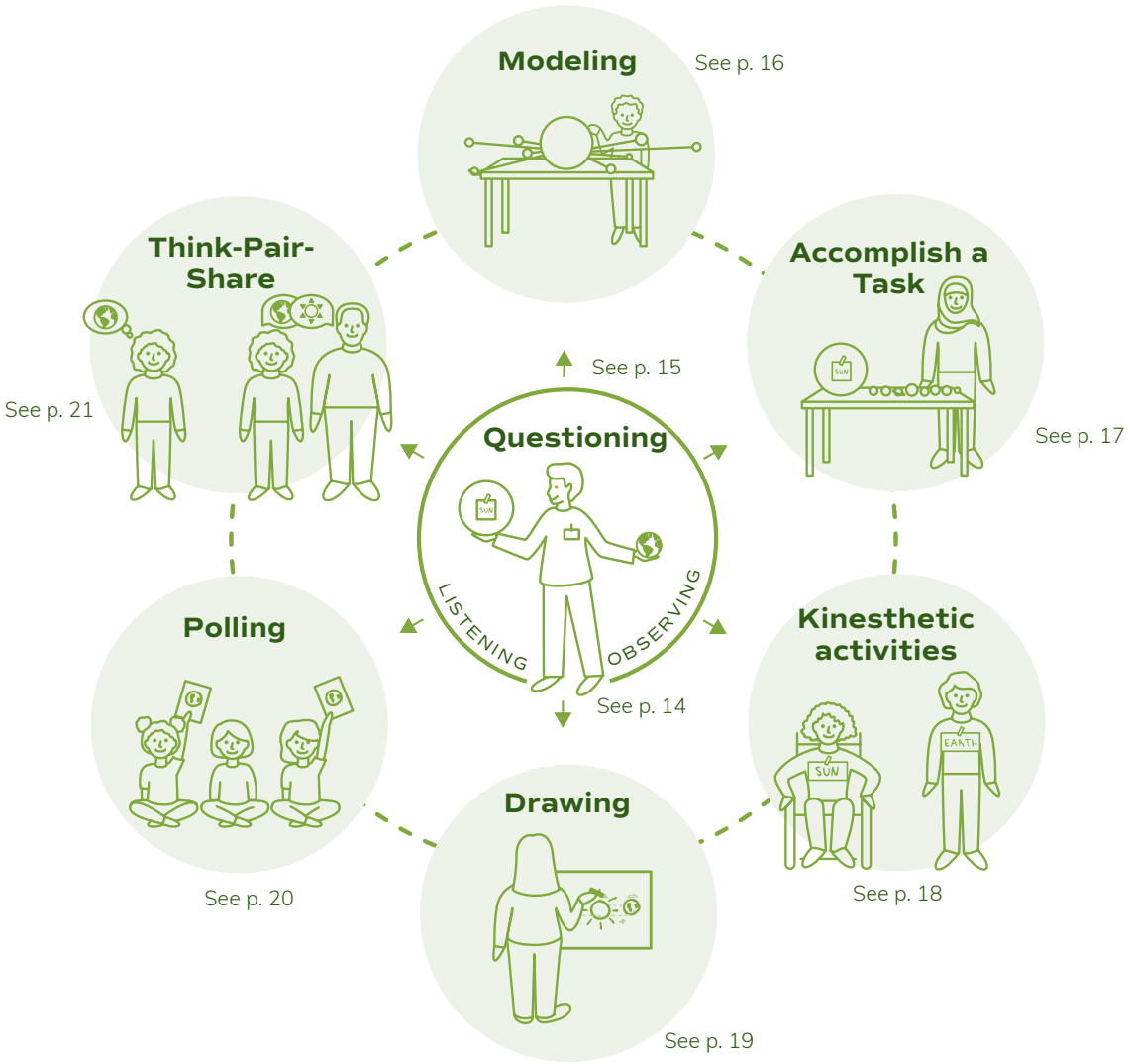
- You may be the first scientist that some members of your audience will have met. Among young children, scientists are still largely perceived as white, middle-aged/elderly males who wear lab coats and work indoors. If you or your work environment differs from this, you might highlight this in an effort to contribute to the public's understanding of the diversity of scientists and scientific work. Particularly, if your work involves collecting data in unique environments, sharing that might help to dispel misconceptions.
- Some audience members may express curiosity (or, even rudeness) when meeting a scientist who doesn't fit their assumptions. Younger, non-white, and non-male scientists may be put in a position where a participant pressures them to "justify" themselves as scientists and representatives of science. If you experience this, you might be able to use it as an opportunity to challenge someone's bias by asking "why are you surprised to learn that I'm a scientist?"
- Drawing on the media's depictions of scientists, many people think of scientists as some version of the lone genius shouting "Eureka!" in their isolated lab. Depicting science as a collaborative endeavor will make it seem more inviting to some audience members. There are many ways to approach any problem and collaborating with others with different perspectives can help us be better problem-solvers. To counter unrealistic depictions of the way that scientists do their work you might also take time to discuss members of your team, people you collaborate with, or members of the local community who are scientists.
- Many believe that science is highly abstract and removed from day-to-day life. If your work has applications with regard to your audience members' lives, or to the life of someone in their community, you should certainly highlight that.
- Be honest about failure. Some people may not recognize that all scientists (like any other experts) are lifelong learners. The notion that scientists still make mistakes or have setbacks can be very empowering to a young learner. Moreover, it is useful to emphasize that failures are a natural process of the scientific method, helping to propel discoveries and inventions.
- Be honest about challenges you've encountered in science (to whatever degree you feel comfortable). The path to becoming a scientist can be complicated and there is value in sharing the challenges you face or have had to overcome to get to where you are.

7 On-the-Spot Feedback Tactics

How to make use of what you learn

On-the-Spot Feedback Tactics are powerful because they can be used to provide crucial feedback on many different topics and in many situations.

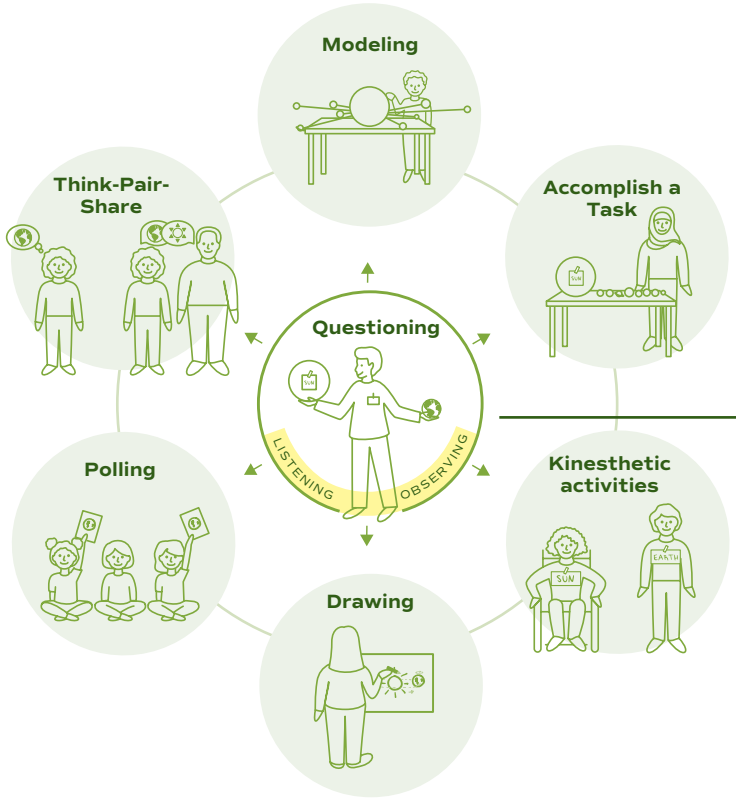
The seven tactics provide mechanisms to understand the motivation, interest, prior knowledge and understanding of your audience. While we list them separately for ease of discussion, they are not independent of each other. In practice, you will often employ more than one tactic simultaneously. Effective use of all the tactics is supported by strong ***Listening*** and ***Observing*** skills.



Listening and Observing

Foundational Skills of On-the-Spot Feedback

Listening and ***Observing*** are skills that serve as the foundation for all of the tactics described throughout this guide. Remember that these tactics can only support better interactions if you are attentive to the feedback your participants offer. As you listen and observe, focus both on what your participants are directly saying or doing, and on what you can learn from their behavior, mannerisms, or energy level. In some cases, you may discover that a participant is enthusiastic and attentive to the discussion, even if they are not providing the responses you anticipate.



Listening and ***Observing***

are your primary tools for collecting feedback, which you will then interpret and use to adjust your approach.

Here are some things you might like to know when collecting feedback to adapt your facilitation.

- What do they already know?
- What are their goals for the interaction or motivation for being here? Related to my topic, what are they interested in learning more about?
- Do participants feel welcome? Does my presentation honor diverse ways that science is viewed and practiced?
- Do they understand the information I am conveying, and do I understand the questions and ideas they are bringing to the interaction?
- Can they demonstrate their knowledge or apply that information to a new situation?
- Is the participant leaving the interaction feeling more curious, empowered, excited, and validated? Have I planted a seed, or nurtured an existing sprout?
- Am I doing a good job engaging in a two-way dialogue with participants?
- Are they enjoying themselves?

Questioning

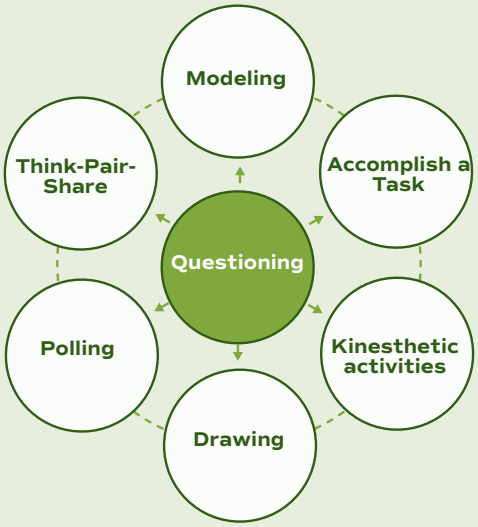
The thoughtful use of the **Questioning** tactic can accomplish many things including revealing participants' prior knowledge or emotions about a topic, inviting participation, encouraging experimentation, and facilitating reflection. Questioning is the foundational tactic, so is found at the center of the tactics diagram. It is foundational because the six other tactics are really just different ways of asking questions and receiving a response; often Questioning is used in conjunction with the other feedback tactics. When used as a standalone tactic Questioning should employ open-ended questions: questions that encourage participants to answer in a full sentence, or more, to elaborate. An open-ended question can be employed as an opening question, an exploration question, or a making-meaning question.

For engagement

Questioning can be a powerful tool for sparking curiosity and facilitating a rich dialogue with and among public engagement participants. Research in the learning sciences shows that greater learning occurs when people grapple with a question and discuss it with others. Scientists can use questions to support participants in making their own discoveries and having a meaningful engagement experience.

For feedback

Asking questions might seem very straightforward, but it is important to remember to use best practices to ask thoughtful and productive questions. For example, make sure you phrase your query to be easily understood, speak clearly and deliberately, and do not ask too many things at once. Be mindful of asking too many yes/no or closed-ended questions as that might stifle curiosity and participation (e.g., “Do you know what DNA is?” or “Are you interested in science?”). When you design a question, think ahead to consider how you will incorporate the range of feedback you collect from participants.



A question can...

- Spark curiosity
- Change the direction of a conversation
- Help collect quick feedback
- Be an invitation for participants to share their perspective

Good contexts for using Questioning

- This is the foundational tactic and is appropriate to use in any context, often with another feedback tactic.

Considerations for accessibility and inclusion

- Not everyone will speak up immediately. Provide ample wait time as some participants may need more time to think.
- Asking open-ended questions may help participants feel more confident participating as there's not only one correct answer to your question.
- Frame the questions as part of a conversation with your participants rather than an evaluation of their knowledge.

Learn more about
Questioning
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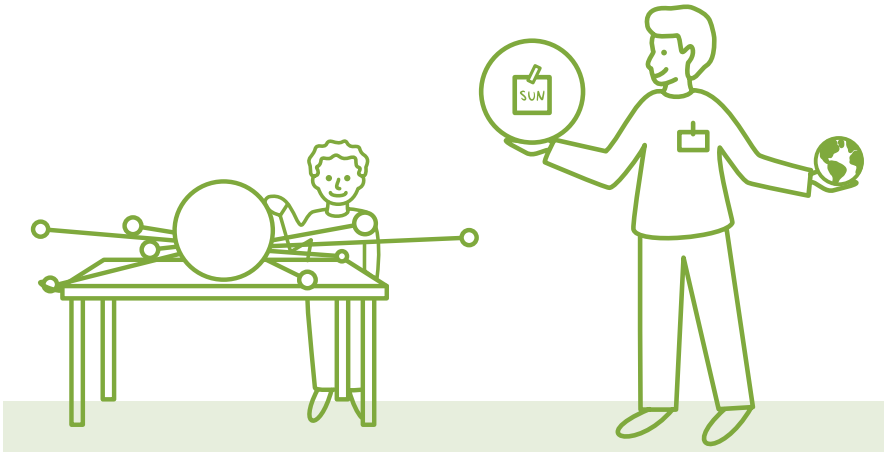
Modeling



When engaging in **Modeling**, learners manipulate physical or virtual models to demonstrate their understanding of a phenomenon. They can build a model from provided materials to convey their understanding, or they can move and manipulate the elements of a model you provide. Models are particularly good tools to help learners work through their ideas and make abstract concepts more tangible. Learners can also use models to ask questions or to demonstrate parts of a system they do not fully understand. Additionally, they're also a great way to engage young learners or shy/apprehensive participants.

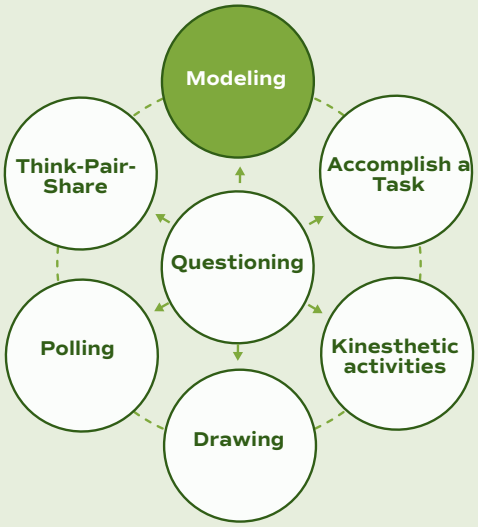
For engagement

In public engagement, as in scientific investigations, a model can simplify the representation of a phenomena or concept to make it more accessible to a learner. A model can take many forms: a scale model, a drawing, mathematical equation, a chart or graph, an idealized version of the phenomenon under investigation, and many more.

For feedback

Using an interactive model allows a participant to demonstrate (to themselves and others) what they believe or think, which also provides you valuable feedback to improve your facilitation. The insights gained from your observations of what your audience does or does not understand can inform how you move forward in your presentation.

For example, imagine participants are exploring what causes the phases of the Moon by modeling a lightbulb in the front of the room as the Sun, their heads as the Earth, and a tennis ball "Moon" held at arm's length. When asked to demonstrate where the Moon would be in its orbit to show a full Moon phase, if several audience members are holding their tennis balls on the opposite (wrong) side of Earth, how would you use this feedback to identify your next steps?



A model can be...

- Created with everyday materials
- Manipulated or built by the audience
- Used by you as a demonstration tool
- A great way to discuss scale
- Used to make abstract concepts tangible

Good contexts for using Modeling

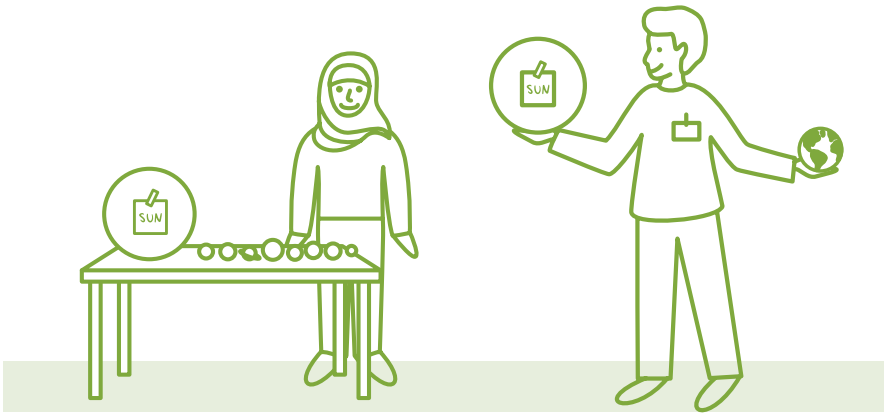
- Settings with a high level of interactivity (e.g., tabletop exhibits at festivals and fairs, museum demonstration stations, and other small group sessions).
- Large audience situations, particularly when using a model of sufficient size where everyone can see it.

Accessibility and inclusion

- Your model should be appropriate for the motor skills of your audience.
- Models can be a powerful tool for two-way communication when there is a language barrier.

Learn more about
Modeling
PAGE 43

Accomplish a Task



When asked to **Accomplish a Task**, audience members may follow instructions to build something or demonstrate their ability to do something. Tasks can be narrowly defined, or more open-ended to allow the learner to make choices. By observing their process of doing the task and/or the final product they create, you can gain insight into participants' understanding, interest, or perspectives. Common tasks might include engaging in authentic science tasks (e.g., observing specimens, graphing results), categorizing or ordering objects, etc. This can take place at the start of an interaction to provide feedback on their current understanding and interests, or can be embedded within an activity to provide feedback on the overall experience.

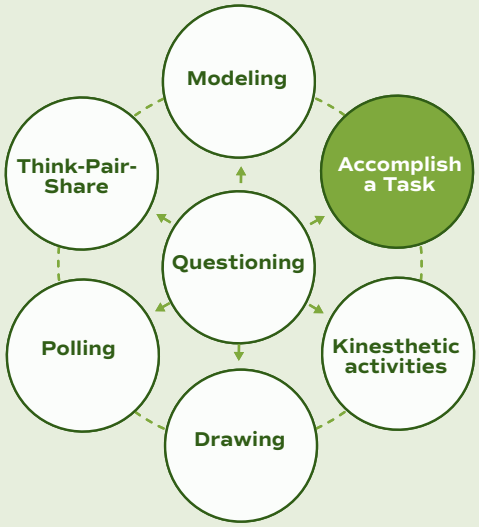
For engagement

Directing participants to Accomplish a Task can be useful to promote an active, hands-on engagement experience, and to facilitate dialogue with and among audience members. Providing participants with the opportunity to independently complete a relevant task can be a powerful way to help them explore new ideas.

For feedback

The Accomplish a Task tactic can provide useful feedback to the facilitator leading the public engagement by making participants' thinking visible and highlighting sticking points. Watch carefully when learners are invited to create, build, or do something. Did they understand the instructions? What did they prioritize in their process or thinking? Did they approach the problem similarly or differently than you (a scientist) might? How will this information inform your next steps?

For example, if you asked participants to use raw spaghetti and tape to design a bridge to hold a weight, and you observe them taping long pieces of spaghetti together, how would that help you identify what support to provide next?



Accomplishing tasks can...

- Engage learners
- Demonstrate their degree of mastery
- Visualize abstract concepts

Good contexts for using Accomplishing Tasks

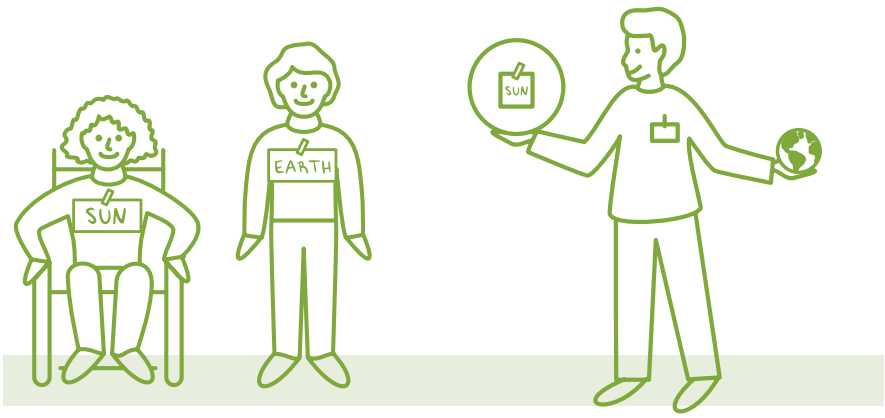
- When working with individuals or small groups it's a great way to get very rich and specific feedback from individuals
- Audiences where people already know each other.
- Audience with a mixture of children and adults

Accessibility and inclusion

- Some conditions that limit a participant's ability to complete a task may not be visible.
- When possible pose your task as an invitation and frame it as an enjoyable, low-stakes activity.

Learn more about
Accomplish a Task
PAGE 46

Kinesthetic Activities



When engaging in **Kinesthetic Activities,** learners will move their bodies to demonstrate a science phenomenon, express their opinions, etc. You might invite them to create an original movement to illustrate their understanding (e.g., show me how a sunflower moves with the Sun throughout the day), or you might teach them a movement and then ask them to show it back to you. Movement prompts can be for individuals, for pairs, or for groups, and may involve moving part of their body or their full body to convey ideas.

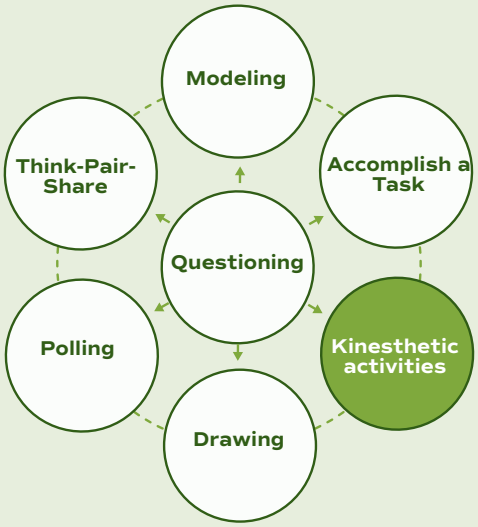
For engagement

Giving learners the opportunity to physically embody concepts, particularly to learn abstract information, can be a powerful way to help people connect with ideas and explore how new information either enhances or contradicts their prior knowledge about a subject.

For feedback

Asking participants to move their bodies to demonstrate a phenomenon provides you with information about what they are thinking. For example, you can ask your audience to move their bodies to respond to a prompt, such as positioning their bodies so it is sunset in a particular location on the Earth (e.g., sunset on their nose, if their head is a model of the Earth) relative to the Sun (a lightbulb).

If they are moving in a way that conveys gaps in their understanding of the relative positions of the Earth and Sun you then have the opportunity to fill in those gaps. Feedback from their movements will help you identify your next steps.



Kinesthetic Activities can...

- Convey abstract ideas
- Enliven your event
- Help participants pay attention

Good contexts for using Kinesthetic Activities

- Audiences with children
- Large groups of people working together
- When you have enough facilitators and space to move around

Accessibility and inclusion

- Be aware of physical limitations posed by the space you're in
- If suggesting movement cues, know your audience. Factors such as age, physical ability, cultural considerations, etc. can impact willingness to participate

Learn more about
Kinesthetic Activities
PAGE 50

Drawing

Drawing can be a helpful tool when you'd like to know more about audience members' knowledge, opinions, or understanding of what is being experienced or conveyed. You might give learners a specific prompt to respond to, ask them to label parts of a system, or otherwise use the drawing to convey their ideas (e.g., draw what a scientist looks like). Usually each person produces a drawing to reveal their thinking or understanding, or you can ask learners to work together in small groups. Drawing can also be used to showcase local knowledge or a community's specific connection to a topic, and are particularly helpful to determine how to adjust at the start of an interaction.

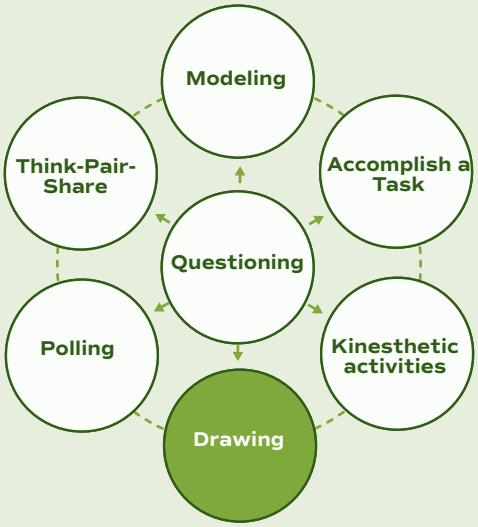
For engagement

Drawing can be used to support a range of activities, from a quick icebreaker activity to a deeper reflection. If you ask your participants to draw something about your topic as the activity opener, you have instantly activated their prior understanding, invited them to contribute, and provided a low-stakes way for them to participate.

For feedback

Drawings done by participants, either as individuals or in groups, may provide insights into participants' thinking or feeling that can't be easily be accessed with words or by other tactics. This could be additional information about the cultural or social context of the participants, and may allow a scientist to not only better understand and connect with their audience but can also be used to inform how the presenter structures the rest of the engagement.

For example, if you first ask participants to draw their local ecosystem, pay attention to what they include and what is not included. If a human is not included in their drawing, how will that change the starting point for your conversation?



Drawing can...

- Convey abstract ideas
- Enliven your event
- Engage younger learners

Good contexts for using Drawing

- Audiences with a range of ages
- Virtual settings

Accessibility and inclusion

- Be careful to avoid jargon in your prompts and use directions that are age appropriate.
- If you ask participants to draw something specific be sure to provide clear instructions.

Learn more about
Drawing
PAGE 53

Polling

What is the audience members' prior knowledge? What opinions do they hold? What relevant interests or lived experiences do they have? **Polling** is a quick way to collect responses to a closed-ended question prompt (e.g., multiple choice, yes/no). When responding to a poll learners can select between given choices to indicate their opinion, choose the best answer, or provide information about their experience. Creating a really effective poll question and answer options is not always straightforward, and takes practice. Polls are successful with both large and small groups and provide insights into how the whole group is thinking rather than how individuals in the group are thinking. Responses can be collected via technology and displayed with a projector or by asking participants to raise their hands. You can also use a poll to learn more about learners' interests and let the audience choose which topic you talk about next.

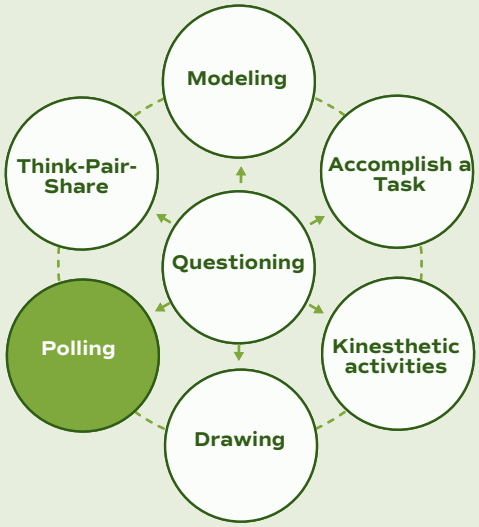
For engagement

Polling your audience can be a great way to engage people, promote lively discussion, and give insight into what people believe or know. A poll is a question you present to an audience that contains several predetermined responses to select from. Polling can be a fun and low-effort way to create interactivity and help participants feel a sense of camaraderie with other participants.

For feedback

Polls are a quick way to get information about the beliefs, knowledge, past experiences, or opinions of a group of people. Depending on your goal, polls can be structured in several different ways to collect different types of feedback. Polls that pose questions and include options without clear right and wrong answers can be more fruitful to advancing deeper discussion, nuance, or audience-centered explorations.

For example, if your goal is to understand what concerns your audience most about the effect of climate change on their local environment, you can use their response to help guide the direction of your presentation to make it align more with their interests and concerns.



Polling can...

- Be used without any materials
- Start a discussion about participants' differences in opinions, ideas, and perspective
- Help you quickly gauge how participants think and feel about a topic
- Provide feedback on what topic your audience wants to hear next

Good contexts for using Polling

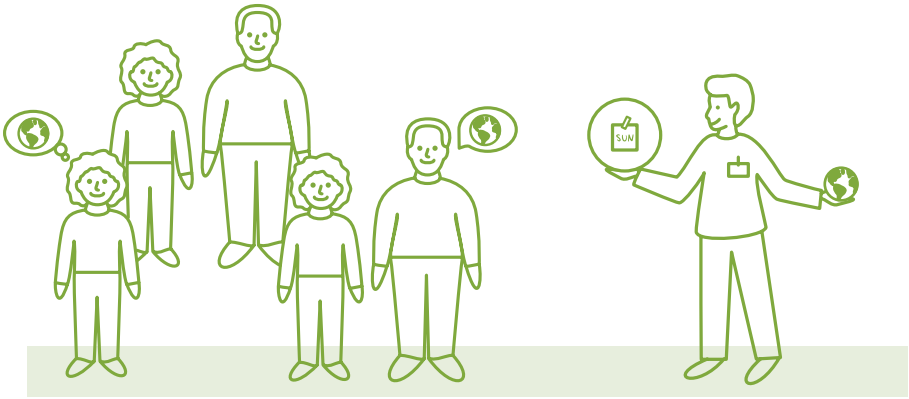
- Large or small groups
- Virtual or in-person events

Accessibility and inclusion

- Use analogies and examples that are known to a broad audience
- When depicting people represent a diverse group and avoid stereotypes
- Polling tools should be accessible. (Voting cards should be unambiguous to color blind participants, polling apps should be available to all participants, etc.)

Learn more about
Polling
PAGE 58

Think-Pair-Share



During **Think-Pair-Share** learners have a short amount of time to individually think about a prompt, discuss it with other audience members near them, and then a few participants share what they discussed in their small groups with the rest of the audience. You might choose this tactic when you'd like information about audience members' thoughts on a subject, or if you'd like to try to more directly involve participants who are hanging back in the large group. Make sure you give clear directions and the questions you ask are not too wordy or complicated. Writing the questions in a place where people can read them is helpful, particularly if you ask them to discuss more than one question.

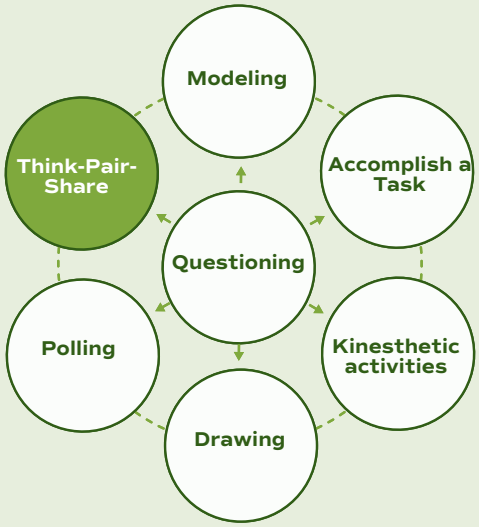
For engagement

Think-Pair-Share can be a great way to get all participants involved, particularly if some people are likely to hang back in large group settings. A good, thought-provoking discussion prompt is a great invitation and can be used as an icebreaker at the start of an engagement, or later on to support participants delving deeper into a topic. Remember that it is important to set aside enough time for each of the "Think", "Pair", and "Share" portions of this tactic.

For feedback

Think, Pair Share is an excellent way to get feedback, particularly when collected at the beginning or middle of an event, to guide the rest of the event. By listening to what the small groups discuss and to what individuals share with the whole group, you can decide on specific details to include in your engagement or alter the direction of the engagement to better address the background, interest and knowledge of audience members.

For example, when training people to identify the difference between ravens and crows, while moving between groups and listening in on group conversations and then during the group share-out you will see common points where participants are struggling with their identification. This can help you decide what characteristics to focus on.



Think-Pair-Share can...

- Provide time for participants to discuss their ideas.
- Asks all participants to contribute
- Allows you to have time to engage with multiple groups

Good contexts for using Think-Pair-Share

- When you have ample time and won't need to rush discussions
- Medium to large group settings
- When audience members know each other

Accessibility and inclusion

- Be mindful of what questions you ask and if your participants will be comfortable sharing information with others
- This tactic can be loud and make participation difficult for people with hearing challenges, especially if it is used in a crowded space

Learn more about
Think-Pair-Share
PAGE 62

SECTION

2

Planning & Design

Audience Considerations for Inclusion

While planning your event

Representation matters

When participating in an event that promotes public engagement with science, you are representing the culture of science—whether you intend to or not. The scientists who participate in a public engagement program may be the very first scientist some audience members have encountered. An important goal is to make sure the interaction doesn't leave a negative impression or discourage anyone you interact with from having an interest in science. If asked about your career path, as much as you are comfortable doing so, be open and honest about your experience. Be careful not to project or make assumptions about similarities or differences between your life and the lives of your audience. If you plan to dress casually for the event, be mindful of the appropriateness of any slogans or images that are on your clothes.

Focus on your audience

As you prepare for an event, think about how you can make sure the event attendees are a focus of the planning process. Talk to the program organizer ahead of time and ask what you should know in advance about the audience you will be working with that might impact your planning. How can you design your activity so there is ample space for an expression and exchange of ideas? Remember that everyone has expertise. The most effective and memorable public engagement interactions draw on the expertise of not only the facilitator or scientist, but also audience members.

Design to support inclusion

Let this serve as a reminder that you should design for outcomes beyond the acquisition of content knowledge by participants. You might want to talk to your event organizer about the host organization and their commitment to inclusion and their priorities for public engagement. If available, you could also reach out to a representative from the community you will be working with, whether that be a tribal community, a teacher who will be attending the program with their class, etc.

TIP

If you gather this kind of information ahead of time, you will be in a better position to design and facilitate a learning experience that is a good fit for the circumstances.

FOR EXAMPLE

Imagine an outdoor fair where people may stop by various booths as they wander around. This environment has some obvious implications for your engagement activity (e.g., don't rely on specific lighting or sound levels, and be prepared for some people to stay for just a few minutes). **The environment should also inform the kind of feedback you try to gather**; in this kind of environment you'll need to look for quick and fun ways to solicit feedback from participants since they have the freedom to move on any time they want to.

1 | Consider the context of the event

Before an engagement event, spend some time thinking about your audience and the setting. Consider, what is the nature of the event, participants, and the event location? What do you know, what information are you missing, and who do you need to talk to ahead of time to learn more? This is especially important if you are working with a community or organization for the first time.

What type of event will it be?

- ☐ Lecture
- ☐ Demonstration
- ☐ Small groups
- ☐ Virtual event
- ☐ Other _____

What will the location be?

- ☐ Lecture hall
- ☐ Museum floor
- ☐ Classroom
- ☐ Outdoors
- ☐ Other _____

What do you know about the event context?

What kinds of resources are available for use (e.g., a table, projection capability, can you dim the lights, etc.)?

How many people do you expect to attend? Can they drop in and out?

How much time will you have with them?

What have they been told about the program ahead of time?

What expectations do the event organizers have of you?

What do you know about the audience?

What is the mix of ages, educational backgrounds, and cultural backgrounds you might expect?

What might they already know about your subject?

Are they required to attend or what might be their motivation for participating in the event?

How interested in your topic do you think they are?

TIP

When designing learning experiences, realize that **audience members may come with their own desired outcomes** for the experience. It is essential that you take this into account!

There are many situations where the best course of action is to adjust your facilitation to something more aligned with your participants' desired outcomes.

TIP

Remember to **think expansively about potential outcomes** and keep in mind that the best outcome is when both the facilitator and audience members come away from an engagement experience having gained insights from one another.

2 | Identify outcomes for the event

Before an event consider what realistic and desirable outcomes you plan to design for. Appropriate outcomes will differ based on a number of variables, including the amount of time you spend with a particular audience member (e.g., 5 minutes, 1 hour). Be cognizant of what may be realistic. "Inspiring a classroom of kindergarteners to become scientists" may not be a realistic or appropriate outcome. When thinking about what you hope participants will gain from the experience, it is also important to remember that there are many kinds of audience outcomes to consider and design for beyond learning science content. There are two levels of outcomes to consider.

What audience outcomes you will prioritize?

(Choose 1–3)

Increased or sustained...

- ☐ Enjoyment and/or satisfaction engaging in a science activity
- ☐ Excitement about science
- ☐ Knowledge or awareness about a particular science topic
- ☐ Understanding of how scientific knowledge is discovered or developed
- ☐ Understanding how the topic relates to issues they consider important
- ☐ Understanding of the different ways that science understanding is viewed and used by individuals and communities
- ☐ Interest in learning more
- ☐ Satisfaction in meeting their personal goals for the interaction
- ☐ Knowledge of and affinity for scientists (particularly by meeting a scientist and learning about their personal history and interests)
- ☐ Feeling more confident in their ability or understanding
- ☐ Greater ability to do something related to the topic, e.g., use a tool, accomplish a task

What outcomes for yourself will you prioritize?

(Choose 1–3)

Increased or sustained...

- ☐ Confidence in conducting a two-way dialogue with the participants (this confidence may not develop immediately, but comes with opportunities to practice facilitation over time)
- ☐ Confidence in interacting with audience members of different ages and backgrounds
- ☐ Appreciation for and understanding of the participants
- ☐ Understanding of common audience misconceptions about your topic
- ☐ Understanding of audience interests and questions related to your topic
- ☐ Understanding what people in your community think about your topic
- ☐ Confidence in incorporating audiences' prior knowledge, interests, experiences, and worldview into your facilitation
- ☐ Enjoyment doing public engagement
- ☐ Satisfaction after achieving the outcomes you want for your audience

3 | Identify what the audience will do during the event

What will you do during the engagement portion of the event in order to support your audience in achieving the outcomes?

What tools will you use to support the engagement experience (e.g., PowerPoint, images, simulations, models, equipment)?

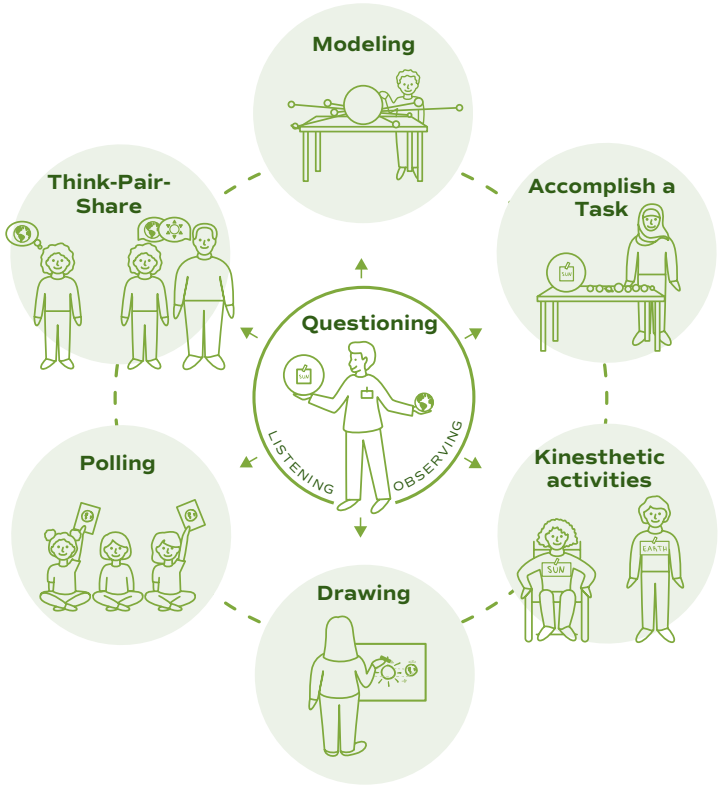
What will the audience do during the engagement to achieve the outcomes?

How will you plan to draw on the assets of the community you are working with, and how will you design for inclusion of diverse participants and perspectives?

What role do you envision feedback playing during the event, and what will you do to create moments for the audience to share their experiences, ideas, or otherwise provide feedback?

4 | Choose On-the-Spot Feedback tactics to use.

Consider what kind of feedback you plan to collect and, how you might respond depending on how the audience reacts to each tactic, and how much time you will need. Thinking this through in advance is crucial, and will make it more likely the feedback you collect can be used to improve the engagement experience. While you can't know all the ways that participants will respond, you can do some preparation so you have adjustments "at the ready". Identify which two or three (or more, for longer events) OTSF tactics will you use to determine if your audience is on the path to achieve your planned outcomes. Carefully consider how these tactics will fit into your planned engagement.



Learn more about these tactics starting on page 13

On-the-Spot Feedback Tactic	What Will You Do?
Tactic 1	Feedback Activity 1
Tactic 2	Feedback Activity 2

5 | Consider how you will adjust based on the feedback you might receive.

If you can't name anything you would do differently after participants respond, you might be using a tactic for engagement, but not feedback. Getting your audience engaged is a great first step, but the On-the-Spot tactics can help you create deeper and more meaningful interactions if you are able to customize the experience to each participant.

e.g.

FOR EXAMPLE

If you are gathering feedback to determine whether participants are having fun and you discover some are not, how will you change the activity on-the-spot? If you are hoping to learn whether participants are making personal connections to your science topic and you discover they are not, how will you adjust what you're doing on-the-spot?

Tactic 1:

What are some of the ways that you think participants will respond to tactic 1?

What adjustments would you make?

Hypothetical Response

Adjustment

Hypothetical Response

Adjustment

Hypothetical Response

Adjustment

Planning ahead and thinking through how you might adjust in the moment is challenging, but critical!

Tactic 2:

What are some of the ways that you think participants will respond to tactic 2?	What adjustments would you make based on this response?
Hypothetical Response	**Adjustment**
Hypothetical Response	**Adjustment**
Hypothetical Response	**Adjustment**

TIP

The On-the-Spot Feedback tactics are best used at virtual public engagement events that:

- Are **synchronous**, with no or limited asynchronous engagement
- Are **organized as an event** with a specific and limited timeframe
- Thoughtfully **employ the available technology to interact** with the audience

We certainly applaud other types of virtual public engagement (e.g., blog posts, Listserv interactions, pre-recorded videos), but these do not lend themselves to effective use of the OTSF tactics.

Virtual Engagement

Using On-the-Spot Feedback virtually

The On-the-Spot Feedback tactics discussed in this guide may be successfully used to enhance a virtual event with the public, in addition to in-person interactions. There are some additional considerations when planning for and engaging with audiences virtually, which will be discussed below. First, it is important to clarify what we mean by virtual engagement in the context of the OTSF interaction model.

When planning a virtual public engagement experience:

Remember that a virtual engagement with the public can take many formats. An event being virtual does not necessarily dictate the structure of an event.

For example, a lecture-style presentation followed by a Q&A could take place either in person or virtually. An engagement activity that involves small group work, pair-and-share activities, and even hands-on activities can also be facilitated in-person or virtually. Indeed, engaging with an audience virtually can take many different forms, with some plans being more conducive to audience interaction than others.

Planning for a virtal public engagement can be approached in a few different ways. Sometimes an activity you delivered in an in-person context can successfully translate to an online context. For example, if a hands-on activity uses common household materials that you would normally provide at an in-person event, in the lead-up to a virtual event the participants could be prompted to gather the materials ahead of time. (The materials should be common objects if you do this: spoons, pen/pencil, paper, roll of toilet paper, etc.)

There are also many virtual tools that can support strong engagement practices in an online format and give participants the chance to work through ideas collaboratively including online polling tools, virtual whiteboards, and programs that can create virtual breakout rooms to allow participants to work in small groups. These tools are also useful for gathering feedback, as discussed in the Deep Dives section, starting on page 38.

Do keep in mind that not all in-person activities are well suited for virtual formats. Sometimes it is best to approach your planning by first considering the context of your virtual engagement, the affordances and limitations of the technology, and your desired outcomes for the event. Consider these additional points when using the *OTSF Engagement Planning Worksheets* (starting on page 24) to prepare for a virtual event. It is important to stay focused on your desired outcomes and mindfully incorporate strong practices for virtual engagement and virtual feedback into your plan.

Connect with the event coordinator to familiarize yourself with their virtual event context and discuss logistical considerations.

- Have they hosted virtual events like this before? What have they learned?
- What virtual platform will be available (e.g. Zoom, Teams)?
- What issues (technology-related and otherwise) might arise during your virtual event? How would you navigate those issues? Will you have staff support to help troubleshoot?
- Will staff be available to help you monitor audience engagement and feedback (e.g., monitor a chat feature and collect audience questions)?

Consider the technology tools available as you are planning for your virtual engagement.

- What technology tools are available to you to use? Have you used this technology before? Would it be helpful to you to test the virtual engagement tools or platforms ahead of the engagement event?
- What are the specific affordances and limitations of the technology tools available?
- How will the audience provide you feedback? Will participants be on camera? Will they have access to a microphone? To a chat box? Will the audience be able to engage with the screen using virtual tools (e.g., annotating)? Can you poll the audience? Will all audience members have access to these feedback tools?
- Will you be able to share your screen with participants?
- Can you divide the audience into smaller groups so they can talk to each other?
- Are there any additional virtual tools you can use to support your audiences' ability to provide feedback (e.g., Poll Everywhere, Jamboard, Mentimeter)

Consider your audience in the context of the virtual engagement.

- Will the audience members be joining your event individually, or will they be in the same room as other participants?
- Are participants already likely to be familiar with the technology you will be using? Or, will you need to spend some time to familiarize them with specific tools you will ask them to use?
- Will audience members be able to gather materials ahead of time to follow along with you and engage in a simple activity together?
- How can you invite them to share their expertise, community-based or cultural knowledge that aligns to your presentation?

SECTION

3

Reflecting after your event

Audience Considerations for Inclusion

After your event

Reflect on the inclusiveness of your event.

- Did you set the goal of creating a welcoming environment for audience participants (e.g., by expanding notions of who does science, who science is for, and whose experiences or questions are valued)? If so, what did you do during your engagement to support this desired outcome? Did you feel your actions and your approach to creating a welcoming environment were successful? Why or why not? Would you do anything differently in the future?
- Did you find opportunities to highlight the unique perspectives and contributions of audience members during the event?
- Did you rely on assumptions or stereotypes to guess at participant interest, demeanor, skill, etc., or were you using feedback to consider the specific audience in front of you?
- What feedback did you collect (verbal, nonverbal) to assess the inclusiveness of your event? If you did not collect any feedback pertaining to inclusion, what tactics might you use in the future to address this?

These considerations are just a starting point. Many thoughtful people are engaged in making science communication more inclusive. Here are additional resources for further reading:

Canfield, K. & Menezes, S. (2020). *The State of Inclusive Science Communication: A Landscape Study.* Metcalf Institute, University of Rhode Island. Kingston, RI. 77 pp.

National Academies of Sciences, Engineering, and Medicine. (2018). *How People Learn II: Learners, Contexts, and Cultures.* Washington, DC: The National Academies Press. See especially ch. 2, pp. 21-33

1 | Reflect on your use of the OTSF tactics

Reflect on the successes, challenges and lessons learned during your event, including both the effectiveness of each OTSF tactic you used and the effectiveness of your responses to the feedback as they relate your desired outcomes for your interactions with participants

How did participants respond to your use of each of the tactics?

Were you able to collect the feedback you needed?

How did you respond to the feedback you collected?

How did that information influence what you did next?

Did anything surprising or unexpected happen when collecting or responding to feedback?

2 | Changes for the next public event

What went well at your event overall and what needs improvement?

What was unexpected?

What will you do differently next time?

Did this event give you any ideas for new things to try?

Will you use the same feedback tactics next time or try some new tactics?

Will you collect feedback on the same topics?

Appendix

Deep Dive into the Tactics

Questioning
DEEP DIVE

You've probably attended a public engagement event where the scientist asks a good question, but then only focuses on one person to answer it and moves on, giving no one else a chance to share and discuss their response. Or maybe they ask a question that is never discussed, let alone answered. We often ask questions to get the participants thinking and talking, and to provide information about what they know or believe. It takes some practice to formulate good questions, and to ask them in a way that will engage your audience and also provide you with information that can inform what you do next.

What does it look like?

You may be most familiar with asking direct questions to learn more about participants' knowledge or experiences (e.g., "What kind of birds do you see in your neighborhood?" "What are some differences you notice about days in the summer and winter?" "What are some of the differences between the Tyrannosaurus rex and Triceratops in this display?").

Questioning is also useful for learning more about participants' familiarity or comfort level, although it is most helpful to not ask these questions too directly. For example, instead of starting a dialogue by asking, "How familiar are you with science?" you might ask, "Can someone tell me about a scientist you know?" If you are speaking to a group where no one indicates they know a scientist, how might that change your conversation with them?

How is Questioning useful for *engagement*?

Questioning can be a powerful tool for sparking curiosity and facilitating a rich dialogue with and among public engagement participants. Research in the learning sciences shows that greater learning occurs when people grapple with a question and discuss it with others. Scientists can use questions to support participants in making their own discoveries and having a meaningful engagement experience. Often questions are asked and responded to verbally, but remember that you can pose questions in other ways (e.g., by showing a puzzling visual image), and the audience can also respond to a question nonverbally, by doing or demonstrating something.

Types of Questions

- Opening Questions
- Exploration Questions
- Making-Meaning Questions

Questions should

- Not be too abstract
- Be accessible and relevant to your audience
- Avoid jargon
- Invite some open-ended responses, and not be only yes/no or fact-oriented.

How is Questioning useful for *feedback*?

Asking questions might seem very straightforward, but it is important to remember to use best practices to ask thoughtful and productive questions. For example, make sure you phrase your query to be easily understood, speak clearly and deliberately, and do not ask too many things at once. Be mindful of asking too many yes/no or closed-ended questions as that might stifle curiosity and participation (e.g., "Do you know what DNA is?" or "Are you interested in science?"). In both of these examples, the participant isn't invited to share much beyond a one-word answer. If the answer to a close-ended question is "no," the potential participant is unlikely to remain open to further discussion, even if they might otherwise have found the subsequent experience to be interesting.

Attentive listening is just as important as the questioning. If you are asking for a verbal response, remember to give participants time to think and use adequate wait time; try pausing for three-five seconds after you ask a question and see how that impacts the number and quality of responses you receive. Also try to attend to the full range of feedback you receive and not just the most common response or the response that is easiest to engage with. Listening closely to participant responses can provide feedback that can then be used to adjust and improve the public engagement. Indeed, listening to feedback is essential in order to tailor the rest of your engagement to the individual(s) in front of you. Attentive listening can also help you adjust the questions you ask on the spot to match the experiences, interests, and ages of the groups you are working with.

Good feedback-generating questions come in three varieties and can be used throughout an interaction. The following question types are particularly powerful when thoughtfully sequenced: begin with opening questions to "hook" the participant, then transition to exploration questions to invite them to dive in more deeply, and finally move to making-meaning questions.

1 | Opening questions

Opening questions can be used to capture an audience member's interest, invite participation and provoke curiosity. Particularly in a larger group, be careful not to assume that one or two responses to an opening question represent the interest or knowledge level of the whole group—some people may take more time to become comfortable and ready to respond to your questions.

Examples of Opening Questions: Would you like to try this? What does this [image, prop] remind you of? Would you like to help me solve this problem? Have you ever [been to the ocean, looked up at the stars, felt an earthquake]? Tell me about it. Have you ever seen this [image, prop] before? Have you ever wondered [how many stars you can see in the night sky, how some sea turtles find their way back to the same beach they were born to lay their eggs, how sea level rise will impact our freshwater supply over the next 20 years]?

2 | Exploration questions

Exploration questions encourage active play, experimentation, discovery, and thoughtfulness. They help to access prior knowledge of individuals in your audience.

Examples of Exploration Questions: In what ways are these materials different? In what ways are these materials the same? What materials did you use? What would happen if..? What might you try instead? What does it look like? What does it remind you of? What can you tell me about what just happened? What could you do instead? Which one do you have more of? How are you going to do that?

What do you [feel, see, hear, taste, smell]? What is it made of? What do you call the things you are using? Have you ever seen anything like this before? What happens when [two magnets are held together, a rock is dropped, water is heated up]? What if we try...? What do you want to try next?

3 | Making-meaning questions

Making-meaning questions facilitate reflection, support inference, aid understanding, and inspire further exploration.

Examples of Making-Meaning Questions
Why do you think that happened? What evidence makes you think that? How do you think we could explain that? What if we changed [one variable]? What do you suppose the connection might be between..? What do you think this tells us about..? How could we find out if this is true? Do you have an idea how we could test this out? What do you think we might learn if we repeated this experiment again and again? What would you need to find out more? Does this remind you of something you've seen or tried before? Did this happen the way you expected? What was surprising?

As each question is asked, listen carefully as the response should help direct the next step in the experience. You should also invite the participants to ask you questions throughout the interaction.

How to use feedback gained from your use of the Questioning tactic

Listening closely to what your participants say can reveal something about what they know or don't know, including misunderstandings or preconceptions. It also provideds information about what they believe or what they're interested in. When you have a better sense of what they want to know more about, adjusting your "presentation" to align with their interests will provide a much more memorable experience for them, with greater opportunity for "ah-ha" moments and perhaps some important learning, even in short interactions with them. This also allows you to adjust your presentation to help them gain a better understanding of your topic. Remember that all responses are informative, even (or especially!) those you weren't expecting.

Using Questioning at your events

Questions should

- not be too abstract
- be accessible and relevant to your audience
- avoid jargon
- invite some open-ended responses
- not be only yes/no or fact-oriented

Good questions can be provocative, but one should be prepared for the type of responses you're likely to generate. Likewise, good questions might lead to a "deep dive" or tangent which can be just fine, but again preparedness for this is important.

Time management is something to take into consideration; make sure you build in sufficient time to respond to the feedback prompted by your questions and sufficient time to respond to participants' questions. Be mindful about spending too much time with one person (especially one trying to monopolize your time) at the expense of engaging the other people in the audience. Try to be as inclusive as possible with whom you call on or direct your questions to, making sure individuals from groups that have been historically excluded from science feel as welcome and engaged as others.

Considerations for accessibility and inclusion

- All individuals, from babies to adults, collect information about their environment and make decisions based on that evidence. Even so, the specific process that scientists use within scientific investigations to generate reproducible evidence may not be familiar to your audience. Keep this in mind as you discuss your work. You may be more successful if you leave time to not only discuss the content of your work but also the process and your day-to-day practice as a scientist.
- If your participants are used to thinking of scientists as the holders of knowledge, the questions you ask them may feel stressful, or like a test. In this situation, your challenge may be to frame the questions as part of a conversation with your participants rather than an evaluation of their knowledge.
- One pervasive challenge with asking questions, whether in a formal classroom setting or in informal outreach settings, is to be inclusive. While you don't want to squash the enthusiasm of one eager hand-waver, you need to be careful to draw others into that enthusiasm by asking open-ended questions where there isn't a single right answer, but answers that can draw upon the personal experiences of your participants. Those answers will help shape your next steps so that you have a greater connection with more of your participants.
- Be aware that not everyone will speak up immediately. Provide ample wait time as some participants will need more time to think through their responses than others. As an engagement continues, you might also make space and specifically ask for people who have not yet had a chance to speak to share their ideas.
- See page 23 for more in-depth information on considerations for inclusion when planning your event. Build these considerations into your planning and design for your engagement event. This may require you to do some research ahead of time to find out about your audience.

Contexts where Questioning is especially useful

The Questioning tactic is a foundational tactic, so is a component of all the other tactics. Questioning is appropriate to use in any context you would like to collect feedback, and you'll be thinking about Questioning while reading through the other deep dives. While using open-ended questions is useful in all event contexts, it is especially effective in one-on-one or one-on-few *interactions* between scientists and the public, for instance at a science festival booth, a laboratory open house, or a museum table or exhibit, etc.

Specific situations and contexts to consider

- **Audience with mixture of children and adults**— These types of public engagements tend more toward interactions with families and groups of children, but can also include rich conversations with interested adults. It is important to be very flexible and prepared for participants of wide-ranging ages and experiences, adjusting even minute-to-minute as different groups come along and interact with you. Some activities are better for this type of situation than others; when planning your event ahead of time, brainstorm a few different opening questions or entry points you might use depending on the needs and interests of the specific participants. Also, think carefully about the desired outcomes, especially if you expect large numbers of children. Children can become uninterested or bored quickly if not engaged with questions, activities, or materials that provoke and reward their curiosity and points of view. What do you want children (or adults) to walk away from the interaction with? Be ready to adapt your questions and interactions, for young and old, novice and expert. This may include adjusting the examples you use, or the vocabulary you introduce.

- **Larger vs. smaller audiences**—Some of the example questions listed earlier in this section can also work with larger groups, but how do you listen to people's responses effectively or facilitate discussion that engages a large audience? If you find yourself in this situation, make sure to read more about other OTSF tactics such as Polling or Think-Pair-Share.
- **Sharing air time?**—To facilitate a productive conversation where multiple audience members have the opportunity to participate, you may sometimes need to manage the conversation. If one audience member is dominating the conversation, you might try "Thank you, let's have some other comments." Or, "What do other people think?"

Additional tools and resources

"Questioning Strategies: For Adults Only" from The Docent Educator, 1991

How People Learn: Bridging Research and Practice—Chapter 2—National Research Council, 1999

Modeling
DEEP DIVE

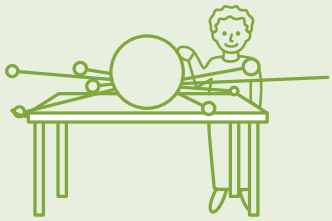
One of the best ways to turn a passive audience into an active one is through using models. A powerful engagement tool, Modeling leads to a more interactive and often immersive experience for participants. When used to gather feedback, models can also help make participants' ideas and thinking visible both to you and themselves. A good model can also motivate your audience to participate more fully, help them generate and articulate questions, and increase their interest in science.

What does it look like?

Models are particularly helpful when discussing scales of objects or systems that are very large or very small, or not easily observed (e.g., change that takes place over long periods of time). In an engagement experience about robotic exploration of the solar system you might first make sure your participants understand how large the solar system is through modeling. Consider showing a group of participants a soccer ball to stand in as a model for the Sun. How large would the Earth be on this scale, and how far from the Sun (soccer ball) would it be in this model? How large and far away would the largest planet in the solar system, Jupiter, be on this scale? What about the Alpha Centauri system, the star system that is closest to our own? When you create opportunities for participants to share their ideas, it is important to have a plan to acknowledge and incorporate participants' feedback. How might their preconceptions about the distances between objects influence the direction and content of a presentation about space travel?

How is Modeling useful for *engagement*?

In public engagement, as in scientific investigations, a model can simplify the representation of a phenomena or concept to make it more accessible to an audience. A model can take many forms: a scale model, a drawing, mathematical equation, a chart or graph, an idealized version of the phenomenon under investigation, and many more. When using models to engage with an audience, your goal is to provide participants the opportunity to interact with the concept under investigation and demonstrate their understanding. Remember that all models have limitations, and no model is perfect. It is important that the models you choose (or your use of them) does not create or reinforce misconceptions. If you decide to use this tactic, make sure you point out what the limitations of the model might be.



Examples of using Modeling

EXAMPLE 1

While giving a presentation on climate change, have a model set up where two clear plastic boxes are heated at the same time, one with a clear lid, the other with no lid. Ask the audience to predict the temperature difference between the two at a later time point during the presentation. Use the audience response to the differing temperatures produced by these atmospheric models to help determine how you will approach your discussion about the retention of energy on Earth due to its atmospheric composition.

EXAMPLE 2

Use a dime and quarter to model the separation and relative sizes of the Milky Way and Andromeda galaxies. As you slowly separate the dime and quarter, ask audience members to put up their hands when you reach the appropriate distance between the two based on their size in this model. Use this feedback to decide how much time you will spend discussing the distances between astronomical objects.

For example, a scale model of the solar system might have the sizes of the planets right but not the distances (or vice versa); a drawing of a food chain in an ecosystem may be simplified and not show all of the complex interactions present in the system.

How is Modeling useful for *feedback*?

Using an interactive model allows a participant to demonstrate (to themselves and others) what they believe or think, which also provides you valuable feedback to improve your public engagement. The insights gained from your observations can inform how you move forward in your presentation. By attending to how they manipulate the materials in the model, and asking thoughtful and purposeful questions about what they did or how they knew what to do, or suggesting new things for them to try, you can help expand their thinking about the phenomena being modeled. You may also learn that you need to shift your plan to elaborate more on details you thought were obvious (e.g., if you see participants struggle with the task at hand or with the concepts illustrated). Conversely, if participants were more successful with their model manipulation than you expected, you should consider spending less time on more basic ideas and more time delving into more in-depth explanations of the concept.

How to use feedback gained from Modeling

Pairing Questioning with the Modeling tactic is especially useful for soliciting audience ideas and impressions. Careful listening to and observing participants as they interact with a model is also crucial. Audience members who do not make a "correct" model are actually providing you a lot of good information, and should inform the remainder of your presentation. Make sure you, as the presenter, have an idea of which responses you might expect from each model you introduce. Plan for how you will address those responses to ensure your audience has the data/evidence needed to understand the phenomenon under investigation. For example, if you notice participants struggling with a model, it might suggest the ideas you are sharing are too abstract and that you may need to make fewer assumptions about people's ability to conceptualize large (or small) numbers, or understand how to interpret a graph or equation.

It can be useful to have a few analogies ready that you can use to help make the topic more concrete. You might use the Think-Pair-Share tactic to have audience members discuss the model, which will often lead to a better understanding of the topic by those who are struggling with the model.

Tips for using Modeling at your events

- It is important to select a model that is straightforward and also appropriately represents the natural phenomenon you are demonstrating.
- When using a physical model, allow ample time for audience members to interact with it, to manipulate different components and explore in an unstructured way, in addition to using the model to demonstrate their understanding of the phenomenon represented.
- A non-physical model, such as a mathematical equation or graph, may require some additional explanation or use of questions to help participants understand the information it conveys.
- Anticipate that a model with the potential for open-ended interpretation (e.g., some graphs) will provide a variety of responses from the audience.
- In general, when choosing a model, make sure it clearly demonstrates the phenomenon you are presenting, and allows participants the best chance of showing their understanding.

Considerations for accessibility and inclusion

- The model should always support the goal, add to audience understanding, and ideally provide feedback to the presenter about audience engagement. But if it is not relatable due to differences in experience or culture, or too difficult to use because of physical limitations, it will be ineffective.

- Is the model appropriate for the motor skill development of the participants? While gross motor skills involve the bigger muscles, fine motor skills are about dexterity and working the smaller muscles of the hands, fingers, and wrists. Is your audience developmentally in a place to accomplish the demands of your model? Is teamwork an option to assist and work with those who may have physical limitations?
- Is there knowledge or areas of expertise that your audience may have developed that are transferable skills to understanding your model? How can you tie the model back to their lived experiences?

Contexts where Modeling is especially useful

There are circumstances when a model is especially useful, such as in situations where audiences are unable to directly observe a complicated system. Scale models are frequently used to help audiences grasp extremely large and small distances, sizes, and also spans of time. By coming back to a model more than once, you can also use models to help you see and better understand how participants' ideas are evolving over time and whether your outreach activity is making a difference.

Asking participants to interact with a model is useful in settings where there is already a high level of interactivity (e.g., tabletop exhibits at festivals and science fairs, museum demonstration stations, and other small group sessions). But modeling can also be used creatively in large audience situations, particularly when using a model of sufficient size that everyone can see.

Additional Tools and Resources

"Teaching With Models" overview from Carleton College's Science Education Research Center

"Methods and Strategies: Using Models Effectively" article from the National Science Teaching Association Press—

"Modeling in Science and Mathematics Education" Resource Spotlight from NSF's CADRE network (Community for Advancing Discovery Research in Education)

Accomplish a Task

DEEP DIVE

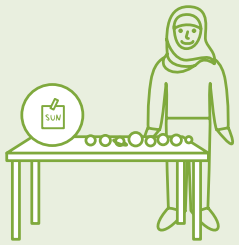
One of the strongest indicators of learning and understanding is putting knowledge into practice. When a learner engages in a task, the facilitator is able to see the participant's abilities, degree of mastery, new ideas and interests related to a concept.

What does it look like?

The tactic Accomplish a Task overlaps substantially with what is often described as “hands-on” science. There are many ways to bring this tactic into your public engagement, and it can provide you with excellent feedback. Learners can be asked to make observations, use tools, build something, mix substances, collect specimens, etc. Learners can also be asked to engage in an activity like a card sort, as described in Example 1. A card sort, like the example provided about birds, is a great open-ended task that can invite many different conversations with participants. By asking learners to use the cards to come up with more than one classification scheme you can invite a discussion about their prior knowledge of birds as well as the classification systems that ornithologists and other scientists may use in their work. Structuring conversations around an activity like a card sort, which invites participants to think creatively and has more than one correct answer, can also be a great way to engage with participants who may be shy or feel intimidated talking with a scientist.

How is Accomplish A Task useful for *engagement*?

Directing participants to Accomplish a Task can be useful for promoting an active, hands-on engagement experience, and to facilitate dialogue with and among audience members. Providing participants with the opportunity to independently (in small groups or individually) complete a relevant task can be a powerful way to help them explore new ideas. For example, when teaching about aerodynamics and the forces of thrust, lift, drag, and gravity, you might invite your audience to fold different types of paper airplanes and test for themselves what variables influence how far their airplane can fly. The invitation and opportunity to create, build, innovate, or do some task can also add fun, spontaneity, and enjoyment to engagement activities. When supported correctly, this engagement approach can provide audience members the opportunity to experience success, receive encouragement and positive reinforcement from a scientist, feel proud of their accomplishment, and share their new mastery and understanding with others.



Examples of Accomplish a Task

Example 1

You might provide a learner with sixteen pictures of birds and ask them to categorize the birds into groups. Learners with little experience with birds might choose to categorize the birds by physical characteristics like size or color, while learners with greater familiarity with birds might choose to classify them by habitat or species.

Example 2

Show participants several cuttings from a plant with each cutting showing structures at different stages of flowering. Ask participants to arrange the cuttings in a progression illustrating how the plant develops and blooms over time, explaining about early- mid- and late-flower stages. Invite a discussion about the identifiable structures of the plant and their function, and the pollinators that might interact with the plant. Choosing a native plant as the exemplar can also invite conversations about the role of native plants and pollinators in local ecosystems

How is Accomplish A Task useful for *feedback*?

The Accomplish a Task tactic can also provide useful feedback to the person leading the public engagement by making participants' thinking visible and highlighting sticking points. Watch carefully when learners are invited to create, build, or do something.

- Did they understand the instructions?
- Did they perform the task as intended?
- Did they innovate a unique solution?
- Did they behave as you expected?
- Did they try something novel that surprised you and could reveal thinking that is worth exploring further?
- Did they have fun and appear to enjoy the experience?
- Did the task prompt them to ask questions?
- Did they feel confident or embarrassed?

In each case, remember that your role is to adjust in order to meet them on their own learning journey. Consider how you will adjust what you do next based on what they did with the task.

Types of Accomplish a Task for public engagement

- **Ordering or organizing things**—This includes ordering items on cards by size or distance, as a scaling exercise (e.g., order microscopic objects from largest to smallest). This also includes organizing a set of cards with pictures, as an attempt at scientific categorization (e.g., species, geologic features, galaxies by shape).
- **Performance tasks in authentic scientific contexts**—This includes participating in a physical experiment or demonstration in a lab setting (e.g., determining which dissolves faster: a whole antacid tablet or a crushed antacid tablet), or a set of field observations in nature (e.g., counting dragonflies as they fly by, birdwatching, or night sky observing). It is helpful to make tasks more relevant or interesting to participants by using real-world examples or contexts.
- **Modeling, Kinesthetic Activities, or Drawing**—Some of the other tactics described in this guide may overlap with the Accomplish a Task tactic. For example: making and manipulating a model of the Earth, Moon and Sun to answer a question about lunar phases, or drawing what the Moon looks like each day for a week to see how the Moon phases change over time in the sky involves accomplishing a task. Asking participants to attempt to pick up a coin from the floor without bending their knees is a task that could help demonstrate whether they understand how to use parts of their body as a counterweight in the same way Tyrannosaurus rex used its long tail.

How to use feedback gained from Accomplish A Task

Watch closely to see what your participants do when you provide instructions for the task. If you observe that they are reserved, not wanting to take initiative, or appear confused by the instructions, then offer more personal interaction to make them more comfortable and support their engagement. Would it help if you participated in the task with them or demonstrated what to do? If you learn something specific about their interest in your topic, try to work that into the conversation about the activity. If the audience is too large for much personal attention from you, you can also suggest they partner with someone having less difficulty. Even better would be to plan for this possibility ahead of time by designing the activity so that all people work in pairs or small groups. Pay attention to body language and movement cues: if you see that participants are having difficulty understanding a new idea or engaging with an activity, ask them to explain what they are trying or to explain their thought process and then connect this to how you understand the concept. Remember that careful observation is a critical skill you will need in order to eventually act on the feedback provided by participants.

Using Accomplish A Task at your event

An Accomplish a Task feedback activity can take on a range of formats. Some require more space for groups to engage in field observations, such as birdwatching. Other activities can work well in more confined spaces, such as on a table or at a booth at a science festival. Tabletop setups typically allow the audience members to move and manipulate materials or to create or build something.

This tactic can be employed at the beginning of an outreach interaction to help you better understand a participant's prior knowledge or interest. You can then use this feedback to personalize the rest of your interaction at the appropriate level for that individual. This tactic can also be used towards the end of a public engagement to give the participants an opportunity to try out or demonstrate their new knowledge or skill, and allow you an opportunity to clarify any concepts or correct any misconceptions. It can also be useful for the participant to engage in a task in the middle of the interaction and use the shared activity as the central focus of your interaction with them.

Accessibility and inclusion considerations

Keep in mind that the participants you engage with will have different capacities to participate in the performance task you are asking them to do. Planning for and providing alternate ways for participants to engage is always good practice. Some things to consider when crafting the tasks that you will use for feedback:

- Remember that some conditions that limit a participant's active engagement in a performance task activity may not be visible or apparent to you. For example, some settings may be too noisy for people with hearing loss to follow your verbal instructions.
- Remember that comfort with physical participation might vary for different individuals. Some people may worry about damaging an expensive piece of equipment (e.g., microscope or telescope). Others may not be comfortable constructing objects from blocks or craft materials. Recognize that some individuals may act more as curious observers or bystanders and would prefer not to be the center of attention and instead prefer to participate in a more passive way. When possible, pose your task as an invitation to participate and frame it as an enjoyable, low-stakes activity. Offer alternative ways to engage when possible, such as having people work in pairs so people can support one another's participation.

Contexts where Accomplish a Task is especially useful

The examples described in this brief are most readily employed in small-group interactions, but they could also be applied in one-on-one (or one-on-few) interactions at a science festival or open-house booth, as long as the task is easily understood and can be done in a limited period of time. The feedback you can collect from the Accomplish a Task tactic can be very rich and specific to the individual. For this reason, this tactic may be less useful for collecting and effectively acting on feedback when engaging with a large group of participants.

Accomplish a Task activities are excellent to use with families, but can also encourage rich interaction with interested adults. In an event that is open to the public, it is important to be agile and prepared to work with participants of wide-ranging ages, adjusting your instructions even minute-to-minute as different groups interact with you. Think carefully about the desired outcomes you have for your engagement, especially if you expect a large number of children. Children can become uninterested or, worse, discouraged, when faced with an activity that is ill-designed or too complicated for them. Consider what you want children (or adults) to learn and enjoy from their engagement experience with you.

Be ready to adapt your activity, for young and old alike.

Keep in mind that there are many situations with families where the parents or adult participants prefer to be less involved as participants, and instead act as facilitators to support their children's learning and engagement. Don't necessarily consider it a "loss" if parents aren't actively engaged, as allowing children the opportunity to discover things for themselves without parents speaking for them or guiding all their "doing" can be very powerful for children. This can be very age-dependent and vary with different parent-child dynamics that you may have no or little influence over. Don't feel shy about asking parents for support; parents can be particularly helpful and "translate" to their child what a scientist is trying to explain, or can help connect the topic or task to a prior experience the family has had.

Additional Tools and Resources

"Short Performance Assessments" from the *Stanford NGSS Assessment Project*

"Birds Near and Far: Students investigate local environmental phenomena on campus and at a local pond," article published in *Science and Children* (2020, Volume 58, Issue 1), by Erin Bridges Bird, Peggy Harte, and Heidi Ballard.

Kinesthetic Activities

DEEP DIVE

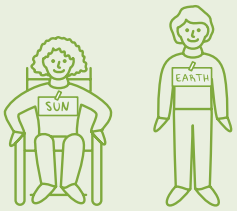
We've all heard the quote, "Tell me and I forget, teach me and I may remember, involve me and I learn." One of the most engaging ways to involve your audience is to get them up and moving. Kinesthetic activities ask the audience to move all or some part of their bodies in response to a prompt from the facilitator. For young children who may not be developmentally able to fully verbalize what they are thinking, the movement of their bodies can often speak volumes.

What does it look like?

Ask learners to work in groups of three and pretend one person is the Sun, another is the Earth, and another is Earth's Moon. Direct each triad to work together to position themselves to illustrate the positions of the Sun, Earth, and Moon when a lunar eclipse occurs. Ask them to next illustrate a solar eclipse. Giving these prompts at the beginning of an audience engagement would provide feedback about participants' level of understanding and could be used to help you tailor your subsequent presentation. How would you adjust if all audience members already knew how eclipses occurred? If none of them knew? If some of them knew? Alternatively, instead of asking learners to demonstrate eclipses at the start of the audience engagement, you might instead provide these prompts towards the middle or the end of an activity. Observing participants at this stage of the engagement could provide feedback on the extent to which they understand what you previously shared about eclipses. You might use this feedback to assess whether you met your goal for the engagement experience and to help you decide what clarification or additional instruction you'll provide.

How is the Kinesthetic Activities tactic useful for *engagement*?

Giving learners the opportunity to physically embody concepts, particularly to learn abstract information, can be a powerful way to help people connect with ideas and explore how new information either enhances or contradicts their prior knowledge about a subject. You might have participants move around the room like molecules in the atmosphere under different temperature conditions or you might teach them and have them demonstrate the "waggle dance" that bees use to communicate information about where to find nectar.



Examples of using Kinesthetic Activities

Example 1

Ask participants to configure or move their bodies to demonstrate their understanding of a phenomenon, e.g., a dance, a pose, a shape. Troubleshoot, and drop hints and reminders if people are moving in ways that demonstrate different levels of understanding

Example 3

When discussing the size difference between two objects, ask participants to hold up their hands to model the scale of those objects. For example, if a virus were as big as my head, how large would a bacterium be? If the Moon was as big as my fist, how big would the Earth be?

Letting your audience move can change the pace and enliven your event while adding fun and enjoyment to the engagement activities. For learners of all ages, but particularly for younger learners, learning through movement can often be more impactful than learning by listening to an explanation.

How is the Kinesthetic Activities tactic useful for *feedback*?

Asking participants to move their bodies to demonstrate a phenomenon provides you with information about what they are thinking. For example, you can ask your audience to move their bodies to respond to a prompt, such as positioning their bodies so it is sunset in a particular location on the Earth (e.g., sunset on their nose, if their head is a model of the Earth) relative to the Sun (a lightbulb). By observing who is challenged by this request, you can identify people you may need to give more attention to during the rest of your presentation, take a different approach to explain the phenomenon under investigation, or add in time for participants to *Think-Pair-Share* with their neighbors to work through their ideas together. If feasible, you might also provide some individualized feedback and instruction to the participant.

How to use the feedback gained from your use of the Kinesthetic Activities tactic

When learners are invited to move, watch carefully.

- Did they understand the prompt?
- Did they model the concept as you expected?
- Did they try something novel that surprised you, which could reveal thinking that can be explored further?
- Did they have fun and appear to enjoy the experience?
- Did it prompt them to ask questions?
- Did they feel confident or embarrassed?

In each case, remember your role is to adjust in order to accompany them on their own learning journey, so use those responses to judge whether or not they are ready to move on, if you need to change your approach, or dig deeper into a topic.

Using the Kinesthetic Activities tactic at your events

There are many different ways to use kinesthetic activities to get feedback about what your participants are thinking and understanding

Modeling scientific phenomena

Ask participants to configure or move their bodies to demonstrate their understanding of a phenomenon, e.g., a dance, a pose, a shape. Troubleshoot, and drop hints and reminders if people are moving in ways that demonstrate different levels of understanding.

- After a review of the Earth's motion around the Sun, have each participant embody the Earth and ask them to tilt their bodies to show the axial tilt. Have them demonstrate a day by spinning around, and then a year by "orbiting" around the "Sun."
- When discussing the size difference between two objects, ask participants to hold up their hands to model the scale of those objects. For example, if a virus were as big as my head, how large would a bacterium be? If the Moon was as big as my fist, how big would the Earth be?
- Teach people a dance or series of movements that convey a sequence of steps in a scientific cycle or process. Ask them to use this structure to demonstrate their knowledge of a topic (e.g., a supernova collapse and explosion, cell mitosis).
- To investigate how Tyrannosaurus rex's long counterbalancing tail was beneficial, have participants stand against the wall and try to pick up an object on the floor a couple feet in front of them without bending their knees or moving the bottom half of their body away from the wall. When they find they can't do it, have them move away from the wall and ask them what they need to do to pick up the object without bending their legs.

- To understand the spread of viruses, ask participants to stand three feet apart and face in any direction they desire. Have them take three steps as you count one, two, three. They should stop if they run into anyone. After counting to three, ask them to turn 90 degrees to the right and repeat the process. Do this for at least 10 moves, having them keep track of how many times they run into another person. Have them repeat the process with everyone six feet apart at the beginning. The number of times a person runs into someone else helps explain why social distancing reduces the transmission of viruses.

Kinesthetically polling for information

You may use kinesthetic movement to collect information from participants. For example, ask people to position or orient their bodies around a room in response to a prompt in order to indicate their perspectives, attitudes, experiences or understanding. You might use the following prompts:

- Please stand in this corner if you are an only child, in that corner if you have one sibling, and in the far corner if you have two or more siblings.
- Form a line: please stand at this end of the room if you love spending time outside and towards the far wall if you're more indoorsy. Stand near the middle if you're both!
- Ask everyone to stand in a circle and then make a statement. Those who agree with the statement should move to the center of the circle, those who disagree should stay in the outer circle. Then have pairs or small groups discuss their different perspectives.

Considerations for accessibility and inclusion

Some things to consider when crafting your kinesthetic feedback activities:

- Be aware of the physical limitations posed by the space you are in, and your participants. How can you adjust your directions so more people can participate?
- Can everyone hear or read the instructions clearly?
- Does everyone have the ability to participate?
- Cultural considerations could include norms of what is acceptable behavior (e.g., exuberance could be appropriate or even expected), so know your audience.

Outreach context where Kinesthetic Activities are especially useful

The setting of your activity may dictate how active the kinesthetic activities can be. If you're in an auditorium or lecture-style setting with fixed chairs, you may be limited to asking your participants to stand up, point, tilt their heads, or spread their arms apart to indicate a distance or a size. If you have room for participants to move into and out of groups, form a large circle or run around, you may involve them in more physical activities and have them vote by grouping themselves with like-minded participants. Acting out how molecules move in the air, or how the coronavirus spreads, would require more open space. If you're in a virtual environment, make sure your participants are in a safe setting for completing the movements you may ask them to make.

Additional tools and resources

"Kinesthetic Astronomy" by Cheri Morrow

Drawing
DEEP DIVE

Galileo's drawings of the Moon or da Vinci's study of hands document not only the process of scientific understanding and a way to record information, but also the long tradition of using a visual representation to communicate science as experienced. Drawing can be a less intimidating way to connect with your audience, removing barriers that might otherwise prohibit individuals from engaging with a scientist.

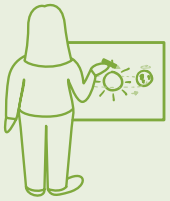
What does it look like?

If you ask people to draw a picture of where their water comes from, one person might draw their kitchen sink, another might draw a rain cloud, another might draw a polluted lake, and another still might draw a plastic water bottle. How might you use their drawings to direct a conversation about water reclamation?

How is Drawing useful for *engagement*?

Drawing can be used to support a range of activities, from a quick icebreaker activity to a deeper reflection. If you ask your participants to draw something about your topic as the activity opener, you have instantly activated their prior understanding, invited them to contribute, and provided a low-stakes way for them to participate. An important aspect of using drawing is that it provides an alternative, often-neglected modality for participants to express themselves and to engage with their ideas, concerns, and understanding. It may also help you broaden participation (a common goal scientists have for their outreach) by engaging members of the audience who might not otherwise be inclined to participate.

Employed later in an event, the Drawing tactic can be used as a mechanism to shift the audience role from listener to active participant. Drawing provides participants the means to record their understanding of the topic without the need for field-specific jargon or fluency with the English language. It can provide a space for participants to craft a response or describe a process, and since there are endless ways an individual may "answer," no two answers will be identical. The organizer may set criteria or boundaries based on supplies available or time considerations, but the boundaries are limitless to the process or how the participant responds through a drawing.



Examples of using Drawing

Example 1

Ask participants to engage their observation and drawing skills through the use of sketchbooks, journaling, and field notes. Use the feedback returned to decide your next step, e.g., by adjusting to focus on plants that are well-known by your audience, or to review details that may have been missed in the observations. (This approach works particularly well if you are meeting with the same participants over an extended period of time.)

Example 2

Ask participants to draw an ecosystem. Participants can label or verbally identify processes, aspects, or roles within the ecosystem (e.g., spheres, diversity, habitats, food chains/web, change/stability, nutrient cycling) to demonstrate their understanding of ecosystems or a particular phenomenon such as how energy transfers in a food chain. You might use the provided feedback to adjust your engagement plan; e.g., if participants have an understanding of the water cycle process, but are unfamiliar with the scientific terminology, you might adjust your delivery to emphasize the terminology.

As participants are called on to share their ideas with both the scientist and other participants, the engagement experience shifts to center the expertise and ideas of the participants.

How is Drawing useful for *feedback*?

Drawings done by participants, either as individuals or in groups, often provide additional context not provided when using other tactics. This could be additional information about the cultural or social context of the participants, and may allow scientists to not only better understand and connect with participants but can also be used to inform how the presenter structures the rest of the engagement. For example, in a conversation about structural engineering you might ask young participants to draw a picture of a school. These drawings can reveal whether they are more familiar with large or small, urban or rural school environments, which should inform your subsequent discussions of building-types. (In this example it would be important not to ask them to draw their schools, and especially not their homes, so as not to invite comparisons.)

When inviting participants to draw something, be thoughtful about the wording you use and how that might impact what is drawn. Think about your desired outcomes and identify a specific and clear question that provides the feedback you are looking for. For example, "Draw a flower" and "Draw the parts of a flower" would likely yield very different results. The second question would be more likely to provide information about participants' depth of knowledge of flower anatomy. Also be mindful that if you frame a question more broadly (e.g., "Draw a flower") you should be prepared to receive a broad range of responses, from an example of a specific genus (e.g., a rose, a tulip), to a picture of flowers growing in a garden, to a drawing of a vase of cut flowers. Drawings prompted by more open-ended instructions can be useful too. You learn from the choices participants make in their drawings, particularly what they choose to focus on (or omit). The simple request to "draw a flower" may provide the presenter insights into the participant's experiences with flowers and an opportunity to acknowledge the breadth of the topic before zeroing in on your activity. A word of caution here: try not to over-interpret participants' drawings and assume meaning that is not there. Drawings are great to get the conversation started, so don't be afraid to ask questions about specific parts of a drawing or ask the participant to describe what they drew and why.

At the start of an engagement, drawings can provide helpful feedback about fruitful starting points with each new audience. Some drawings may reveal misconceptions that can be intentionally addressed during the engagement. With more complex systems like the water cycle or ecosystems, reviewing audience drawings can provide insights into the audience perception of the system. Imagine the variety of drawings that would result from the request to draw a tree in its ecosystem. Are they deciduous, evergreen? Alone or in a forest? What kind of landscape are they on? Are any animals or humans in the picture that are dependent on the tree?

To monitor change in understanding, you might compare two drawings made by the same participant to at the beginning and end of an engagement. A drawing of a featureless crescent in the sky may become a cratered world, a single tree may become a component of an ecosystem. Drawing empowers the participants to express that change in thinking, and make that change in thinking visible to the presenter and to themselves. This feedback from participants provides you with the opportunity to adjust your delivery, facilitation strategy, or to tune the content presented as needed. Adjustments made from feedback may also be recognized as a learning opportunity for the scientist and used to guide facilitation at future events.

Additional examples of how Drawing might be used to gather feedback:

- Ask participants to engage their observation skills through the use of sketchbooks, journaling, and field notes. Use the feedback returned to decide your next step, e.g., by adjusting to focus on plants that are well-known by your audience, or to review details that may have been missed in the observations. (This approach works particularly well if you are meeting with the same participants over an extended period of time.)
- Ask participants to draw an ecosystem. Participants can label or verbally identify processes, aspects, or roles within the ecosystem (e.g., spheres, diversity, habitats, food chains/web, change/stability, nutrient cycling) to demonstrate their understanding of ecosystems or a particular phenomenon such as how energy transfers in a food chain. You might use the provided feedback to adjust your engagement plan; e.g., if participants have an understanding of the water cycle process, but are unfamiliar with the scientific terminology, you might adjust your delivery to emphasize the terminology.
- Use a model to introduce the anatomical structure of the human heart. Ask participants to draw the heart based on the model. Discuss their results, and assess and adjust your plan based on feedback. Invite participants to continue to add detail to their drawing as you continue your presentation. For example, they might add arrows indicating the direction of blood flow in veins and arteries, or represent oxygenated blood versus non-oxygenated blood with specific colors.
- Provide tape so participants can post their drawings on the walls around the room. Build in time for a "gallery walk" so participants can observe and discuss each other's drawings and see how the same idea is represented differently. This also allows you the opportunity to gather feedback, by observing the drawings and by listening to comments as participants discuss each other's drawings.

How to use feedback gained from your use of the Drawing tactic

If drawings expose misconceptions, you can address these before moving on in order to better achieve any learning-related outcomes for the activity. If you observe that participants' drawings lack detail, or if they are not deeply engaged with the drawing task, you can adjust by adding additional, more specific prompts. For example, you might say, "That is great. I see several representations of the Moon. Now can you show me where the Moon is in relation to the Earth and the Sun, and label them?" Adding additional prompts can help gain useful feedback, particularly if you are hoping to learn something specific about the participants' ideas. Sometimes, drawings reveal that participants have a more complex or complete understanding of a topic than was expected. When this happens, you can adjust your engagement plan to provide a more condensed overview of the topic before moving on to more advanced content.

The Drawing tactic may also be used to help the audience member and scientist both see how participants' understandings have changed. For example, the scientist may ask a participant to draw something at the start of an activity (e.g., draw the lifecycle of a honeybee), and also ask them to draw the same thing at the end of the activity or, alternatively, use a different-colored pen to add to or adjust the drawing they made at the start of the activity to reflect their new understanding. The facilitator can use this drawing comparison task to better understand what participants learned from the activity, and what misconceptions still remain. This feedback may be used to adjust and improve future engagement opportunities.

The Drawing tactic is a useful tool to gain information about your audience's perspective or particular interests related to a broader topic. Feedback from audience drawings provides you the opportunity to adjust your program, making it more relevant to your audience by

creating meaningful connections between their experiences and the desired outcomes of your program. For example, suppose you are giving a talk on the topic of climate change, and after asking the audience to draw an outcome of climate change that concerns them, you notice that a majority of the audience is concerned about wildfires. From this feedback you can adjust your delivery to focus on climate change vulnerability assessment, particularly aspects of the assessment related to wildfires.

Gaining feedback about your audience's different "ways of knowing" can also be useful information to help you adjust your program on the spot. For example, if you are holding a demonstration on virus replication, and through participant drawings of a virus's life cycle you discover that there are several audience members who have included particular plants in their drawings that are associated with herbal medicine. This would be a great opportunity to build on the ideas the participants shared and discuss how bioactive compounds/phytochemicals in plants react with the virus life cycle. You might also ask the participants to clarify or affirm what is represented in their drawings as a way to acknowledge the expertise of, and incorporate, indigenous knowledge and ways of knowing into the public engagement experience.

Using Drawing at your events

Successful use of this tactic can be dependent on the nature of the event, such as how much time you have to incorporate the tactic, the age of your audience and age-appropriate drawing ability, and materials available. If you are using this tactic in a virtual environment and participants are using materials from home, be mindful that they may have access to different drawing materials.

- Make sure that the drawing prompts you provide are aligned to your desired outcomes (e.g., building understanding about specific content, addressing misconceptions).
- Give clear instructions; these can be oral, written, or both.
- Be specific about features you wish to see (e.g., "Draw the phases of the Moon" versus "Draw what the Moon looks like").
- State if you want something labeled.
- You might provide a template for people to draw on or fill in, instead of providing a blank sheet of paper. (e.g., A diagram of the human heart with arrows pointing to different features to be labeled).
- Remember that not everyone's drawing skills are the same, but this tactic can provide useful feedback even if participants roughly sketch their ideas. Drawings don't need to be artistic masterpieces. It is easy to misinterpret a drawing or features within a drawing. Try not to be judgmental or over-interpret what someone has drawn; asking participants to explain what they have drawn can be helpful.
- Provide ample time for the task to be completed. Communicate if you plan to limit the amount of time for participants to draw.

Considerations for accessibility and inclusion

Some things to consider when planning how you will use the drawing feedback tactic:

- Be careful to avoid jargon in your prompt, and use directions that are appropriate for your audience. For example, if you know there is a chance your audience is unfamiliar with the layers of the ocean, then instead of asking them to draw sea life that lives in the Bathypelagic Zone, a more appropriate prompt might be to ask them to draw sea life that lives deep in the ocean where no sunlight reaches.
- If you are asking participants to draw something specific or complex, always provide very clear, step-by-step instructions through the drawing process. Providing instructions one step at a time, instead of all at once at the beginning of the task, can be helpful—particularly for younger audiences.
- If you ask people to draw based on an experience, keep it general so most/all people will have something to contribute.

- Some participants may struggle to take a three-dimensional concept and make it two-dimensional. Remember that drawings can be three-dimensional, though we sometimes call those drawings "models."

  You might find that the activity is more successful when participants use three-dimensional materials (e.g., PlayDoh, toothpicks, popsicle sticks, cotton balls, Legos or other building blocks) to express their ideas.
- Keep in mind specific needs that may need additional support or reframing, (i.e., color-blindness when using colored pencils or crayons, adequate lighting for the visually impaired, and sensory-motor skills/processing differences that require diverse materials or supports).
- Technology tools can also support drawing. See the resources section for a few ideas.

Contexts where Drawing is especially useful

- **Audience with children**—Drawing may be especially useful when working with young children. It is often less threatening or less of a barrier than asking children questions. It also provides children space to engage and concentrate with their own understanding of a concept. Review the tips provided above for crafting clear prompts and directions, particularly when working with children
- **In virtual settings**—Employing the drawing feedback tactic virtually can be tricky but can also support some unique engagement opportunities. If you are asking participants to draw, make sure to send out an advance notice so they can be prepared with the necessary materials (pen, marker, or pencil and blank paper) and confirm that you will be able to see your participants (e.g., in some virtual platforms using a webinar mode, you cannot). You can ask participants to draw on their paper and then hold up the paper to the camera to share. Some virtual platforms (e.g., Zoom, Padlet, Jamboard) allow for annotations on the screen, so consider using this feature to create a group drawing as you move through a presentation. Ask participants to add to a picture template you share (e.g., parts of a cell, elements of an ecosystem).

Additional tools and resources

"Google Drawings Tutorial" video for an online drawing tool

"Using Creativity to Fuel Physics Teaching and Learning" research brief from Relating Research to Practice

"Drawing to Learn in Science," article from ***Science***

Polling
DEEP DIVE

Polling is one of the easiest tactics to use to collect feedback from your audience, either planned in advance or implemented spontaneously. Collecting feedback through polls can be fun, quick, and there are many tools available to help, but remember that there is only so much nuance you can glean from a poll.

What does it look like?

Oftentimes scientists find themselves in a position where they have much more information and many more activities to share than can fit into the time limit for a given engagement event. Picking what to share and what to omit can be frustrating, especially for a presenter who really enjoys the topic they are sharing! Polling the audience about their interests can be a useful way to help guide the direction of the learning experience. Providing opportunities like this can lead to more memorable and impactful learning experiences for the participants and can also create a more interesting and challenging (in a good way!) experience for the presenter.

How is Polling useful for *engagement*?

Polling your audience can be a great way to engage people, promote lively discussion, and give insight into what people believe or know. A poll is a question you present to an audience that contains several predetermined responses to select from. Polling can be a fun and low-effort way to create interactivity and help participants feel a sense of camaraderie with other participants.

How is Polling useful for *feedback*?

Polls are a quick and easy way to get information about the beliefs, knowledge, past experiences, or opinions of a group of people. Depending on your goal, polls can be structured in several different ways to collect different types of feedback. Polls can include a “correct” answer as one of the possible options, but they certainly don’t have to. For instance, an opinion poll has no correct answer. Response options can include many choices or as few as two.

Because polls are fast to execute in outreach settings, they are an excellent tool for collecting feedback, but be careful not to over-use them. Polling works best when you are reasonably certain your audience is likely to hold one of some number of common ideas.

Examples of using Polling

Example 1

You might poll an audience to ask their opinion about a question related to your field. You might ask them to identify the birds they see most often outside, and use that information as a stepping-off point for your engagement.

Acknowledging a range of opinions and perspectives related to your topic provides useful feedback to you about your audience and can also be a way to increase participants' interest in what comes next.

Example 2

If you have 20 minutes to share your expertise about sea turtles with several small groups, sequentially, perhaps you start each group with the same 10-minute introduction and activity, and then you take a poll: “Would you like to talk more about: a) the unique features of the seven species of sea turtles, b) sea turtle nesting behaviors, or c) how sea turtles evolved from land and freshwater turtles?”

For example, you might poll an audience to ask their opinion about a question related to your field. You might ask which local birds they have seen around their home, and use that information as a stepping-off point for your engagement. You might ask "Is it a good or bad idea to colonize Mars?" or "Is genetic engineering of humans ethical?" if your goal is to get into a serious discussion of these topics. These opinion questions will help you gauge how participants think and feel about the topic, particularly if you include more than a "Yes" and "No" answer choice, such as "I don't know" or "I haven't made up my mind yet."

If your priority is to identify misconceptions, or if you are focused on potentially controversial questions, an *anonymous* poll is more likely to create a low-risk environment for participants to share their ideas. That said, it is important to remember polls are not simply about determining who is right and who is wrong—even when the question itself does have a right or wrong answer! Be careful to make sure your poll does not seem like a test; participants should not feel there is a penalty for a wrong answer. Instead, a poll can be a way to expose thinking, especially when you follow up by asking respondents to discuss why they chose the answer they did. When you craft your poll, try to think about what you will learn from and do with each possible answer. Most importantly, think about how the information gathered will inform the direction of your engagement. Written well, polls can be fun for your audience and spark their curiosity.

Remember that your polls can ask a factual question, an opinion question, or a question based on values. You can even add pictures into your poll to make them more thought-provoking. Adding images to a poll and using few words can be particularly useful for engaging young children or during public events where language can be a barrier.

How to use feedback gained from your use of the Polling tactic

Remember you are using a poll not just as a test of knowledge but as an opportunity to start a dialogue. For this reason, it is not always best to immediately give the audience the correct answer or, in the case of opinion polls, offer your own thoughts or those of the scientific community. If you designed a good poll, you will get a diversity of answers, and identifying one of them as right or "best" will immediately make a large number of people in your audience feel ill-informed or wrong. No one wants to feel that way. So, what should you do instead?

How can you use the feedback you get from the poll to engage your audience in the moment?

- **Discuss.** Look at the distribution of answers. Is your audience divided between two choices? Great! Use this as an opportunity to have a friendly debate. Is the group equally divided between all choices? Maybe everyone was guessing, but maybe there is a real diversity of thought. Ask questions to find out. Did everyone get the answer "right"? Either your question was too easy or you have a very well-informed audience.
- **Make every response valuable.** No matter how they answered, you should point out something of value in every possible selection. For example, saying, "Many people believe this," or "I used to think the exact same thing," or "There are a lot of good reasons to think this is the case." No one in the room should feel bad about their answer. If you can't think of something positive to say about a selection, maybe it shouldn't be in your poll.
- **Inquire about the thinking behind choices people made.** One main strategy for using poll data is to explore participants' reasoning for the choices they made. This is a common practice in effective teaching and an excellent way to understand, and potentially discuss, commonly held mental models about a scientific phenomenon. Ask, "Would someone who chose option C tell us why option C made the most sense?" You can go through all options that way, but only reveal the "best" option at the end. "This use of polling feedback may

take a bit of time, so prepare for this in your event planning.

- **Revealing the right answer.** When should you tell the audience which response was correct (if there was a correct answer)? It depends. Maybe this is something you want to have the audience discover for themselves (with your facilitation) as the event proceeds. Maybe you want to wait until the very end of the event, return to the responses, and see if people have changed their beliefs. Sometimes you might need to give them the correct answer right away because this is a concept your audience needs to understand at the outset.
- **Reflecting on your outreach strategy.** You might get responses that surprise you and force you to rethink your approach. Perhaps the responses will help you realize that you should change something about your plan or add an activity during the event. Maybe you need to think about how you will change things for a future event. In particular, consider if how you ask the poll should change; you may realize it would be better to ask participants to raise their hands instead of attempting an electronic poll. The poll question itself might also need to be rewritten or reframed to better serve the participants. You may realize that using polling during your particular event, or with your specific audience, isn't the best tactic to choose.

Using Polling at your events

Remember that this tactic is intended to elicit actionable information. Keep it short and simple and useful.

An effective audience poll

- **Provides you with useful information** about what your audience thinks or feels in the moment. Limit the number of choices to the most important or relevant. Best not to go on an unnecessary fishing expedition for audience ideas. Craft polls that will help you reach your desired outcomes.
- **Ignites audience curiosity.** After answering the poll, your audience should be curious and want to know more.
- **Uses understandable language.** It is important to use vocabulary your audience understands and to avoid jargon and acronyms. Always adjust poll questions to be age-appropriate.
- **Includes "I am not sure," or "no opinion," or "other."** It's often valuable to include these options, when relevant.
- **Does not involve math that requires mental calculations.** Most participants don't want to have to "do math" before making a selection, or they might find the math to be intimidating. If the options include numerical values or units of measure, these should be familiar to your audience. For example, centimeters per second is not a unit used in daily life, while miles per hour is more familiar to most people.
- **Might reveal commonly held mental models** (i.e., an understanding of how something works in the world), which allows you to discuss those with participants.
- **Will take practice to develop.** Creating an effective poll question and answer options is not always straightforward, and takes practice. Be open to adjusting your question and answer choices between events.

Engaging formats you can use to collect poll information from your audience.

Electronic polling—There are now a number of applications for smartphones that can collect audience responses and send the results to your phone or computer for instant analysis. An advantage of electronic polling is that each audience member will be anonymous. People are often hesitant to answer polls when their ideas are on display (e.g., when asked to vote by raising their hand), anonymous polls are helpful when discussing sensitive subjects or when people might feel embarrassed to share their ideas or answer incorrectly in a public setting.

The disadvantage of electronic polls is that some participants won't have access to smartphones, and people have varying levels of comfort with using technology to navigate to a website or app. Provide clear instructions when directing

people to access your electronic poll, and plan on spending some time troubleshooting. Depending on the poll questions, it may be a good strategy to ask people to work in small groups to discuss their ideas and submit their group's consensus response to the poll.

This approach may mitigate the situation where not all audience members have a smartphone or facility with new technology tools. Remember: even if everyone has a smartphone, be sure to allow the time needed for people to access the app and understand how it works. This can take significant time away from the main topic. For this reason, you may find it better to use a less technologically dependent polling strategy.

Kinesthetic polling—There are many ways participants can move or use their bodies to make their thinking visible. They can hold up signs (A, B, C, D), signal with 1-5 fingers, raise hands as you go through options, or move to different corners of the room. Once audience members make a selection, you can make this kind of poll even more engaging by breaking them up into groups based on their choices to discuss their ideas. This is particularly useful if you want groups to have a deeper conversation around a topic.

Considerations for accessibility and inclusion

- When depicting or describing people, are you representing diverse groups and avoiding negative stereotypes? Are you creating a scenario where your audience can see themselves in the situation?
- Are you using analogies and examples that everyone will understand? When using pop culture references, remember to consider the age of your participants. If you use analogies involving objects, choose items that your audience is likely to be familiar with.
- Will everyone be able to participate? Are there accommodations you can make so that participants who are hearing- or vision-impaired can participate? Could someone who is color blind make sense of important details in your visuals? Is a cell phone needed?

Contexts where Polling is especially useful

Polling an audience, as opposed to asking open-ended questions (described in the Questioning Deep Dive), requires a sufficient audience size for the results to have meaning. Polling works best for audience sizes of ten and up.

The type of audience and context for the outreach are also important to consider. Incorporating pictures into your polls and using fewer words or kinesthetic polling may be best with children, while using electronic polling will require a tech-ready audience.

Additional Tools and Resources

Tools to use cell phones to collect and interpret audience responses

Poll Everywhere
Mentimeter

Tools to use virtual whiteboards

Jamboard
Miro
Stormboard

Tips to write effective poll questions

Think-Pair-Share

DEEP DIVE

Research illustrates that learning is enhanced when individuals reflect on their ideas and are provided the opportunity to discuss their understanding and thinking with others. Using Think-Pair-Share in public engagement settings not only supports participant learning, but also helps the facilitator understand participant thinking and provides information about their specific interests or questions related to the engagement topic.

What does it look like?

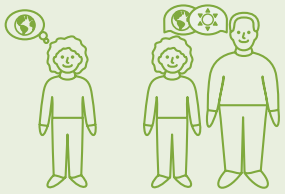
Sometimes the information you would like to share with participants is about a topic they may have very little experience with and might be a topic that appears advanced or intimidating. In this situation, getting the participants to generate ideas on their own before you introduce your topic can be helpful. For example, as a lead-in to your presentation and activity about the application of LiDAR (light detection and ranging) to remote sensing in order to map the ruins of ancient civilizations, you might ask the audience to Think-Pair-Share and consider the question: "What kinds of tools are helpful to scientists to explore remote regions of the Earth?"

How is Think-Pair-Share useful for *engagement*?

Think-Pair-Share first asks audience members to take a short time to think and individually consider a question (e.g., What do you think are the most important factors causing climate change? If there is life on Mars, what might it look like? What are the three most important things you can do to maintain a healthy lifestyle?). Taking time to intentionally examine their ideas will help them better-articulate their thinking.

After a brief period of individual contemplation, instruct people to pair with someone nearby to discuss their ideas and compare their thinking with one another. This can be done with more than two people but be sure to keep groups small enough that everyone in the group has the opportunity to contribute. Enough time should be provided for everyone to share their ideas. This paired conversation allows participants to hear other viewpoints, examine how well they understand the concept, and consider how they might modify their thinking based on what others say.

Next, invite a few participants to share what they discussed in the small groups with the rest of the audience. This provides additional opportunities for individuals to refine their understanding and thinking, and be primed to learn from the rest of the engagement.



Examples of using Think-Pair-Share

Example 1

As a lead-in to your presentation and activity about the application of LiDar (light detection and ranging) to remote sensing in order to map the ruins of ancient civilizations, you might ask the audience to Think-Pair-Share and consider the question: "What kinds of tools are helpful to scientists to explore remote regions of the Earth?"

Example 2

After asking the audience to use a model of the Earth, Sun and Moon to explain lunar phases, you could ask them to Think-Pair-Share to discuss what phase the Moon needs to be in to produce solar and lunar eclipses.

During the **THINK** part of the tactic, you can watch as participants use their model Moon to individually work through their ideas about how to produce eclipses.

The **PAIR** part of the tactic then allows them to articulate their thinking with others and clarify their ideas.

The **SHARE** part provides additional time to share ideas and for the presenter to reinforce what causes lunar and solar eclipses.

Think-Pair-Share should ideally prepare participants to better engage with the rest of the engagement experience.

How is Think-Pair-Share useful for *feedback*?

Think-Pair-Share is an excellent way to get On-the-Spot Feedback to guide the rest of the event. By listening to what the small groups discuss and to what individuals share with the whole group, you can decide on specific details to include in your engagement or alter the direction of the engagement to better address the background, interest and knowledge of audience members. For example, you might realize when hearing a small group talk about talk about energy efficient building construction that they do not think about the cost of producing the construction material or the cost of the building upkeep after construction. This could inform what you emphasize next in your presentation.

How to use the feedback gained from your use of the Think-Pair-Share tactic

Walking among the groups during the pairing time and listening to their conversations can reveal:

- what aspect of your topic is of greatest interest to audience members
- what local or cultural influences are audience members bringing to the event
- what misconceptions audience members might have
- what questions audience members might have

The sharing time will continue to reveal information about the audience to help you decide how to adjust your engagement strategy to best incorporate what you discovered.

Using Think-Pair-Share at your events

Think-Pair-Share is often used at the beginning of an engagement to:

- make people comfortable interacting with others in the audience
- get them thinking about the topic to be discussed
- see what aspect of the topic is of highest interest to audience members
- determine what individuals already know about a topic
- determine what misconceptions they may have about the topic

This feedback tactic is also useful at key times in the middle of an engagement to see how well the audience is enjoying the engagement and understanding the content, and to provide you with important information about their ideas, relevant prior experiences, and questions.

Considerations for accessibility and inclusion

- Think about how you can structure the Think-Pair-Share to make it more comfortable for participants and more inclusive. When planning you might consider whether your participants know each other, or how comfortable they might be talking and sharing ideas with strangers. Make sure that the questions and ideas you have them sharing don't cross boundaries that they may not be comfortable with. If they are a group of strangers, build in time for them to introduce themselves before sharing ideas.
- Are there any language barriers that need to be considered and accommodated?
- Are there any physical barriers that need to be considered and accommodated? Will the layout of the room allow for this tactic?
- Will the discussion get loud so those with partial hearing might be challenged to participate in a one-on-one discussion? If so, make sure people can move to a quieter spot and have a clear signal to call people back to the larger group.

Contexts where Think-Pair-Share is especially useful

Think-Pair-Share often requires a fair amount of time (at least 10 minutes), and works best in an engagement environment like a lecture, science café, classroom, summer camp, etc. It is easiest to use when the audience members know each other (e.g., a class of students, summer camp or after-school program, an event with groups of family members attending together). Programs where people do not know each other (e.g., science café, public lecture) may require a little more encouragement to get people talking with each other. It is not the best tactic to use with young children, but works well with 10-year-olds and older.

Additional tools and resources

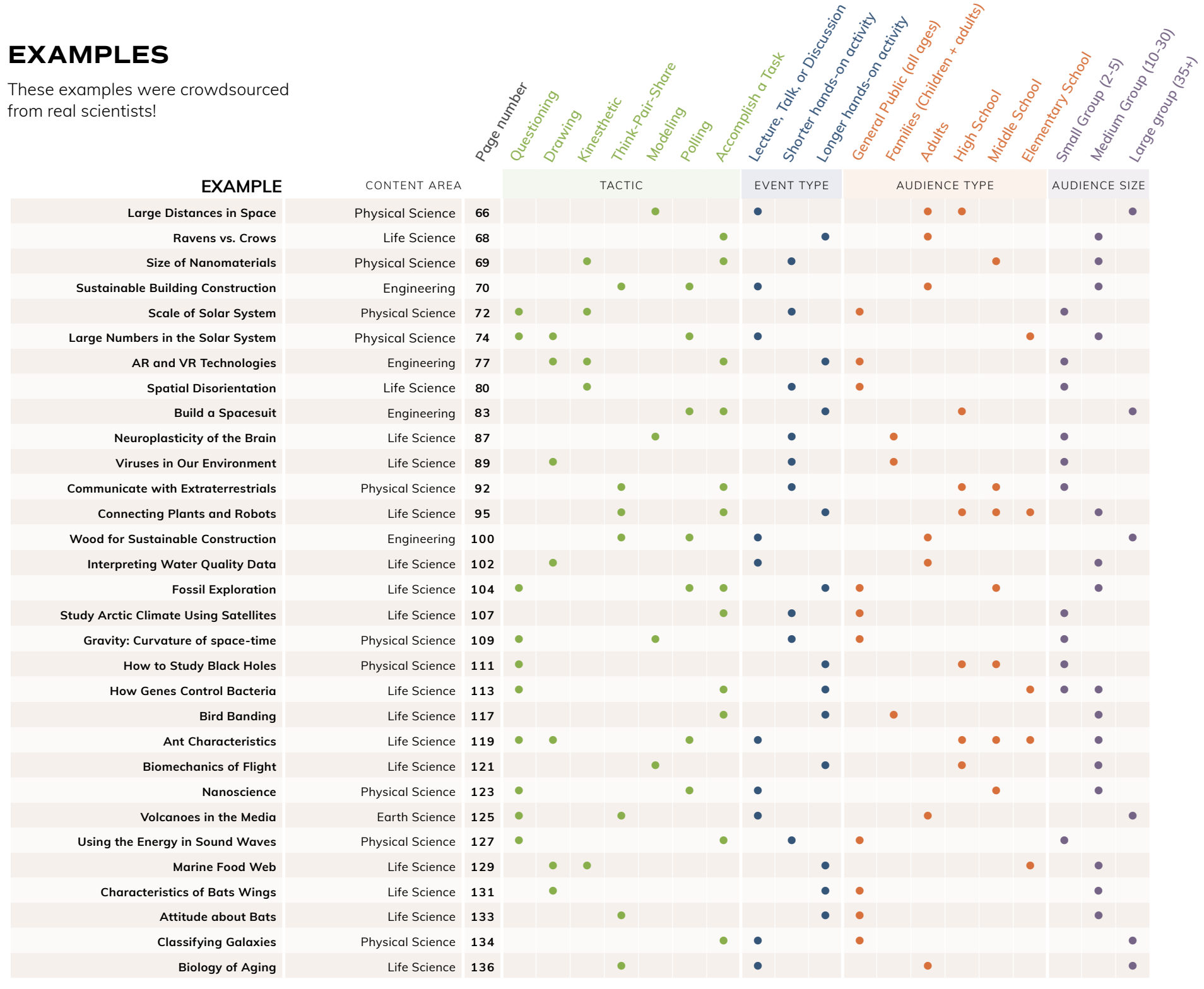
"Think-Pair-Share" overview from Carleton College's Science Education Research Center

"Pair and Share" overview from *Harvard University's ABLConnect*

How People Learn: Bridging Research and Practice, National Research Council, 1999 (see especially ch.2, pp 10-24)

EXAMPLES

These examples were crowdsourced from real scientists!



EXAMPLE	CONTENT AREA	Page number	TACTIC							EVENT TYPE			AUDIENCE TYPE						AUDIENCE SIZE		
			Questioning	Drawing	Kinesthetic	Think-Pair-Share	Modeling	Polling	Accomplish a Task	Lecture, Talk, or Discussion	Shorter hands-on activity	Longer hands-on activity	General Public (all ages)	Families (Children + adults)	Adults	High School	Middle School	Elementary School	Small Group (2-5)	Medium Group (10-30)	Large group (35+)
Large Distances in Space	Physical Science	**66**					●			●					●	●					●
Ravens vs. Crows	Life Science	**68**							●			●			●					●	
Size of Nanomaterials	Physical Science	**69**			●				●		●						●			●	
Sustainable Building Construction	Engineering	**70**				●		●		●					●					●	
Scale of Solar System	Physical Science	**72**	●		●						●		●						●		
Large Numbers in the Solar System	Physical Science	**74**	●	●				●		●								●		●	
AR and VR Technologies	Engineering	**77**		●	●				●			●	●						●		
Spatial Disorientation	Life Science	**80**			●						●		●						●		
Build a Spacesuit	Engineering	**83**						●	●			●				●					●
Neuroplasticity of the Brain	Life Science	**87**					●				●			●					●		
Viruses in Our Environment	Life Science	**89**		●							●			●					●		
Communicate with Extraterrestrials	Physical Science	**92**				●			●		●					●	●		●		
Connecting Plants and Robots	Life Science	**95**				●			●			●				●	●	●		●	
Wood for Sustainable Construction	Engineering	**100**				●		●		●					●						●
Interpreting Water Quality Data	Life Science	**102**		●						●					●					●	
Fossil Exploration	Life Science	**104**	●					●	●			●	●				●			●	
Study Arctic Climate Using Satellites	Life Science	**107**							●		●		●						●		
Gravity: Curvature of space-time	Physical Science	**109**	●				●				●		●						●		
How to Study Black Holes	Physical Science	**111**	●									●				●	●		●		
How Genes Control Bacteria	Life Science	**113**	●						●			●						●	●	●	
Bird Banding	Life Science	**117**							●			●		●						●	
Ant Characteristics	Life Science	**119**	●	●				●		●						●	●	●		●	
Biomechanics of Flight	Life Science	**121**					●					●				●				●	
Nanoscience	Physical Science	**123**	●					●		●							●			●	
Volcanoes in the Media	Earth Science	**125**	●			●				●					●						●
Using the Energy in Sound Waves	Physical Science	**127**	●						●		●		●						●		
Marine Food Web	Life Science	**129**		●	●							●						●		●	
Characteristics of Bats Wings	Life Science	**131**		●								●	●							●	
Attitude about Bats	Life Science	**133**				●						●	●							●	
Classifying Galaxies	Physical Science	**134**							●	●			●								●
Biology of Aging	Life Science	**136**				●				●					●						●

Large Distances in Space

AUTHOR
On-the-Spot Feedback team

TOPIC
How telescopes help us understand the size of the Universe.

SETTING
A public lecture taking place at a community center auditorium.

AUDIENCE
100+ science-interested adults and teens. Participants likely have a range of astronomy knowledge.

OTSF TACTIC TO USE
Modeling

What are the desired outcomes for the engagement event?

- Participants will better understand the vast distances in the Universe.
- Participants will have increased interest in and appreciation of how advances in telescopes have helped scientists gain this knowledge.

What will the audience do during the engagement event?

- Begin with an image of the Andromeda Nebula. Ask: "What is this cloudy thing?" "Is it inside or outside our Milky Way galaxy?" Address the historical debate about the Andromeda Nebula.
- Address how this controversy was resolved by Sir Edwin Hubble using state-of-the-art telescopic observations of Cepheid variable stars.
- Model the size and distance of the Andromeda and Milky Way galaxies.
- Discuss historical telescopic observations and modeling of the Local Group of galaxies.
- Talk concludes with a description of how space telescopes (like the Hubble Telescope) help scientists look even further into the universe.

What OTSF Tactic will you use?

Have audience members model the size and distance of the Andromeda and Milky Way galaxies. You might say: "Reach into your pocket, purses, or wallets and pull out a dime and a quarter. The dime represents the Milky Way Galaxy; the quarter represents the Andromeda Galaxy. How far apart do you think the two coins should be in space? Show me your guesses by holding up your coins."

AUTHOR
On-the-Spot Feedback team

TOPIC
How telescopes help us understand the size of the Universe.

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A public lecture taking place at a community center auditorium.

AUDIENCE
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OTSF TACTIC TO USE
Modeling

Large Distances in Space, cont

How will you adjust based on the feedback you might receive?

Possible audience responses include accurate scaled distances, and overestimating or underestimating the distances. If the majority of the audience were close to the correct distance, reinforce what that means observationally. If guesses were mostly too far apart, show how powerful a telescope would be needed to measure the distance. If most answers were an underestimate, discuss what would have been possible with even more modest technology.

How would this help you reach your desired outcomes?

By embedding this simple activity into the lecture, the presenter is: (1) getting the audience members' initial ideas about galactic size and scale distance, (2) engaging the audience in a memorable hands-on activity designed to surprise and spark interest in the lecture to follow, and (3) establishing a distance comparison that can be related to throughout the presentation.

Ravens vs. Crows

AUTHOR
On-the-Spot Feedback team

TOPIC
How to collect data on birds for a field study.

SETTING
An urban park where a large population of ravens and crows share the habitat.

AUDIENCE
Ten volunteer birders, mostly retired people over the age of 60. Participants are eager to assist in the study of ravens and crows, want to contribute to environmental research, and look forward to interacting with a real scientist.

OTSF TACTIC TO USE
Accomplish a task

What are the desired outcomes for the engagement event?

To identify what the volunteers already know about the difference between crows and ravens, and what they still need to learn before collecting data for the field study.

What will the audience do during the engagement event?

The scientist leading the field study project gives volunteers binoculars and assigned locations. The volunteers fill out an observation protocol that has them list the different characteristics of the crows/ravens they observe.

What OTSF Tactic will you use?

The scientist might say: "Look around and you will see some large black birds. Are these ravens or crows? It's hard to tell at first and you might think all these black birds are the same, but in fact they are very different. Your job today is to look very closely at the large black birds in the area and see if you can notice any distinguishing features. Look at their beaks, tails, feathers, and wings, for example. Watch how they fly. Listen to the sounds they make. Watch how they walk on the ground. See if you can come up with a list that distinguishes the two different large black birds and prepare to share these at the end of the session."

How will you adjust based on the feedback you might receive?

When the group reconvenes and shares their lists, pay attention to where the group is having problems. For example, did the volunteers observe key differences, e.g. ravens have larger, thicker beaks, glide more than flap their wings when in flight, walk more deliberately and slowly, are more frequently seen in pairs, and have many more kinds of vocalizations. Plan out the next day's discussion based on what volunteers still need to learn.

How would this help you reach your desired outcomes?

By starting this volunteer field study project with this activity, the scientist is doing four things: (1) determining what the group knows about crows and ravens so that additional learning opportunities can be planned; (2) honing volunteers' observation skills, which is a science skill needed in the project; (3) getting the volunteers to appreciate the birds and become more interested in them; and (4) making sure volunteers can tell the difference between crows and ravens so they can be identified more accurately during data collection.

Size of Nanomaterials

AUTHOR

On-the-Spot Feedback team

TOPIC

Understanding the nature of nanomaterials

SETTING

A demonstration station at a large science museum's "Nano Days" festival.

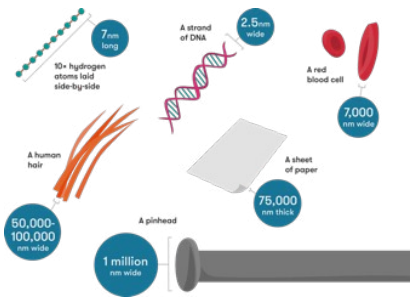
AUDIENCE

Urban middle school students on field trips. Groups of about 10-15 students at a time will visit the station at regular intervals.

OTSF TACTIC TO USE

Kinesthetic Activity

Accomplish a Task



What are the desired outcomes for the engagement event?

- Students will understand the scale of the nanoworld.
- Students will become more interested in nanoscience.
- Students will meet a real scientist studying the nanoworld.

What will the audience do during the engagement event?

The station includes examples of nanostructures (butterfly wings, gecko feet, etc.) that children can examine with microscopes and other magnifying devices.

What OTSF Tactic will you use?

The scientist prompts visitors to engage in a Kinesthetic activity. They might say: "I would like each person to take a card and study it. You'll find a familiar object on your card (a dime, red blood cell, width of human hair, a virus, an ant, the head of a pin, thickness of a sheet of paper…). Please work together and line yourselves up from the smallest object to the largest object."

How will you adjust based on the feedback you might receive?

Look at the line-up, discuss, and suggest adjustments when needed. Look for confusion or misunderstandings, and help the students struggling, while reassuring and encouraging those who get things quickly. "Good. Now that you have done that, on the table there are examples of some objects I study. Let's see how each compares in size to the objects on the cards and where they fit in your line-up."

How would this help you reach your desired outcomes?

- This kinesthetic activity quickly gives the scientist information about what students believe about the scale of things in their everyday world. There will likely be preconceptions that should be addressed before the nanoscale is introduced (e.g., children often think viruses are larger than red blood cells).
- Kinesthetic learning experiences are usually more successful than lectures or presentations at engaging children's minds. (3) The activity helps students appreciate the advancements in technology required to design and build at these scales (i.e., the width of a human hair is about 100,000 times larger than objects at the scale the scientist studies).

Sustainable Building Construction

AUTHOR

On-the-Spot Feedback team

TOPIC

Considerations for environmentally-friendly building construction.

SETTING

A virtual lecture or science cafe, using Zoom technology.

AUDIENCE

Group of 20-25 mainly adults, interested in the environment, science and technology.

OTSF TACTIC TO USE

Polling

Think-Pair-Share

What are the desired outcomes for the engagement event?

- Participants consider the different factors involved in deciding what are environmentally-friendly building construction approaches.
- Participants understand that it is not just the construction costs, but also ongoing operation costs and environmental impact of obtaining construction materials that need to be considered.

What will the audience do during the engagement event?

- Assess the audience's existing conceptions of what needs to be considered when constructing an environmentally-friendly building.
- Discuss the different factors to consider, highlighting the pros and cons of different types of construction, including building cost, operating costs, impact on environment – both to source materials and to operate buildings.
- Highlight policy issues to consider for future building construction.

What OTSF Tactic will you use?

Think-Pair-Share: Begin the activity by screen-sharing images of two buildings, one primarily of metal/concrete and the other primarily of wood. Tell the audience that they are architects giving advice regarding the building of a new office building for a company that wants to be as environmentally friendly as possible. Provide a list of factors one might consider when deciding on which to build (e.g., cost of materials, energy required to produce the raw materials, renewable nature of construction materials, long-term durability of materials, energy efficiency of operating buildings). Give people a couple minutes to personally consider the factors and which might lead to a more environmentally friendly building. Break people into Zoom Breakout rooms with 2 to 5 people, depending on how many attend. Give them 5 minutes to have a conversation and discuss which building will be most environmentally friendly, based on the factors provided. Bring back the groups to share out their conversation.

Polling: Near the end of the activity, after discussing the pros and cons of each factor, put the two images back up for everyone to see and list the factors under each image. Have audience members use the stamps in the annotation feature of Zoom to select which factors are most environmentally friendly under each building type.

AUTHOR

On-the-Spot Feedback team

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A virtual lecture or science cafe, using Zoom technology.

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Group of 20-25 mainly adults, interested in the environment, science and technology.

OTSF TACTIC TO USE

Polling

Think-Pair-Share

Sustainable Building Construction, cont.

How will you adjust based on the feedback you might receive?

The responses to the Think-Pair-Share provides information regarding how much the audience already knows and how interested they are in the subject. If more interest is needed, try to make it more personal, such as focus on home construction that the audience members can better identify with. By getting a sense of what they know, you can make sure to deal more with the fundamentals, or can get into more detail if it seems they already know a lot. You might also build from the statements they make during the pair and share portions of the Think-Pair-Share tactic.

The Polling at the end provides insights into whether the audience understands the tradeoffs that are a part of decision making, and can help inform what to emphasize before closing the online session, or in future public engagements.

NASA/JPL-Caltech

Scale of the Solar System

AUTHOR

Anna Payne, University of Hawaii, Institute for Astronomy

TOPIC

Understanding the scale of the solar system.

SETTING

A public outreach event at a library showing the general public the Sun through a solar telescope.

AUDIENCE

Urban middle school students on field trips. Groups of about 10-15 students at a time will visit the station at regular intervals.

OTSF TACTIC TO USE

Kinesthetic Activity
Questioning

What are the desired outcomes for the engagement event?

- Showing the Sun through a solar telescope, answering questions about the Sun and astronomy in general, show sunspots, and communicating the scale of the solar system.

What will the audience do during the engagement event?

For many, this was their first time viewing the Sun through a solar telescope, and their first time being able to ask astronomy questions to an astronomer. We demonstrated the scale of the solar system so that people understood distances and sizes of the planets relative to the Sun in the case of the audience not having a good grasp of how far away the Sun is from Earth.

What OTSF Tactic will you use?

For some groups, the visitors had difficulty visualizing the size of the solar system and how far away the planets are from the Sun. I asked the group first if they knew how far away the Sun is from the Earth. If no one had a close estimate, then I would ask if they had a sense of how far away the Earth would be if the Sun was the size of this basketball. Many groups had difficulty estimating this or visualizing the scale of the Solar System. This was then I used the full kinesthetic activity of the scale solar system. I first asked for guesses of each planet. After the group discussion, I asked the audience members to walk a certain number of steps away from me to demonstrate the scale of the solar system. I had a basketball and told them to walk 10 step, then another 9 steps, and finally another 7 steps to demonstrate the distance to Mercury, Venus, and Earth respectively. At that distance away, I told them that the size of the planets would be about the size of a pinhead (assuming 1 inch = 100,000 miles). I then discussed that they would have to walk hundreds and hundreds of more steps to reach the outer solar system.

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OTSF TACTIC TO USE

Kinesthetic Activity

Questioning

Scale of the Solar System, cont.

How will you adjust based on the feedback you might receive?

I used this kinesthetic activity model if the group gave incorrect estimates for how far away the Sun is from the Earth. This activity was effective to correct misconceptions and helped me adjust to what level of understanding each particular audience had in terms of astronomy knowledge. The audience was asked their predictions before saying the answers. Pausing between planets and checking for audience understanding ensured the opportunity for discussion, and for the awe of the enormous scale of the solar system to really sink in.

How would this help you reach your desired outcomes?

Communicating the scale of the solar system in a kinesthetic way more easily facilitated audience understanding of this concept. This was especially successful for children and made them more engaged with understanding the universe. In addition, doing this kinesthetic activity during solar viewing helped them to better understand how far away the Sun is from Earth. It was impactful because it further connected concepts about the universe with what they are actively experiencing with their senses, including being engaged during the walking portions. A common reaction was that of awe and surprise, indicating to me that it was a memorable experience and that they now had a better understanding of the solar system, which was a key desired outcome.

NASA, ESA/Hubble and the Hubble Heritage Team

Large Numbers in the Solar System

AUTHOR

Erin Cox, Northwestern University, Center for Interdisciplinary Exploration and Research in Astrophysics (CIERA)

TOPIC

Understanding what an astronomer does and the nature of large numbers.

SETTING

Skype a scientist (using zoom technology). Each student was logged in on their own device.

AUDIENCE

20-30 third graders, interested in space

OTSF TACTIC TO USE

Drawing
Polling
Questioning

What are the desired outcomes for the engagement event?

- Students will be able to interact (ask questions) with a real astronomer.
- Students will learn how to think about astronomical (large) numbers and how to think critically about their surroundings.
- Students will broaden their scientific interests and learn how to be involved

What will the audience do during the engagement event?

The audience will be participating via zoom, using the zoom reactions. Students supply a list of questions for the astronomer prior to the engagement. Each student submitted one question to the list, and during the event the students are called upon by the teacher/aide to ask their question. Since the list of questions is distributed before the event, slides may be prepared ahead of time to use as a visual aid to explain certain questions. The event is meant to be relaxed, so follow-up questions may be asked by any student virtually raises his/her hand and discussions will naturally occur. Since this event takes place over zoom, the presenter is able to quickly look up any visual aid not prepared ahead of time, though this should be limited to only when necessary.

What OTSF Tactic will you use?

1. Drawing – The students will be asked to draw a picture of a scientist prior to the event. At the start of the event, the students will put their pictures up to the camera and discuss similarities and differences. Have a slide of diverse scientists ready to show the students that anyone can be a scientist and that science does not always occur in a lab. If the students have already drawn a diverse set of scientists in various settings, then move on from the activity without showing this slide. If the students either only draw one type of person, or one type of science (e.g., a man in a lab with beakers), then show the ready-made slide and point out all the different ways one can be a scientist. Let the students have input in this discussion.

2. Polling – Use polling to guide the students into how to think about astronomically large numbers. The polling function on zoom allows the presenter to see exactly how many students chose the different answers. Using this, the presenter can adjust their explanation. The point of the polling is not to be exact in the calculations, but to gain a better understanding in how large astronomy numbers are and see how one can make estimates.

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OTSF TACTIC TO USE

Drawing
Polling
Questioning

Large Numbers in the Solar System, cont.

Based on the questions that were submitted prior to the event, I created three polls that addressed numbers. Many students are interested in the size of solar system objects (planets, asteroids), so I created a slide showing the relative sizes of planets vs. the Sun. Then, I showed the class different variations of the Earth covering the diameter of the Sun (i.e., one, two, five, 100) and polled the class as to which one is correct. I then did a similar poll with the size of Jupiter, showing the slide with the relative sizes between each poll. Using the answers from each poll, I addressed any common misconceptions as to how the planets sizes compare with the Sun's. Another common question the students had was in regards to the age of the Solar System. To address this, I polled the students on how long it would take to count to a million (i.e., minutes, hours, days, or weeks) and then how long it would take to count to a billion (~100 years). This helped them understand just how much bigger one billion is than one million when we discussed the age of our Solar System.

3. Questioning and Listening – Throughout the engagement, ask the students questions relating to why they choose the answers that they do and listen to their thought process. This can be related to why they drew the scientist that they did, if they've ever met a scientist/astronomer before, what they think scientists/astronomers do, etc. While the engagement consists mostly in a question/answer format, it is a good opportunity to turn the question back to them. For example, a common question is whether astronomers go to space. One could pose a question back to the class asking what it takes to get to space, breaking it down into digestible pieces. Then answer that question explaining why they do not, using the information the class provided.

How will you adjust based on the feedback you might receive?

1. The drawing activity will provide information about who the students think of when they think of a scientist. Discuss the drawings for a few minutes and ask if anyone has met a scientist in real life and what they think scientists do. If most students think all science occurs in a lab, discuss how many scientists do their work out in the field. Also discuss the use of computers in scientific analysis.

2. The polling of the different sized objects in the Solar System and how to think about large numbers will provide insight into where the students are coming from and whether they absorbed the slides that addressed this. Take note of any confusion in the students' responses. If everyone gets it wrong, ask what their thought process was to answer the question and gently guide them on not just what the right answer is, but how to think about deducing the right answer.

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AUDIENCE

20-30 third graders, interested in space

OTSF TACTIC TO USE

Drawing
Polling
Questioning

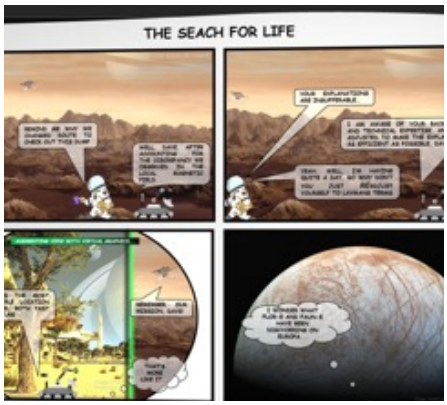
Large Numbers in the Solar System, cont.

3. Throughout the entire engagement, ask the students questions and listen to their answers. Prior to the engagement, try to anticipate possible areas of confusion and create slides on that topic so that there is a visual aid to use. If possible, go over the goals with a non-astronomer and see where they have questions to better address any confusion. Try to ask leading questions when possible to get the student to the right answer on their own.

How would this help you reach your desired outcomes?

(1) This kinesthetic activity quickly gives the scientist information about what students believe about the scale of things in their everyday world. There will likely be preconceptions that should be addressed before the nanoscale is introduced (e.g., children often think viruses are larger than red blood cells)

(2) Kinesthetic learning experiences are usually more successful than lectures or presentations at engaging children's minds. (3) The activity helps students appreciate the advancements in technology required to design and build at these scales (i.e., the width of a human hair is about 100,000 times larger than objects at the scale the scientist studies).



NASA/JPL-Caltech

AV and VR Technologies

AUTHOR

Jordan Dixon, University of Colorado, Bioastronautics Department

TOPIC

Planetary navigation without GPS and Earth-based resources

SETTING

Boulder Public Library with ~12 different presenters/ stations in a large room

AUDIENCE

All ages and backgrounds, open to the public. Motivation for attending unknown.

OTSF TACTIC TO USE

Kinesthetic

Accomplish a Task

Drawing

What are the desired outcomes for the engagement event?

- Increase excitement about emerging technologies being used to enable human exploration of the solar system.
- Increase awareness of how technology development for spaceflight transfers to applications here on Earth and to things they interact with in their everyday life
- Improve understanding of the current state and trends of new "near-future" technologies and how it may affect their lives
- Improve my confidence at incorporating audiences' prior knowledge (or lack thereof) into my facilitation of explaining complex technologies and topics

What will the audience do during the engagement event?

1. First, I have a fun comic strip (See Figure 1) that integrates planetary navigation into a colorful story. This is intended to be engaging for all ages, and acts as a tool for knowing how well we've introduced the concepts at the end of their time at the station.

2. The kinesthetic, accomplish-a-task using Google Cardboards demonstrates Virtual/Augmented realities, and demonstrates difficulties in navigation communication for planetary exploration. Observing their various strategies while using Google Cardboards will provide me with more information for questioning afterwards. This is done in pairs, where one participant acts as the navigator (finding a landmark in first-person-view google maps), and the other provides verbal instructions using top-down maps of the area. This is analogous to Mission Control or Intra-vehicular activity (IVA) astronauts assisting extra-vehicular activity (EVA) astronauts complete their mission.

3. This is followed up by a drawing task, asking them to "create a heads-up display that would help them to perform that task more effectively" using a printout of their first-person view as seen in the Google Cardboard (See Figure 2).

4. Other iOS and Google Play applications will be linked for participants to explore, and to encourage continued exploration into these technologies at home.

Large Numbers in the Solar System, cont.

AUTHOR

Jordan Dixon, University of Colorado, Bioastronautics Department

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SETTING

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AUDIENCE

All ages and backgrounds, open to the public. Motivation for attending unknown.

OTSF TACTIC TO USE

Kinesthetic

Accomplish a Task

Drawing

What OTSF Tactic will you use?

1. To begin, questioning and polling are used with the comic/poster to gather background understanding, and note where they may have experience with the technologies discussed. For example, I might ask whether they have experienced a VR headset, or played Pokémon Go on their phone, which is an example of Augmented reality (adding information to the 'real world'). Additionally, I may ask whether they have interacted with robotic assets such as Alexa or chatbots online (verbal communication back and forth with a program).

2. A kinesthetic, accomplish-a-task demonstration with Google Cardboards and a navigation task allows participants to authentically experience the challenges of navigation and communication.

3. A drawing, think-pair-share strategy follows up navigation/communication task, asking them to draw a heads-up display (augmented reality) that could assist them in better completing the task.

4. Additional kinesthetic, questioning and discussion follows for interested persons that would like to spend more time at the station

How will you adjust based on the feedback you might receive?

1. Based on the feedback given from initial questioning/polling, I may keep explanations of the technologies within the context of terrestrial use to better engage those who are not interested in or have negative feelings about spaceflight. This can relate to tourism navigation in new cities, persons working in GPS-denied environments (e.g., military missions in rural terrain), pilots operating complicated aircraft systems, etc.

2. Based on observing the kinesthetic complete-a-task activity, I probe participants during the drawing task to see how they think about the situation differently after having completed the task. This may warrant going back to questioning and discussion.

3. After completing those activities, I ask participants to point out where in the visual poster comic they see those technologies being used. This will highlight their understanding of the information conveyed during the expereience, and facilitate extension of the knowledge to different environments.

Large Numbers in the Solar System, cont.

AUTHOR

Jordan Dixon, University of Colorado, Bioastronautics Department

TOPIC

Planetary navigation without GPS and Earth-based resources

SETTING

Boulder Public Library with ~12 different presenters/ stations in a large room

AUDIENCE

All ages and backgrounds, open to the public. Motivation for attending unknown.

OTSF TACTIC TO USE

Kinesthetic

Accomplish a Task

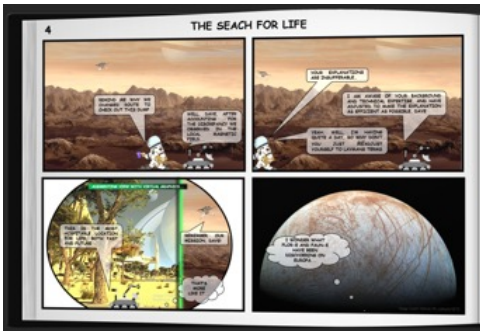
Drawing

How would this help you reach your desired outcomes?

1. The drawing activity where participants design their own heads-up-display will provide an opportunity to extend knowledge gains into environments they are familiar with. Highlighting these concepts in the context of space exploration will demonstrate that almost all technologies we develop in order to work and live in space have direct applications and benefits for terrestrial life on Earth.

2. The immersive AR/VR environment using the Google Cardboards will provide a novel experience for participants unfamiliar with these emerging technologies. This is intended to garner interest in STEM-based research and space exploration.

3. Providing (QR-code) links to AR/VR mobile applications at the end of the activity is to encourage continued exploration and learning at home following the engagement event.



A comic highlighting emerging technologies that may be fundamental to future, distant space exploration: (1) Explainable artificial intelligence, (2) Augmented, Virtual and Mixed reality, and (3) Adaptive and Adaptable automation.

An example of from an outreach event of an elementary student designing an Augmented Reality (AR) Heads-Up Display to enhance navigation tasks in novel/unknown environments. This follows an activity using a Google Cardboard simulation with Street View whereby a second person provides directions to Google Cardboard participant to navigate from a random point in Paris to the Eiffel Tower without AR assistance.

Spatial Disorientation

AUTHOR

Jordan Dixon, University of Colorado, Bioastronautics Department

TOPIC

Spatial Disorientation

SETTING

Boulder Public Library with~12 different presenters/stations in large room

AUDIENCE

All ages and backgrounds, open to the public. Motivation for attending unknown.

OTSF TACTIC TO USE

Kinesthetic Activity

What are the desired outcomes for the engagement event?

- Increase awareness of the impacts of spatial disorientation (SD) on safety, and the many domains in which it presents itself. Ideally, this will instill safer practices by participants if/when they perform these kinds of activities, such as SCUBA-diving.
- Increase interest in science and human physiology; a deeper understanding of how much we learn by studying ourselves.
- Improve my approach and confidence explaining this research to public, non-scientific audiences, and getting across the serious risk SD presents.
- Garner interest in the general public engaging with and participating in scientific research studies.

What will the audience do during the engagement event?

1. First, I explain the concept of spatial disorientation with a poster full of pictures that is intended to appeal to a diverse set of backgrounds, as it involves many different environments and professions people may have connections to (e.g., SCUBA divers, firefighters, astronauts, etc.). This is for "breaking the ice", gaining an understanding on participants existing knowledge, and acting as a segue to the kinesthetic demonstration. Specifically, I'm able to relate past experiences to specific sensory experiences that could have been disorienting, even if they did not realize at the time. For example, when snorkeling or scuba diving, one must primarily use vision in order to sense which direction is "up" since tactile cueing is even on all sides of the body. If someone scuba dives at night, it is very difficult without instruments to tell which way to swim to get to the surface.

2. The kinesthetic demonstration of semicircular canal washout (inner ear balance organs) is surprising even to professionals that have learned about SD and how it arises. An example of this is when an aircraft makes a constant turn for 20+ seconds. The inner ear will stop sensing the rotation of the aircraft without visual references, and a person will perceive that they are flying straight ahead. This can lead to dangerous situations for pilots, as they may make incorrect motions of the aircraft based on what their body is telling them. The demonstration is engaging to everyone present (not just the direct participant): a blindfolded participant is seated in an office chair with his or her eyes closed. I begin to spin the chair, and instruct the participant to hold out their fist with a thumb up, and tilt it left or right to indicate their perception of the direction and magnitude of left/right spinning.

Spacial Disorientation, cont.

AUTHOR
Jordan Dixon, University of Colorado, Bioastronautics Department

TOPIC
Spatial Disorientation

SETTING
Boulder Public Library with~12 different presenters/stations in large room

AUDIENCE
All ages and backgrounds, open to the public. Motivation for attending unknown.

OTSF TACTIC TO USE
Kinesthetic Activity

At constant rotation speeds, the perception of rotation decays over time. The audience will observe a participant initially indicating their perceived rotation in the correct direction, but will eventually tilt their thumb upright to indicate they no longer perceive themselves to be spinning in either direction. After this occurs, I instruct the participant to open their eyes so they too can see how easily humans become spatially disoriented.

3. The demonstration is followed up with questions/examples of where they may experience SD in everyday life, and to keep it in mind next time they're in such an environment (e.g. takeoff on an aircraft).

What OTSF Tactic will you use?

1. Questioning and polling is used with the poster to gather background understanding, and illustrate where they may have experienced SD in their life. Specifically, I ask about past experiences that most people may have experienced which commonly lead to spatial disorientation, such as being a passenger on an aircraft, or going snorkeling or scuba diving.

2. A kinesthetic demonstration in a spinning office chair will then be used to elicit SD. This demonstration using a single participant is used to visually demonstrate to the rest of the group (as well as the participant in the chair) how easy it can be to become spatially disoriented. Specifically, participants observe a person begin to feel like they are no longer rotating after as little as 20 seconds, when they clearly still spinning at a high rate.

3. Based on group size, either questioning and/or think, pair, share will be the follow up to the demonstration to have them think about other examples of SD that may exist in environments they have experienced.

How will you adjust based on the feedback you might receive?

1. It is possible that persons have never thought about or conceptualized spatial disorientation. This questioning may influence how I begin the kinesthetic activity, or what content I include/add to the poster in future iterations of the outreach event. For example, every time a person has taken off in a passenger aircraft without staring out the window, they have experienced “taking off”, or a pitching back sensation before the aircraft’s front wheels actually leaves the ground. Before the demonstration, persons need to have a baseline understanding of what SD actually means, and that it can be solely due to limitations in our own physiology (i.e. everyone can, and likely has been spatially disoriented).

Spacial Disorientation, cont.

AUTHOR

Jordan Dixon, University of Colorado, Bioastronautics Department

TOPIC

Spatial Disorientation

SETTING

Boulder Public Library with~12 different presenters/stations in large room

AUDIENCE

All ages and backgrounds, open to the public. Motivation for attending unknown.

OTSF TACTIC TO USE

Kinesthetic Activity

2. Some persons may engage more with the 'Why?' than the 'What?'. The 'Why?' is with regards to why human perceptual organs cannot accurately sense orientation in various environments, as opposed to the 'What?' being how that impacts how a human might respond to perceiving a false sense of orientation. The demonstration is to illustrate the 'What?', and the poster includes aspects of both.

However, it is a much more involved topic to begin exploring the 'Why?' in depth, given that limitations of human perception cause different outcomes in different environments (e.g., an astronaut can disregard a lack of sensation of what is "up" as opposed to a scuba diver that constantly needs to know the direction of "up" for safety). Based on participant interest and feedback, I may need to think of additional activities, resources and tactics to engage with what specific aspects of SD the audience is most interested in. For example, is a participant interested in the cause of SD from a physiological perspective? If so, additional physical models of vestibular (balance) organs may be useful in describing inertial forces, and inherent limitations with the physics of peripheral end organs.

How would this help you reach your desired outcomes?

1. The final activity (questioning and/or think-pair-share) will provide feedback on whether they can translate what was just demonstrated to their own lives, or other environments/operations I didn't explicitly talk about. This will be the primary metric of how well I've engaged with the audience, and how effective I was at using the OTSF tactics.

2. Contact information relating to participating in scientific research studies at CU Boulder is provided as a follow-up to encourage continued interest and learning about human perception and physiology, and highlight the importance of basic science research as it relates to safety and health.

Build a Spacesuit

AUTHOR

Jordan Dixon, University of Colorado, Bioastronautics Department

TOPIC

Spacesuits, the smallest human spacecraft

SETTING

Teen Science Café at University of Colorado, Boulder. Large lecture hall with 75-100 students.

AUDIENCE

Ages 14-18, all high school students. Independently attending extracurricular STEM events on weekday evenings; assume interest in science and university education. Some students may have a science fair/ classroom experience related to the concepts we explore in this activity.

OTSF TACTIC TO USE

Polling

Accomplish a Task

What are the desired outcomes for the engagement event?

- Increase interest in space and STEM fields, namely by understanding the diverse makeup of people and knowledge required to accomplish successful STEM missions.
- Increase excitement of human space exploration, and transfer of technology to terrestrial, everyday life.
- Encouragement to explore and pursue university education in STEM fields.
- Understand the fundamentals of how humans can live and work in space.

What will the audience do during the engagement event?

1. A short presentation leads off the event to introduce spaceflight, and the basic requirements for humans to live and work in space. This highlights the many domains and people who work together to accomplish a single space mission, and demonstrates that no matter what skills and background a person may have, they can directly contribute to space-based research.

2. Due to the large group size, students are asked to breakout in groups of 4-5 for the design-and-build activity. To bridge the initial learning objective (diverse makeup of space research teams), students assign themselves ‘roles’. Groups choose a subsystem of a spacesuit to design, and work together with the instructors to build an engineering drawing/design of their proposed system. Instructors provide feedback and “sign off” on the design. Before moving to the building phase, groups present, or “market” their design to the rest of the class.

3. Students then use standard arts and crafts supplies to build a mockup of the spacesuit subsystem. When completed, each group integrates their subsystem into a full mockup spacesuit at the front of the classroom.

Build a Spacesuit cont.

AUTHOR

Jordan Dixon, University of Colorado, Bioastronautics Department

TOPIC

Spacesuits, the smallest human spacecraft

SETTING

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OTSF TACTIC TO USE

Polling

Accomplish a Task

What OTSF Tactic will you use?

1. Begin presentation with polling for adjectives that they think of when thinking about space. Are there cultural boundaries associated with the idea of space exploration and/or space-based research? Example responses to common questions include:

a) explaining why space-based research improves life on Earth as opposed to simply benefiting a few people who get to perform research in space https://www.nasa.gov/specials/60counting/tech.html

b) diversity of background, culture and skills are all needed for successful space-based missions, e.g., artists, writers, engineers, botanists, etc. (https://www.nasa.gov/careers/diversity),

c) pioneering arguably leads to the most revolutionary impacts on human wellness (https://www.amazon.com/Extremes-Death-Limits-Human-Body/dp/1444737740) etc.

2. Visual/model-based examples are shown of mockup spacesuits, habitats and spacecraft, and questioning about the examples will help gauge background knowledge and interest.

3. Drawing of preliminary designs to demonstrate the process of engineering technical systems. Group work with 'roles' to highlight diversity of teams required to accomplish the mission.

4. Kinesthetic/Accomplish a Task where students build a mockup of the spacesuit that they can take home with them. All groups integrate their disparate subsystems to create a complete product. Do the subsystems integrate? What communication between groups is required to have successful integration?

How will you adjust based on the feedback you might receive?

Build a Spacesuit cont.

AUTHOR

Jordan Dixon, University of Colorado, Bioastronautics Department

TOPIC

Spacesuits, the smallest human spacecraft

SETTING

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OTSF TACTIC TO USE

Polling

Accomplish a Task

1. There may need to be divergence from the introductory presentation on space-research and spacesuits based on cultural boundaries associated with the perception of space exploration and research (e.g., climate impacts, benefits to countries without space programs, etc.). Rephrasing the space-based mission objectives in terms of terrestrial applications may be warranted (e.g., relate to SCUBA, firefighting, etc.). Backup slides exist that highlight some of the more political, sociological, and ethical issues that are currently being discussed by policy makers and scientists around the world. Altering the purpose of the protective suit still accomplishes the goal of highlighting the diversity necessary to enable new technologies and continued exploration, while also being inclusive of all perspectives on human use of space and space resources.

2. Groups of students may desire to build similar subsystems based on interest, so that a "complete" spacesuit isn't created. While we want to avoid a sense of "competition", and rather foster a sense of collaboration, we can highlight the real-world applicability of soliciting multiple approaches to the same problem, each of which will have its own strengths.

3. Highlighting differences between subsystem designs can be put in the context of iterating on preliminary designs to reach the 'optimal' solution. This concept is related back to the idea of scientific research among our group of university students and professors at Colorado University, Boulder. University education and research is often where the preliminary designs of new solutions are produced.

4. Probing design choices during the building phase may facilitate deeper dives into other aspects of spacesuit design not covered in the presentation (e.g., soft fabric as a structural component, what materials can and can't be exposed to the vacuum of space, etc.).

How would this help you reach your desired outcomes?

Build a Spacesuit cont.

AUTHOR

Jordan Dixon, University of Colorado, Bioastronautics Department

TOPIC

Spacesuits, the smallest human spacecraft

SETTING

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AUDIENCE

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OTSF TACTIC TO USE

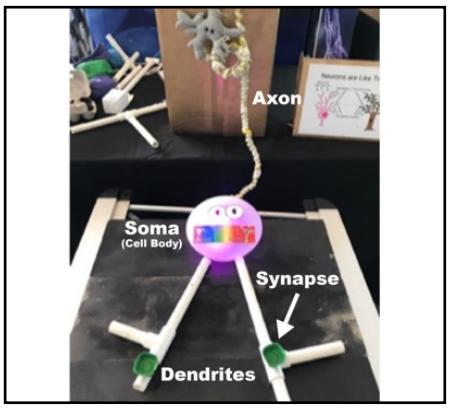
Polling

Accomplish a Task

1. First and foremost, the questioning and presentation are aimed to get across that it takes all domains, cultures and perspectives to accomplish the enormous feats associated with space exploration. This is targeted to inspire students to pursue their passions (as opposed to thinking 'aerospace engineers' are the ones who work in space), because every skill and perspective is needed for to accomplish pioneering exploration.

2. The presented models, and student's preliminary designs facilitate critical thinking of the necessary inputs and outputs humans need to survive in extreme environments other than their own. It allows creative space to propose novel ideas of how to accomplish difficult, undefined tasks.

3. A collaboration across students' independent subsystems facilitates conversation about pros and cons of different technologies. This also closely relates to systems engineering: the concept of organizing many people, teams and ideas that are required to accomplish the enormous tasks that are undertaken in the name of space exploration.



Talk to a Brain Cell exhibit. Participants release neurotransmitter (beads) into the synapse cups on the dendrites until the cell is activated and sends a signal down the axon (flashing lights). Changes to synapses and dendrites effect signaling.

AUTHOR

Atom Lesiak, University of Washington, Department of Genome Sciences

TOPIC

Brain cell development and neuron communication.

SETTING

Public Outreach at Museum or Science Festival

AUDIENCE

Museum attendees, kids (~6 years and older) plus adults, group size during engagement is highly variable 1-6 (max)

OTSF TACTIC TO USE

Modeling

Neuroplasticity of the Brain

What are the desired outcomes for the engagement event?

- Identify parts of a brain cell including dendrites, synapse, and axon.
- Understand how learning takes place in the brain through changes in synaptic connections and neuron structure.
- Changes in brain chemicals (neurotransmitters) change brain function.

What will the audience do during the engagement event?

Audience manipulates and interacts with the parts of the neuron model in response to prompt. Examples:

1. How can the neuron change to become activated faster next time? – Participants say they can release more neurotransmitter faster or release at more sites or grow more sites (i.e., change the physiology).

2. What do you think happens to synaptic connections when you forget? – Physically remove the synapses.

What OTSF Tactic will you use?

I begin by using the tactic, manipulating a model, and describe the way in which neurons communicate with each other. The participants contribute to the activity by creating a hypothesis. For example, I ask them, if there are more synapses, will the neuron be activated Faster, Slower, or the Same? Participants test their hypothesis by moving the model in a way that allows them to change the functioning of the neuron model, and then we determine if the hypothesis was rejected or not.

AUTHOR

Atom Lesiak, University of Washington, Department of Genome Sciences

TOPIC

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OTSF TACTIC TO USE

Modeling

Neuroplasticity of the Brain, cont.

How will you adjust based on the feedback you might receive?

When audience members interact and engage with the model you can use this moment to assess their understanding. Asking questions can determine what elements of the activity are still unclear or ambiguous. For example, I can ask about what they think will happen if they forget something they have learned. They can speculate on the changes to the neuron structure, and often can determine that the new synaptic connections between neurons will likely be lost if they forget.

I tell participants that many brain disorders often have issues with connections between neurons. When they mention a disease of interest, I can ask them how they think the structure of the neuron will be impacted. Example: Parkinson's causes the neuron to degenerate. The final step of asking the audience to contribute to the manipulation of the model, helps identify if the objectives for the activity were met. This iterative engagement of continually challenging and asking questions along the way helps to clarify where along the learning process confusion takes place, and allows for a quick "On-the-Spot" assessment of what is being understood and if the activity outcomes are being reached. Sometimes all the outcomes will not be reached, but the continuous assessment helps identify how to proceed.

How would this help you reach your desired outcomes?

Manipulation of the model, while naming each part, enhances learning the different parts of the neuron, including the beads (aka neurotransmitter/brain chemicals) and other important elements of the anatomy

The real-time questioning and assessment helps build upon the participant's basic anatomical knowledge as we dynamically work toward the higher-end learning outcomes related to the connection between brain signaling and mental states like learning and disease.

Viruses in our Environment

AUTHOR

Marina Good, University of Colorado Boulder, Molecular, Cellular & Developmental Biology

TOPIC

Viruses in our Environment

SETTING

An interactive event at a public library with multiple booths and tables (mine was just one)

AUDIENCE

~50 families interested in learning about science from graduate and undergraduate students. Participants likely have a little knowledge about some topics, and may know about coronavirus due to news coverage of the pandemic

OTSF TACTIC TO USE

Drawing

What are the desired outcomes for the engagement event?

Participants will have a better understanding of what defines a virus.

Participants will have a better appreciation for the diversity and frequency of the viruses that they could come into contact with daily.

Participants will have a brief introduction to a few techniques scientists might use to detect and characterize viruses

What will the audience do during the engagement event?

1. Start with the audience looking at, touching, and describing stuffed cartoon models of viruses and ask whether they know what a virus is and what it might look like – see images of stuffed models to right. This helps to provide sufficient background for the rest of the engagement event.

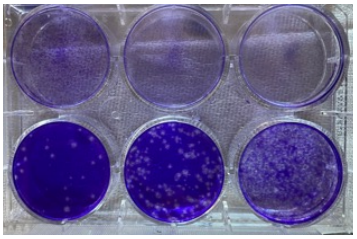
2. Address the obvious adaptation of viruses for the purposes of illustrating/ overexaggerating certain features seen in the stuffed models (See examples to the right). The stuffed models serve as a foundation for the following elements of the engagement event, but it is important to acknowledge that the features seen in the models, and that may carry over into illustrations, are not necessarily biologically accurate.

3. Ask participants to describe their current understanding of viruses and create their own model through drawing/sketching.

4. Discuss any possible misunderstandings or misinformation that they might have about viruses.

5. Conclude the interaction with a show-and-tell of a plaque plate, and a description of how scientists use certain techniques to study viruses. A plaque plate is the result of a plaque assay, in which a virus is serially diluted and used to infect cells. After several days, the cells and virus are fixed and stained so that the plaques can be visualized and counted, with each plaque being a single virus particle (See image below).

Epstein-Barr Virus



Show-and-tell of a plaque plat

AUTHOR

Marina Good, University of Colorado Boulder, Molecular, Cellular & Developmental Biology

TOPIC

Viruses in our Environment

SETTING

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AUDIENCE

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OTSF TACTIC TO USE

Drawing

Viruses in our Environment, cont.

What OTSF Tactic will you use?

Have participants create their own models of viruses, first through questioning, followed by drawing and sketching. You might first ask them to simply create their own virus, and provide some feedback to help correct any inaccuracies. As an example, in an engagement event I conducted there was a young participant (~ 6 years old) who had sketched a round shape with spikes and several pairs of eyes. I provided feedback by first asking the artist where they had pulled inspiration for the various elements of their model virus. We discussed which elements of the drawing were likely not biologically accurate but were more there as an added artistic feature. In this way, I was able to provide feedback in a manner that allowed the participant to actively participate in learning which aspects of a virus were real, instead of simply being told that something was right or wrong. The main goal of this interaction is not to criticize or manipulate their current understanding, but more to encourage critical thinking. You can use the stuffed models as a conversation/thought process initiator, but ultimately the focus should be on introducing or refreshing understanding of participants regarding the topic of viruses.

How will you adjust based on the feedback you might receive?

If participants are not feeling confident or comfortable enough to begin creating their own model, you could propose a “think, pair, share” path forward. This might include you drawing alongside them so they feel less exposed/singled out, or it might look like the child working with family members to create a model of what they think a virus might look like. If the majority of the audience are having trouble with accomplishing the task of modeling a virus, you can provide some information as a starting point. For example, you could establish what shapes are commonly seen in viruses, thus providing a foundation for their drawing. Use the exercise as an opportunity to give participants more information about viruses. If the majority of audience members are too young or not engaged enough to create a model, simply use the cartoon models you have to encourage conversation about viruses and related topics.

AUTHOR
Marina Good, University of Colorado Boulder, Molecular, Cellular & Developmental Biology

TOPIC
Viruses in our Environment

SETTING
An interactive event at a public library with multiple booths and tables (mine was just one)

AUDIENCE
~50 families interested in learning about science from graduate and undergraduate students. Participants likely have a little knowledge about some topics, and may know about coronavirus due to news coverage of the pandemic

OTSF TACTIC TO USE
Drawing

Viruses in our Environment, cont.

How would this help you to reach desired outcomes?

This engagement event would help you to reach the desired outcomes outlined above in a variety of ways. First, through interactions that occur organically through the event, participants will leave having a better understanding of what defines a virus. They will have discussed features of viruses as they observe the stuffed models, create their own illustrations, and work through recognizing elements of their illustrations that may or may not be biologically accurate. Additionally, throughout the event, there are many opportunities to discuss the frequency and diversity of viruses with participants, leading to their appreciation of the many interactions they have every day with these pathogens. Finally, the "show and tell" involving a plaque plate will allow participants to be introduced to one of the many techniques scientists use to characterize viruses.

Communicate with Extraterrestrials

AUTHOR

Xinnan Du, Stanford University, Kavli Institute for Particle Astrophysics and Cosmology

TOPIC

Communicating with extraterrestrial intelligence on a distant planet.

SETTING

A virtual science fair "station" where participants engage in online interactive activities.

AUDIENCE

Groups of ~five students (11-15 year olds) who are interested in astronomy and science fiction.

OTSF TACTIC TO USE

Accomplish a Task

Think, Pair, Share

What are the desired outcomes for the engagement event?

- Participants will gain knowledge of basic methods used in Search for Extraterrestrial Intelligence (SETI).
- Participants will be able to explain how to convert 1D radio signals (binary bits) to 2D images.
- Participants will be able to construct their own 2D images (i.e., "messages") and decipher "messages" sent by others.

What will the audience do during the engagement event?

1. The speaker starts with a short introductory presentation on the basic methods used in SETI, including why and how we use radio signals to attempt communicating with extraterrestrial intelligence.

2. The speaker shows how a series of radio pulses in 1D was sent to the globular cluster M13 using the Arecibo Telescope and the 2D image it represents (See Figure 1). The speaker explains that the radio pulses can be recorded using binary bits ("1" when there is a signal and "0" when there is not). Pose a question to the audience: how did we send the 2D image using 1D radio pulses?

3. The speaker uses an example to show how a 2D image is constructed using binary bits, by choosing prime numbers as the dimension of the 2D image, (e.g., 5x7=35, so that there is a unique solution to prime factorization of 35). Then, participants design their 2D images on a grid of their choice (e.g., 7x7, 13x5, 11x7). After that, they convert their message to a 2D binary image ("0" for an empty box and "1" otherwise). Lastly, the participants read off the digits in each box (from left to right on each row, and going from the top to the bottom row) to convert their 2D binary image into a linear series of 0's and 1's. (See Figure 2)

4. Ask all participants to send their 1D message in the chat, and to choose someone else's message to decipher by reversing the entire process. Given the virtual setting of this activity, the "pairing" is not strictly one to one. Instead, each participant will randomly choose a message that has been posted in the chat to decode. They will not all work on the same message (at least the message sender will work on a different message from the one they just created). In practice, 5 participants will at least decode 3-4 messages, if not all.

5. Participants share in the group what messages they have sent and received.

AUTHOR

Xinnan Du, Stanford University, Kavli Institute for Particle Astrophysics and Cosmology

TOPIC

Communicating with extraterrestrial intelligence on a distant planet.

SETTING

A virtual science fair "station" where participants engage in online interactive activities.

AUDIENCE

Groups of ~five students (11-15 year olds) who are interested in astronomy and science fiction.

OTSF TACTIC TO USE

Accomplish a Task
Think, Pair, Share

Communicate with Extraterrestrials, cont.

What OTSF Tactic will you use?

1. Asking the audience a **question** to gauge their prior knowledge of the communication methods used in SETI

2. Asking the audience to **accomplish a task** by constructing a 2D message to be sent to the "aliens."

3. **Think, Pair, Share** in a group setting: by sending out their message to the group and deciphering a message from others.

How will you adjust based on the feedback you might receive?

Asking a Question: Leave some time (7-15 seconds) for the participants to think about the question, "how did we send the 2D image using 1D radio pulses?" If they shake their heads or look confused, guide them with "think the 2D image as an 'array' of numbers; is there a way that you can 'unfold' this array, making it a series of numbers but preserving their relative order?"

If the participants are still stuck, remind them with how they write a letter or an email, "think about a letter/email you recently wrote. It is a series of words in a certain order that get broken into multiple lines. When you receive a letter/email, it is an 'array' of words but you have no trouble reading the words one after another. Can you do the same with a series of numbers?" For advanced audience, they might be able to answer "you can scan each row of the 2D image and connect the digits you get from each row." In that case, the speaker can pose a slightly harder question for them to think about (while not expecting any correct answers at this point, since they will all be asking this question naturally during the "deciphering" stage): "here is another question for you to think about: if you receive a message that has 24 bits, how would you know the dimension of the original 2D image; is it 2x12, 3x8, or 4x6? You don't have to answer the question now. Just keep it in your mind while doing the activity."

Accomplish a Task: Closely observe each participant's progress and answer questions as they come up. Encourage those who finish first to start deciphering others' messages, or to double-check their message (especially the number of bits) while waiting for the rest of the group. The speaker could say, "You did a great job sending out your message! While waiting for others, you could try deciphering one or more 'messages' in the chat." If no "messages" are in the chat, the speaker could post a back-up one they created earlier, which should not be the same as the example.

AUTHOR

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OTSF TACTIC TO USE

Accomplish a Task

Think, Pair, Share

Communicate with Extraterrestrials, cont.

Step in to help those who may get stuck with prime factorization or 2D-to-1D conversion by going over the example again. "Have you already converted in your 2D image into an array of '1's and '0's?" Typically, participants have no problem getting to this stage. Then, ask them to write out the binary bits from the first row: "This is the first part of your 1D code. Now, let's write out the second row and put these binary bits right after the first row."

Think, Pair, Share: In the end, encourage everyone to share and interpret the meaning of the message they've received. "Now that everyone has deciphered a message, can you please share what kind of a message or image you received? What do you think the other person is trying to show or communicate?" If time allows, the sender of each "message" can confirm the image they created.

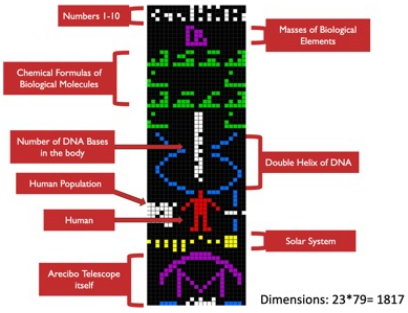
How would this help you reach your desired outcomes?

Through this activity, the speaker will be able to:

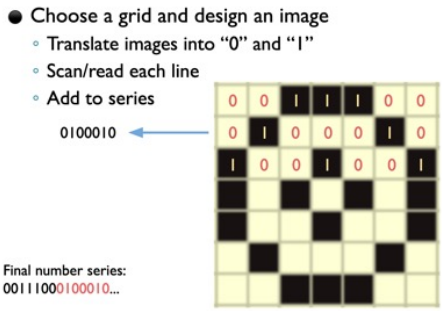
1. Determine the knowledge participants have on SETI and binary bits, and create personalized learning experience based on their levels;

2. Help the participants better understand the connection between 1D and 2D information, by using analogies and discussing the nuts and bolts;

3. Engage participants in critical thinking (e.g., asking questions and finding solutions) and community learning, which mirror authentic research processes.



The 2D image sent out using 1D radio pulses by the Arecibo Telescope in 1974 to a globular cluster, M13.



An example used to guide the participants to create a series of binary bits (i.e., a 1D "message") based on a 2D image of their choice. Participants first convert the 2D image to an array of 0's and 1's, and then read off the digits one by one from left to right on each row, and going from the top to the bottom row to produce a linear 1D sequence of 0's and 1's.

Connecting Plants and Robots

AUTHOR

Travis Tangen, Discovery Connections at University of Wisconsin-Madison, WARF Research Impacts

TOPIC

Robotics, Automation, and Plant Research - Learn about techniques used by UW-Madison Botany Labs that combine robotics, supercomputers, and engineering for their research on plants, crop systems, and growing plants in space. Activities will focus on interdisciplinary applications to study plants

SETTING

An in-person or virtual field trip to a science center or an afterschool activity in a community setting. Small group activities that combine ideas of robotics, automation, and plant research will be part of the experience.

AUDIENCE

Group of 12-25 youth – core ages 9-15 years old (4th – 9th grade)

OTSF TACTIC TO USE

Think, Pair, Share

Accomplish a Task

What are the desired outcomes for the engagement event?

- Participants actively engage in interdisciplinary science activities to see the many roles that are part of plant research.
- Participants understand how the combination of robotics and automation with plant research brings great opportunities in efficiency and scale to understand plants on Earth and outer space.
- Participants experience a positive interaction and develop their STEM Identity through their personal participation in science.

What will the audience do during the engagement event?

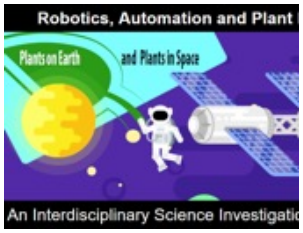
1. Assess their own and peer's existing conceptions of how plants are a part of our everyday lives.

2. Discuss the different factors to consider when designing experiments to understand plant growth on Earth and in outer space.

3. Design and implement a simulated plant research experiment that combines the use of automation and robotics.

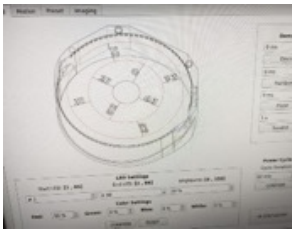
Accomplish a Task

A photo of the "touchomatic" robot in a Botany lab at UW-Madison. The robot moves across the plants in programmed sequences and touch-types. The results are analyzed at the phenotypic and gene response levels. The youth watch a ~40 second "selfie-video" created by a UW-Madison Botany Professor about the 'touchomatic robot' and are encouraged to design and implement their own robot touch experiment as part of the activity.



Think, Pair, Share

The introduction display to the activity that sparks ideas and discussions of interdisciplinary research with connections to Botany in Space.



Accomplish a Task

A screenshot of the graphical interface of the plant growth chambers that youth scientists use to setup experiments that can manipulate light conditions (color, timing, direction) and micro-gravity (rotational frequency, direction, and speed). The youth collaborate and design an experimental protocol to learn about plant growth based on the experiment conditions their team selects.

Connecting Plants and Robots, cont.

AUTHOR

Travis Tangen, Discovery Connections at University of Wisconsin-Madison, WARF Research Impacts

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OTSF TACTIC TO USE

Think, Pair, Share

Accomplish a Task

What OTSF Tactic will you use?

1.Think, Pair, Share: We start the activity by asking the group to first think about the question 'When was the last time you used a plant?' and partner up to share their experiences. After 1-2 minutes of discussion, we select one or two youth members to share their example to the large group. We then provide a few reflective thoughts based on the responses and have the partners think again, pair, and share. Typically, elements around food are some of first responses to the question. We provide a prompt to look out the windows and inside the room to discover how plants are being used "right now". This prompt helps to expand the thinking to plants being used for things like clothing, building materials, flowers, carbon cycle, medicines, etc. After another two minutes of time to share in the partnerships, we ask a few more individuals that we have not heard from to share a part of their conversation. Using think, pair, share at the start of the activity helps to spark ideas of relevance and the abundance of botany applications in our lives.

2. Accomplish a Task: We build the next steps of the activity by a cooperative card game that has three types of cards played in sequence. The first card type focuses around a plant's lifecycle, the next card type is themed around the use of robotics and imaging to identify specific variables to collect data about plant growth, the final card's theme is technology and computer science skills needed to automate plant experiments that use robotics. The card game helps the youth scientists identify the interdisciplinary elements and their roles for potential botany experiments that use robotics, engineering, and computer science. The cards have various 'team tasks' that are completed via discussions, whiteboarding, and multiple-choice. The card game allows different members of the team (typically 2-4 members in a team) to share ideas and have scientific discussions about choices they want to make to follow their curiosity to better understand how plants are impacted by microgravity and light. In addition, the cards help prompt discussions about the engineering and robotics designs the team might create to best capture the change in a plant due to the influence of the selected experimental variables.

After the card game is complete, the youth are challenged to accomplish a task in designing and implementing experiments that study plants using robotics and automation. A UW-Madison Botany Professor who is a science partner with Discovery Connections provides a "selfie video" of an experiment setup in his lab that studies plants using robots and automation. The youth are challenged to design and implement a version of this experiment as part of their field trip or afterschool session.

AUTHOR

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OTSF TACTIC TO USE

Think, Pair, Share

Accomplish a Task

Connecting Plants and Robots, cont.

The youth have an opportunity to setup a light and gravity experiment using the same technology used in the research lab, as well as to develop a touch response robot pathway experiment that tests out a plant's touch response over a period of a plant's life. Youth are encouraged to design an experiment and have three 'challenge' levels to accomplish different degrees of tasks.

How will you adjust based on the feedback you might receive?

1. The responses to the **Think, Pair, Share** provides information regarding how much the youth already know about plants and starts them thinking about learning more through plant research. We also are able to draw out personal connections to science through the ways in which plants are used in the youth's lives. We provide whiteboards and markers and acknowledge ideas as we 'pollinate' the whiteboards during the think/pair/share time. The whiteboards and a thumbs-up voting/polling method help to extend the think/pair/share process when we summarize categories of the individual use cases of plants in the youth's lives. The youth are also encouraged to add a drawing or note on their whiteboards as they hear new ideas from their peers that they can relate to for plant use in their lives.

a. In most cases, the youth focus on the connections of plants and the food they eat. The youth share stories of "whole foods" like carrots, salads, apples, and strawberries and tell a story of the last time they ate or gardened to support a plant's growth. As the discussion occurs, our staff look and listen for new categories outside of food production and consumption. When we find an individual or group that is talking about items like cotton in clothes, or plants in medicine, we ask the entire group to pause and hear an interesting idea and new category of plant use from their fellow youth scientists. The youth with the "new idea" are supported and encouraged to do a brief whole-group share out of the connection to plant uses and provide examples, such as with the clothing items that are derived from plants.

b. Another technique that our staff team uses to spark new ideas of plant-use categories is to encourage the youth to look around their current surroundings and make connections to plants. This might include asking the youth to gently knock on the desk or table surface if it is made of wood. We then encourage youth scientists to continue tracing the connections to building structures and items seen/unseen that are in the immediate surroundings that are derived from plants.

Connecting Plants and Robots, cont.

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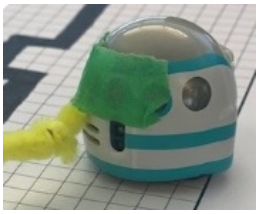
OTSF TACTIC TO USE

Think, Pair, Share

Accomplish a Task

2. The cooperative card game helps our staff to gain insight into what aspects of experiment design the youth have experiences with and pre-conceptions about. As part of the process, our staff members move around the groups and react to the youth's discussions and whiteboard notes/diagrams used during the card game. Our team prompts the youth to provide examples of how they relate to an item from the card game or express to us what might be a new idea. An example of this is a youth member who has participated in gardening and has had different outcomes of success in the harvest of the fruits or vegetables. We might follow up by asking the youth to identify potential differences between gardening successes and failures and narrow in on a variable that might have impacted the differential growth of the fruits or vegetables. We then ask the youth science team to expand on this idea via a discussion regarding how they could design an experiment that might better isolate this "gardening variable" and collect data that might lead to evidence to support or refute this relationship. By getting a sense of what the youth know, we adjust our supports to make sure an appropriate age level understanding of a plant's life cycle is present to setup the next stage of the activity. This assurance helps to better set the context for designing and implementing simulated experiments in the accomplish a task phase of the session.

3. **Accomplish a Task** is the core activity and helps to immerse the youth in scientific practices that are occurring in the plant research labs on campus. The iterative cycles of experiment design and implementation emerges naturally until a point of agreement is reached with the group to do a test run of the design. The ability to reflect and re-design is a key aspect to the session. Even though they may have "Accomplished a Task," the youth group can learn and redesign to accomplish the task with different design aspects that will influence the data collection and research potential of their ideas.



Youth science teams are encouraged to create a plant-touch experiment using small pathfinding robots, a grid to create pathways, code/program movements for the robot using color patterns, and place small synthetic plants on their grid in locations of their choice. The youth have several different design challenges starting with getting one robot plant touch interaction to more advanced design challenges to get two plants touched on opposing sides of the plants in a continuous repeating loop and frequency.

Youth science teams use the plant growth chambers from the UW-Madison Botany labs to setup a timelapse plant growth experiment. Youth teams can program infinite lighting patterns (frequency, intensity, wavelength, location, duration) and setup up parameters of imaging capture to create a timelapse of plant growth under the experimental conditions the group decides on.

Connecting Plants and Robots, cont.

AUTHOR

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AUDIENCE

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OTSF TACTIC TO USE

Think, Pair, Share

Accomplish a Task

How would this help you reach your desired outcomes?

Talking or lecturing about how scientists work in interdisciplinary teams would not have the same impact as youth actively playing the roles of engineers, computer scientists, designers, and botanists in a single experiment. The active process to put the youth in scenarios that mirror what scientists do helps to ensure youth voice and link potential interests in STEM. Involving practicing scientists in displays/videos and using the same equipment and experimental design parameters that scientists use helps the youth to validate the activity and build confidence in their STEM Identity. “Accomplish a Task” is a key strategy that allows the youth to participate as scientists in the design of the experiments. The tasks were developed in consultation with the practicing scientists.

“Think, Pair, Share” helps students to get a sense of the many individual motivations for scientific inquiry, as well as to express their potential connections to plants in their life. These key OTSF strategies help to create a STEM learning activity that is guided by youth voice and youth choice. The result is that the youth science teams see they are participating in the activity as scientists do in their professional work. The youth see themselves as scientists and/or more connected to the practices of scientists.

Photo of University of British Columbia Brock Commons. Photo by: KK Law, Courtesy: Naturally Wood.

Wood for Sustainable Construction

AUTHOR

Pipiet Larasatie, University of Arkansas at Monticello; College of Forestry, Agriculture, and Natural Resources; Arkansas Center for Forest Business

TOPIC

Considering wood as a sustainable, green material for tall building construction

SETTING

A recorded, hybrid class lecture (online via Zoom and in-person at a university classroom)

AUDIENCE

100+ Civil and Construction Engineering students, both undergraduate and graduate. Participants already have a basic knowledge of using wood as a construction material (confirmed with the course instructor).

OTSF TACTIC TO USE

Polling

Think, Pair, Share

What are the desired outcomes for the engagement event?

- In short term, participants understand why wood is considered a sustainable building material
- In long term, participants have increased interest in utilizing wood for their construction projects, including for tall buildings.

What will the audience do during the engagement event?

1. Begin with images of multi storey wooden buildings in the university area (they are actually located across the campus). Ask: “Have you been inside?”

2. For those who answered yes, ask “What do you feel when you are inside?” For those who answered not yet, ask “What do you think you would feel when you are inside?”

3. Continue with different type of tall wood buildings (e.g., student dorm)

4. Connect the audience's perception with existing scientific literature on public perception of tall wood buildings/construction (e.g., Larasatie et al. 2018)

5. Address the rhetorical sustainability debate about wood vs concrete vs steel construction, including in tall buildings

6. Discuss life cycle analysis of using wood in construction with real tall building examples

What OTSF Tactic will you use?

1. **First tactic —Think, Pair, Share**: starting with a screen-sharing images of different tall wood modern buildings (college buildings, classroom, student dorm, etc.). Ask the audience about their feelings if they are inside at each building (e.g., studying at the classroom, living at the student dorm). Give a couple minutes to think and then break people into different groups consisting of two to five people, depending on how many attendees. For audience in Zoom, open breakout rooms. Give five minutes to have a conversation to discuss their feelings. Bring back the groups (offline and in-person) to share out their conversation. Connect with existing scientific literature.

Wood for Sustainable Construction, cont.

AUTHOR

Pipiet Larasatie, University of Arkansas at Monticello; College of Forestry, Agriculture, and Natural Resources; Arkansas Center for Forest Business

TOPIC

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OTSF TACTIC TO USE

Polling

Think, Pair, Share

2. **Second tactic—Polling:** Use mentimeter (Interactive presentation software - Mentimeter) to share the pros and cons of studying/living in tall wood buildings, versus concrete vs steel construction. For example, I will show a picture of a tall wood building in the middle tall non wood buildings, as an introduction.

Ask: "Which building that you prefer to live inside?" Options: (1) Middle, (2) Left/Right, (3) I'm okay with either, (4) Unsure. After the results pop up, ask why they chose the answers by typing the keywords (e.g., fire resistant, beautiful, etc.). Connect with existing scientific literature.

How will you adjust based on the feedback you might receive?

First tactic—Think, Pair, Share: Always give attention to students' responses (ask 1-2 colleagues to help you observe the class, e.g., 1 for the classroom, 1 for zoom) so that I can reword questions and suggest adjustments when needed. By asking questions about students' beliefs/perception, I can get a sense of what they already know vs don't know yet. If they seem already to know a lot, I can go into more details such as carbon storage as a result of life cycle analysis.

Second tactic—Polling: The results provide insights into whether the students are aware and understand the pros and cons of studying/living in tall wood buildings, versus concrete vs steel construction. This can inform what to emphasize before ending the class and giving a final message for the students' future reference. For example, I will encourage them to think of the future that includes cities with wooden skyscrapers.

How would this help you reach your desired outcomes?

Both tactics help me to engage with students during the class. In their reviews, the students wrote that although the idea of using wood in tall buildings is quite new for them (most of them never think about it). They engaged with the topic by considering the tall wood construction examples given during the lecture and doing activities with their peers. The class sparks their interest on the new innovative idea and intrigue them to know more.

Interpreting Water Quality Data

AUTHOR

Beth Norman, Lacawac Sanctuary Field Station and Environmental Education Center

TOPIC

Exploring and interpreting water quality data collected by citizen scientists.

SETTING

A discussion forum with citizen scientists who have collected water quality data from a lake during the summer.

AUDIENCE

10-20 adults, most of whom participated in the volunteer water quality monitoring program during previous months. Most have property or boats on the lake and have already invested time and effort to collect water quality data over the summer.

OTSF TACTIC TO USE

Drawing

What are the desired outcomes for the engagement event?

- Participants will engage with the data that they helped collect.
- Participants will understand the dynamic nature of water quality over time and space within their lake.

What will the audience do during the engagement event?

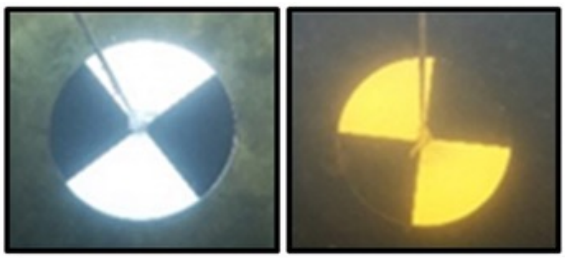
1. Begin with a re-cap of the program, including the number of sites from which data was collected. Thank all those who helped collect data and introduce scientist panel.

2. Begin data exploration by asking participants to think back on their summer of data collection. Ask them to draw a simple graph of Secchi Depth over time at their site. Secchi depth is a way to measure water clarity where a black and while Secchi disk is lowered vertically into the water. The depth at which the disk is no longer visible is the Secchi depth. The deeper the Secchi depth, the clearer the water.

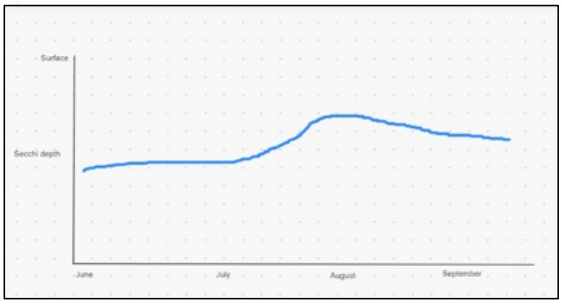
3. Discuss observed changes in key water quality variables over time in the different sections of the lake.

4. Provide long-term context by comparing data collected by the volunteers to previous years.

5. Close with extended Q&A session with panel.



Secchi disk in a clear (left) and murky (right) lake.



Example of a drawing of Secchi depth in Lake Wallenpaupack from June through September by a volunteer water quality monitor using Zoom whiteboards. In this drawing, the lake becomes less clear in mid-July.

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OTSF TACTIC TO USE

Drawing

Interpreting Water Quality Data, cont.

What OTSF Tactic will you use?

Have audience draw a simple graph of Secchi depth over the course of the summer at their site. Start by asking them to remember how the clarity of the lake changed the summer and to "shout out" if the lake generally got more or less clear from June to September. Then give them an example graph with time on the X axis and Secchi depth on the Y axis and ask them to draw the pattern of Secchi depth that they observed – emphasize that they do not need to graph specific numbers, just general patterns. During in-person events, the audience can tape their graphs to poster boards based on their sampling location (e.g., southwest end, midlake, northeast end) and compare patterns within and among boards. During virtual events, ask participants to hold up their drawings or show to camera or use Zoom whiteboards (or similar).

How will you adjust based on the feedback you might receive?

Most people notice and remember how the clarity of their lake changed over the course of the summer. A quick scan of the drawings will show if program participants understand how the Secchi depth they measured is related to their general observations of water clarity (i.e. the more clear the water, the deeper the Secchi depth). If the majority of the drawings show Secchi depth behaving as expected based on observations, then use the drawings to transition to discussion of how the changes in Secchi depth corresponded to variables that affect water clarity, such as the amount of algae or total suspended solids measured from the water samples the volunteers collected. If majority of the drawings suggest there is confusion about how Secchi depth relates to water clarity, remind participants that Secchi depth is directly correlated with clarity. Show photos of a Secchi disk in two lakes with different clarity.

How would this help you reach your desired outcomes?

This activity will help the participants remember their data collection experience and get them thinking about their observations. It will also allow participants to start thinking about their observations in the context of time and changes over time. Finally, this activity will directly engage participants in interpreting Secchi depth as a measure of water clarity – the central variable measured in the program. Once participants understand how water clarity changed over time, they can start thinking about why, leading to correlations with variables that drive clarity, such as algae abundance, temperature, and suspended solids.

Fossil Exploration

AUTHOR

Elizabeth Jones, NC Museum of Natural Sciences and NC State University

TOPIC

Engaging students in learning about paleontology and making fossil discoveries. This is a public science project, Cretaceous Creatures, designed specifically for 8th grade science teachers and students to meet 8th grade science essential standards, plus engage the public in the scientific research process.

SETTING

Classroom with tables or desks and chairs to accommodate teams of three students

AUDIENCE

Approximately 30 8th grade science students or teachers or general public (13+).

OTSF TACTIC TO USE

Questioning
Polling
Accomplish a Task

What are the desired outcomes for the engagement event?

- Students will recognize there are many different people involved in paleontology.
- Students will increase their knowledge of paleontology terminology.
- Students will practice being paleontologists by classifying fossils of ancient organisms.

What will the audience do during the engagement event?

1. Watch a video (eight minutes) about people working in paleontology and how they can contribute to it. Video shows different individuals in paleontology (e.g., collections managers, preparators, technicians, researchers, plus undergraduate and graduate students), and information about how they as middle school students can be involved in paleontology too.

2. Learn about fossil morphology and taphonomy. Show students slides introducing them to the following terminology: 1) morphology (the study of the size, shape, and structure of fossil material to determine their relatedness to other life forms), 2) taphonomy (the process by which organisms decay and fossilize over time). We also discuss terms such as fossils, casts, molds, imprints, microfossils, etc.

3. Practice identifying fossils using 3D printed fossils and an online training module. Each team of three students will have one Fossil Training Sheet, 1 Fossil Training Packet (five different 3D printed fossils), and one laptop with a link to the Fossil Training Module from which they will follow instructions, read prompts, and watch videos as they try to identify each fossil in their packet.

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Polling
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Fossil Exploration, cont.

What OTSF Tactic will you use?

1. **Questioning Tactic**: Ask students to respond to the following questions to assess both their preconceptions of paleontology as a career and their comprehension of video content: a) Did anyone identify with any of the people or the job roles in video? If so, what and why? b) What was surprising about the video? What was something you did not know about paleontology as a career? c) Are you more or less interested in paleontology as a career after watching this video? Why or why not?

2. **Polling Tactic:** Show a series of five slides, each with a picture of a rock or a fossil, and ask students to vote on which they think it is (a rock or a fossil). Ask questions about their votes, and reveal the correct answer following discussion of that slide and before moving on to the next slide/image of a rock or fossil. Repeat the process until finished with the slides.

3. Accomplish a Task Tactic: This is an immersive experience involving critical thinking through a trial and error process using hands-on materials and virtual resources. Once they correctly identify a fossil, they will place it on the worksheet.

How will you adjust based on the feedback you might receive?

1. **Questioning Tactic:** Pay attention to differences or similarities between what students thought about paleontology as a career versus what was revealed in the video. Ask “What do you already know about having a career in paleontology?” and “What was something new you learned about working in paleontology?” Pay attention to whether students felt they could identify more or less with paleontology as a career after watching the video. Ask “Did you ever want to be a paleontologist?” If so, why? If not, why not? You can also ask, “What job in the video would you like to learn more about?” You can adjust your discussion to students’ interests by elaborating on different roles (i.e. fossil preparator or paleoartist) and skills required (i.e. practice by volunteering or pursuing a degree in art).

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Polling

Accomplish a Task

Fossil Exploration, cont.

2. **Polling Tactic:** Some students or overall classrooms may more quickly and correctly identify a fossil from a rock via pictures on the slides. This depends on their previous knowledge of or experience with fossil and geological material. Depending on their answer, the instructor can follow up with any of the following: "What about this object makes you think it is a rock/fossil?"; "What did you look at first to help you make your decision (ex: color, shape, texture, etc.)?"; "Had you seen a similar object that maybe influenced your decision?" Once you reveal the correct answer, you can ask, "What about this object do you think makes it a rock/fossil?" "What might you remember from this example to help you identify fossils in the future?"

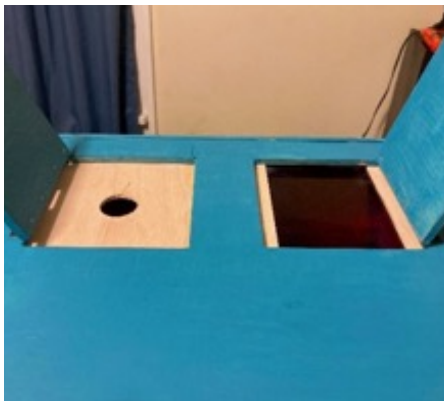
3. **Accomplishing a Task Tactic:** Some students will identify their fossils more quickly than others, and the main goal here is to observe their efforts and remind them that getting the answer wrong (i.e. not correctly identifying the fossil) is part of the process and they are practicing the process for the first time. They are learning by doing, the same as paleontologists do. Specifically, look for "common mistakes" that one or multiple students make repeatedly. This is an indication of a trouble spot where the teaching material can be better explained or more information may need to be provided. A common mistake may be identifying a rock as a tooth. If so, have the students identify another non-fossil object, but this time interact with them by asking the following questions: The first step is to make sure your object is a fossil and not a rock or other object. What about this object makes you think it is a fossil? What might make you think it could be something else?

How would this help you reach your desired outcomes?

Each of the three activities has a specific objective and each tactic helps achieve it. Asking questions involves the audience in sharing their preconceptions of paleontology as a career in an effort to get them to engage with the video content, which is designed to help them recognize that paleontology is more than digging up fossils. Rather, it involves many different people in different roles and they can contribute to it.

Polling the audience also helps the instructor to quickly assess preconceptions related to paleontology, regarding their ideas of what a fossil is and what it is not. This prepares them for the next activity but also helps the instructor identify challenge areas.

Accomplishing a Task directly engages the audience in the process of paleontology by practicing to identify fossils using models of fossils. Getting it "wrong" then "right" through a hands-on activity is part of the discovery experience. This tactic is all about "learning by doing."



Study Arctic Climate Using Satellites

AUTHOR

Daniel Watkins, Brown University, Center for Fluid Mechanics

TOPIC

Using Satellites to understand the Arctic Climate

SETTING

Hands-on Tabletop Demo at Science Museum

AUDIENCE

Museum visitors, mostly k-12, in small groups

OTSF TACTIC TO USE

Accomplish a Task

What are the desired outcomes for the engagement event?

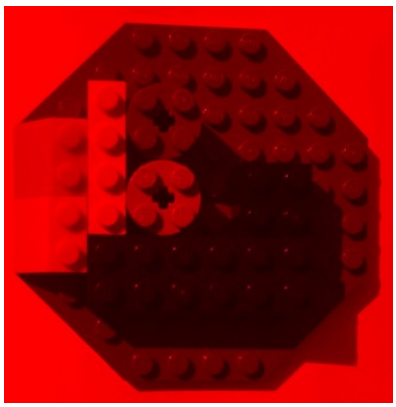
- The event is designed to facilitate conversations between museumgoers and scientists about the Arctic and the difficulty of observing the Arctic climate system. It is also intended to enable attendees to apply problem-solving skills to figure out the solution to a puzzle.

What will the audience do during the engagement event?

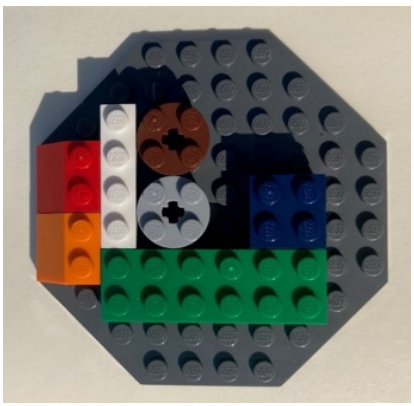
Since the Arctic is so huge and inhospitable, we can't just go measure everything in person. We use satellites to get a picture of the whole Arctic. But each satellite has strengths and weaknesses. Some take detailed photos but can only take pictures when the Sun is out and there's no clouds. Others can see through some clouds and even at night, but make blurrier pictures. By using multiple tools, we can get a better picture than any one tool can do alone.

"Inside this box, I've placed some LEGO pieces on a LEGO base. The arrangement of pieces represents the actual arrangement of sea ice in the ocean.

Your goal is to take the LEGO pieces on the table and place them on the base to match the pieces inside the box. LEGO pieces and base on the table are not shown in photo above. You've got a few options to try and figure out what's inside the box. You can reach inside and feel with your fingers. You can look through the red window—opening on the right. Or you can look through this small porthole—opening on the left."



View of LEGOs and Plate When Looking Through Red Window



Actual Configuration of LEGOs on Plate Inside the Box (color matters)

AUTHOR

Daniel Watkins, Brown University, Center for Fluid Mechanics

TOPIC

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AUDIENCE

Museum visitors, mostly k-12, in small groups

OTSF TACTIC TO USE

Accomplish a Task

Study Arctic Climate Using Satellites cont.

What OTSF Tactic will you use?

Accomplishing a Task

How will you adjust based on the feedback you might receive?

As the person tries the activity, I ask questions like

- What are you finding the most helpful?
- What makes this challenging?

For some kids, the activity is an interesting challenge by itself. Others struggle. If a child is struggling, I point to one of the more recognizable pieces, like a long, bright colored piece, and ask if they can figure out where that one piece goes first. If they have a sibling or friend with them, I point out that scientists usually work as a team, and encourage them to work together.

How would this help you reach your desired outcomes?

I want participants to walk away feeling accomplishment and feeling like they learned something new about the Arctic. Adjusting the activity to the skill level of the participant is important for them to feel accomplished rather than frustrated. Along with that, it is easy for people to concentrate on where they messed up. I make a point of pointing out what they got right. For example, I might say “If you were making a map of sea ice for a ship captain, the captain is not going to care as much about whether the ice is exactly right here or slightly over to the left. They will avoid the areas that have too much ice for their ship to move safely, and your map would help them do that.”

Gravity: Curvature of space-time

AUTHOR

Anna Payne, University of Hawaii, Institute for Astronomy

TOPIC

How objects of different masses affect curvature of space-time to demonstrate gravity.

SETTING

A daylong public outreach event in a mall with different tables that the general public can visit and interact with at their own pace.

AUDIENCE

Hundreds of people from the general public during the daylong event who visited this table and interacted with the model for ~5 minutes per visit. Participants had a range of astronomy knowledge.

OTSF TACTIC TO USE

Modeling

Questioning

What are the desired outcomes for the engagement event?

- Visitors will understand gravity, black holes, and the curvature of space-time, plus how different mass objects (stars, black holes) affect space-time differently, and how small objects approach the black hole in a spiral motion.

What will the audience do during the engagement event?

At this table, there are balls that weigh differently next to a square piece of stretch fabric attached to a frame, an example of which is shown below. The audience places the different balls on top of the stretch fabric sheet to demonstrate and visualize the way gravity works and how different size black holes warp space. There are also smaller beads that audience members can place on different “orbits” to show what the spiral-like motion looks like for objects as they approach the black hole.

What OTSF Tactic will you use?

The concept of gravity and space-time is complex and difficult to visualize for the public. Using this model was effective to teach about this concepts because the visitors directly interacted with the model. I started out each interaction with "what do you know about gravity? what do you visualize when thinking gravity in space?" In several cases, this was the first time visitors were able to visualize gravity and space-time curvature. Everyone knew what placing a heavy object would do to the sheet, but many were surprised about the motions of the marbles around the model black hole. Similarly, this model helped to convey how many knew that there is a "point of no return" where objects are no longer able to escape a black hole. This served as a great introduction to orbits as well because visitors could roll the marbles on the sheet themselves to see what happens, such as making the marble move on longer or shorter orbits before falling in. In addition, this model was important to help visitors understand why planets orbit the Sun.

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OTSF TACTIC TO USE

Modeling

Questioning

Gravity: Curvature of space-time, cont.

How will you adjust based on the feedback you might receive?

I adjusted the level to talk about black holes based on the level of understanding of the visitors. Before placing anything on the sheet, I asked visitors what they knew about black holes/gravity and how it connects to this model. As they tried different weighted balls and different orbits, I connected what they were seeing to how gas and dust gets "eaten" by the black hole in an object called active galactic nuclei (AGN) at the centers of galaxies outside our Milky Way. Some had a hard time initially thinking about black holes in terms of this model, so I more quickly switched to connecting it to the Sun and the orbit of the planets and focused on that instead.

How would this help you reach your desired outcomes?

Everyone knew about gravity, but for the majority of visitors this was a new way to visualize it. This activity effectively connected prior knowledge of gravity to viewing it in a new way and to demonstrating a fundamental aspect of distant black holes that are hard to conceptualize for many.

Example of the model used for this demonstration at the outreach event. Image credit: NASA/JPL-Caltech

The two high school students in the program.

How to Study Black Holes

AUTHOR

Anna Payne, University of Hawaii, Institute for Astronomy

TOPIC

How we study black holes "eating" surrounding material at the center of galaxies outside our own Milky Way, called active galactic nuclei (AGN).

SETTING

An outreach program for high school and middle school students to introduce them to as-tronomy research.

AUDIENCE

Two high school students and one middle school student who are interested in astronomy.

OTSF TACTIC TO USE

Questioning

What are the desired outcomes for the engagement event?

Participants will understand

- what AGN are
- why they are important
- how we study them and with what type of data, and what the data reveal about them.

What will the audience do during the engagement event?

This was a small group of students interested in astronomy but they did not know anything about black holes or AGN. We started off as a small discussion group talking about the things they think of when they hear the words “galaxies, black holes, AGN, and light curves.” After lay-ing a foundation of background understanding, the students worked on a research project to track changes in the amount of energy output by an AGN over a period of time.

What OTSF Tactic will you use?

My goal using this tactic was to start with the big picture and steadily zoom in progressively to more detailed aspects about black holes and why they are important to study. Because I had not worked with these students before and we were about to spend a week working on a re-search project together, I started out asking them “What do you think about when you hear “as-tronomy?” to establish a foundation from which to work. I then asked, “What do you think about when you hear “galaxies” … or “black holes”.. or “AGN” … or “light curves?” in succes-sive order. Because we started out the event as a small discussion group where they could brainstorm what they thought about these concepts and about astronomy in general.

This allowed me to discover what they knew about these topics. They also discovered that they knew more about black holes than they realized, since they saw the recent pictures of the su-permassive black holes at the centers of the galaxy called M87 and the black hole at the center of the Milky Way (see image below) from the Event Horizon Telescope. The discussion also jogged their memory of the black hole scene from Interstellar. So they were able to connect what they had seen in the past to astronomy research and the project they were about to em-bark on for the rest of the week.

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OTSF TACTIC TO USE

Questioning

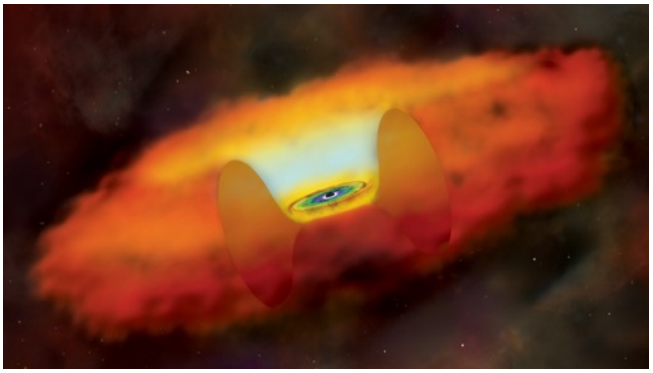
How to Study Black Holes, cont.

How will you adjust based on the feedback you might receive?

This tactic was very effective to use at the beginning of the event. I was able to quickly adjust the way to introduce topics, and the level of depth for background details. For example, I revis-ited the concept of accretion disks to reinforce the concept of light curves and what the physics reveals to us. In a conversational manner, asking them what they already knew was a good approach to work towards laying the foundation for the later work in the program. I learned that it was clearer to them to explain concepts in a visual manner, by using diagrams and illustrations of AGN like the one near the beginning of this example. There was initial confusion about the different components of an AGN, but I was more effectively able to clear up their confusion when connecting it back to the scene in *Interstellar* that all of them had seen before. Specifically, the scene from *Interstellar* helped them picture the concept of how the black hole "eats" surrounding gas and dust in a disk-like structure, and the massive size of supermassive black holes.

How would this help you reach your desired outcomes?

The back and forth conversation made it less intimidating for them to explore their understand-ing and it made them excited about connecting what they previously saw to astronomy re-search. By the end of our conversation, they seemed less intimidated and more excited about astronomy and the week ahead. I learned they are all more visual learners and I was able to use more explanations that used pictures and diagrams than I otherwise would have done.



Artist's illustration of an active galactic nuclei (AGN), the focus of the student en-gagement event. At the centers of galaxies outside of the Milky Way, the supermassive black hole, black object at center, eats the surrounding gas and dust in the accretion disk, and fur-ther away there are clouds of dense dusty material shown in orange.

Chandra X-ray Center

How Genes Control Bacteria

AUTHOR

Rachel Johnson, UNC, Chapel Hill, Department of Chemistry

TOPIC

Evolution of Bacteria

SETTING

A ~45 min to one-hour long, hands-on learning opportunity. Applicable for virtual or in person. Originally completed at "Science in the Stacks", a monthly outreach event at the Chapel Hill Public Library (North Carolina). Suggestion for virtual event: Have parents pick up materials in advance (if possible) or inform the group in advance to have a collection of various dry beans and pasta. Send an image of your collection as an example.

AUDIENCE

Young, elementary-aged children (5 to 11 years old) students on field trips. Groups of about 10-15 students at a time will visit the station at regular intervals.

OTSF TACTIC TO USE

Questioning

Accomplishing a Task

What are the desired outcomes for the engagement event?

Overall, children will practice their observational skills and be excited about science. Specifically, children will learn that...

- Bacteria are microscopic living things (organisms).
- The way bacteria look (phenotype) is controlled by their genes (genetic information).
- Bacteria that look the same often have similar genes.
- Bacteria have different genes because they have changed over time (evolved) to live in different habitats (in our guts, on our skin, in the soil, in the depths of the ocean, in thermal vents, etc.).

What will the audience do during the engagement event?

Throughout the event, students are encouraged to participate by answering questions and will complete several activities that require good observation skills.

Asking questions throughout the event keeps the children excited, engaged, and allows the host of the event to gauge students' understanding in real time to address any misconceptions. The questions asked continuously build on each other. Use a PowerPoint to share images, questions, and new definitions as the lesson progresses. Important questions to ask and the progression of information for each learning outcome are as follows.

Learning outcome 1

Ask, "What is an organism?" and "What are examples of organisms?"

Explain bacteria are single celled microscopic organisms.

Ask students, "What does microscopic mean?" and "How can we see things that are microscopic?"

If in person you could bring a microscope to show the participants.

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OTSF TACTIC TO USE

Questioning

Accomplishing a Task

How Genes Control Bacteria, cont.

Learning outcome 2

Explain the word phenotype means how an organism looks.

To gauge their understanding, use a picture of a Golden Labrador dog and ask, "What are the phenotypes of this dog?"

Pull up a photo of another dog (ex. a Golden Doodle) and ask, "What phenotypes do these dogs have in common?"

Discuss they are different breeds and that explains their differences in appearance.

Activity time:

Provide students with a collection of dry beans and pasta (see image above).

"Imagine each type of pasta or bean are different types of microscopic bacteria!"

Students will write down the phenotypes of each "bacteria" in their personal observation table, provided below (this can be done as a group, in partnership, or individually). Have students share their observations while holding up the "bacteria" they are describing.

BACTERIA #	MATERIAL (PASTA OR BEAN)	COLOR	SHAPE	OTHER OBSERVATIONS
1				

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OTSF TACTIC TO USE

Questioning

Accomplishing a Task

How Genes Control Bacteria, cont.

After discussion of the "bacteria" phenotypes, explain that bacteria from different species look different. This is similar to different breeds of dogs. There are ~30,000 different bacterial species.

Learning outcome 3

Ask, "What causes bacteria to look different?"

Answer: Genes! Genetic material called DNA determines the appearance of an organism.

Ask the kids to look at the collection of pasta and beans. "What bacteria in your collection do you think have similar genes?" Discuss answers together, making sure to probe and ask why they think these certain "bacteria" have similar genes.

Learning outcome 4

Use dogs as an example again to explain how all dogs were once wolves. Over time, they have changed and become more diverse. The process of a species changing over time is evolution!

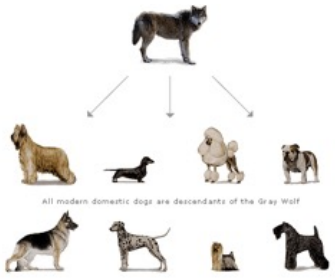
Explain that like dogs, bacteria have evolved overtime to survive in different habitats.

They live in the soil, in our guts, on our skin, in water... almost everywhere!!

Bacteria are able to survive in these different habitats because of their genes.

Examples

- Bacteria in the hot springs at Yellowstone national park can survive in very hot environments (400 – 800 °F)
- Bacteria that live on the angler fish can GLOW (aka luminesce)! A specific gene helps them do this.
- For an older audience, this discussion can be expanded to include antibiotic resistant genes and selective pressure.



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AUDIENCE

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OTSF TACTIC TO USE

Questioning

Accomplishing a Task

How Genes Control Bacteria, cont.

What OTSF Tactic will you use?

The main tactics used are Questioning and Accomplish a Task (filling out the observation table) This can easily be completed in a think/pair/share format when in person.

How will you adjust based on the feedback you might receive?

Based on students' responses to questions from the different learning outcomes, you can go back and explain or elaborate as needed. For example, if the students do not state that the pasta/beans with similar appearance have similar genes (Learning Outcome 3), you may need to go back to review the vocabulary from Learning Outcomes 2 and remind them how genes control phenotypes (i.e. appearance) and/or redefine phenotype. In my experience, the activity gave me confidence that the kids understood the lesson. Children used descriptive adjectives to describe the "bacteria" phenotypes and understood that the beans and/or pasta that looked most similar had the most similar genes (learning outcomes 2 and 3).

In my experience, no answers provided by participants during the questioning or during the task portion of the lesson required clarification for the students to reach the learning outcomes. The questions were broken down with examples and context so that the audience was able to easily follow and understand the scientific concepts.

How would this help you to reach desired outcomes?

Using the answers provided by the audience from questioning and accomplishing a task, it is easy to determine if the children understand and recall the new science vocabulary and if they understand the concepts of genes and phenotypes.

Bird Banding

AUTHOR

Sirena Lao, San Francisco Bay Bird Observatory

TOPIC

How and why scientists study birds by banding them

SETTING

Virtual meeting using Zoom (but this can also be done as an in-person program)

AUDIENCE

Children ages 5-12 and their families who have chosen to sign up for the event through their local library

OTSF TACTIC TO USE

Accomplishing a Task

What are the desired outcomes for the engagement event?

- Increase the audience's appreciation for and knowledge about birds and why they're important
- Help the audience understand how scientists study birds by banding them
- Help the audience understand what information we can learn from bird banding and how this information is relevant to conserving birds

What will the audience do during the engagement event?

The audience will first listen to a brief presentation on why birds are important and what bird banding is (the process of placing a uniquely numbered aluminum band on a bird's leg).

The presenter then demonstrates the bird banding process using banding tools on a felt bird, and the audience will participate in an activity to model the process of bird banding (see process described below).

What OTSF Tactic will you use?

The audience will accomplish the task of "banding" themselves or a family member using a pipe cleaner and beads tied around their wrist or ankle, ensuring that the color combination of beads is different from anyone else in their household. Families often already have these supplies at home and are asked to have them available when they sign up for the event, but we also suggest alternatives in case they do not, such as rubber bands or strings/ ribbons of different colors. We have also found that sometimes libraries are able to provide supplies for families to pick up.

Participants are asked to enter their "band number" (their unique combination of bead colors using the first letter of each color) in the chat as well as share some features they can record about their "bird" that can be measured or observed, such as eye color, hair color, and height. They are encouraged to enter this in the chat as a way to model the process of recording data.

Band Number = GRBY
((Green, Red, Black, Yellow)

AUTHOR

Sirena Lao, San Francisco Bay Bird Observatory

TOPIC

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SETTING

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AUDIENCE

Children ages 5-12 and their families who have chosen to sign up for the event through their local library

OTSF TACTIC TO USE

Accomplishing a Task

Bird Banding, cont.

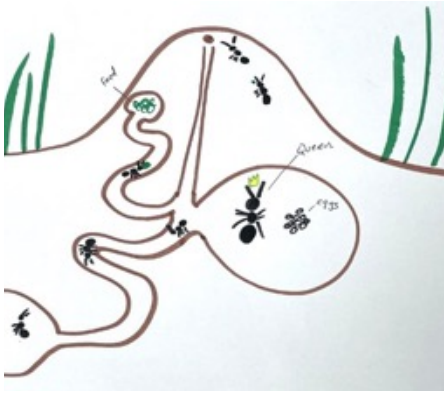
How will you adjust based on the feedback you might receive?

The presenter pays attention to the chat for band numbers entered and to any participant videos where audience members may be showing off their bands. If needed, the presenter can remind the audience why their band combinations should be unique. When the audience shares ideas for features that can be recorded, the presenter gets a sense of whether participants are understanding the process of data collection and what individual features may change over time that are measurable or observable. Based on audience feedback, the presenter can take a variety of approaches, such as:

- Giving examples of things bird banders record and asking the audience what might be a similar observation for humans;
- Asking how a certain measurement or feature might change if we recaptured ourselves in 5/10/50 years;
- Incorporating a migration analogy, such as going to and from school as an example of a regular "migration" that students make, and what differences a "bander" might notice depending on the location, such as wearing different clothes depending on the weather (analogous to some birds having different breeding vs wintering plumage).

How would this help you reach your desired outcomes?

By having the audience successfully complete the banding activity, share data, and give ideas about what measurements can be taken, the audience demonstrates an understanding of the bird banding process as a way for scientists to study birds (and especially migratory birds which are in decline). We hope that by understanding this process, the audience learns to appreciate the importance of scientific data collection and how the information we collect can be used to not only better understand the birds we study, but also inform how we can better protect birds so they can continue to play their important roles in the ecosystem and so people can continue to enjoy them.



Ant Characteristics

AUTHOR

Haley Depner, University of South Florida, Department of Integrative Biology

TOPIC

Ants; how ants cooperate, ant ecology, ant biology.

SETTING

A Zoom meeting with girls from multiple Girl Scout troops.

AUDIENCE

A group of 5-20 science and nature interested girls ages 7-17. Participants likely learned about insects in school.

OTSF TACTIC TO USE

Questioning
Drawing
Polling

What are the desired outcomes for the engagement event?

- For audience members to increase their appreciation and understanding of ants in the ecosystem and ant species diversity.

What will the audience do during the engagement event?

1. Begin with the question: what is an insect? Have the audience reflect in silence. Ask the audience to draw what they think an insect is. After a few minutes, ask the audience to hold up their drawings for all to see. Point out common characters of insects observed in the drawings.

2. Use polling and questions by showing slide of assorted insects. Ask “which are insects?” Have audience point out insects in the photos. Ask, how do they know it is an insect?

3. Show assortment of photos including ants, bees, wasps, and a fly. Have audience use poling tactic to vote on which are ants. Review characteristics of ants. Have audience vote on photos again to see if accuracy has improved.

4. Introduce caste system in ants. Again, a question and drawing are used to find out what the audience thinks is happening underground in an ant hill. Ask audience to reflect in silence about the question before they begin drawing. After a few minutes, have audience members share details of drawings. Elaborate on what goes on in different parts of the anthill.

5. Discuss ant species diversity and the roles of ants in the environment. Ask audience for examples of how ants interact with their ecosystem before sharing details.

6. Conclude with examples of simple experiments children can do at home to learn more about the ants where they live.

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OTSF TACTIC TO USE

Questioning

Drawing

Polling

Ant Characteristics, cont.

What OTSF Tactic will you use?

Questions and Drawings will be used throughout the lecture to assess prior understanding of topics introduced. At the start, see if everyone knows what an insect is. Look for three body segments and six legs in the drawings. Later on, audience draws what they think is going on underground in an anthill. Look for tunnels, chambers, and whether or not the chambers have designated functions and what those functions might be. Polling and questions will be used throughout to assess prior knowledge of topics as they are introduced.

How will you adjust based on the feedback you might receive?

For the question "what is an insect?": Possible responses include drawings of common insects like butterflies, caterpillars, lady bugs, and ants; or other small creatures that are not insects such as earthworms or spiders. Point out characters in drawings that are common to insects, including three body segments, six legs, four wings, and a pair of antennae. Point out how other animals may be mistaken for insects and what makes these creatures unique from insects.

For the question "what goes on in an anthill?": Possible responses include depictions of a single giant chamber existing under the anthill, a series of tunnels or a series of tunnels and chambers. Chambers may or may not have a clear function. Use this to gauge how detailed of a description of ant architecture is necessary. Reference examples given in drawings while discussing division of labor. For example, if a drawing depicted a chamber full of ant eggs with ants caring for the eggs, I might say "as some of you illustrated in your drawings, there are specialized chambers where immature ants live and grow..."

Polling and questioning at the start of a new topic allows me to assess what they already know. If they do well, I can go into more depth on specific details or quickly move on to the next topic in the lecture.

How would this help you reach your desired outcomes?

By embedding multiple drawing activities throughout the virtual lecture, the presenter is (1) assessing the audience's prior understanding of topics before providing explanations (2) engaging a virtual audience using a hands-on activity and (3) build rapport by giving audience members a chance to share what they created. The polling activity allows me to know how well my audience knows topics as I go, so that I can adjust to the level of detail needed.

Biomechanics of Flight

AUTHOR

Ivan Heerdegen, Florida Atlantic University, Florida Atlantic Biomechanics Lab

TOPIC

Understanding the Biomechanics of Flight Using Comparative Analysis of Pterosaurs, Bats, and Birds.

SETTING

Guest presentation in a classroom setting lasting 45 minutes.

AUDIENCE

About 25 high school students per session. Students are taking biology at the university's high school. They are advanced placement students who would have a higher level of understanding of biological and physical properties.

OTSF TACTIC TO USE

Modeling

What are the desired outcomes for the engagement event?

- Learn at least three different terms used in biomechanics (such as wing loading, lift, and morphology).
- Be engaged throughout the presentation and feel free to ask questions.
- 3Have fun by learning the concepts through interesting organisms and applying knowledge during an activity.

What will the audience do during the engagement event?

1. Introduce the topic of flight biomechanics in an unexpected way by using the topic of dragons.

2. Gauge pre-knowledge by having the students build their own dragon in small groups.

3. The goal is to assemble a dragon that could most likely fly based on biomechanical properties that they have yet to learn in the presentation.

4. Students receive a set of different body sizes, wing shapes, and tail shapes and select the parts that they think would make a functional flying dragon.

5. Classroom re-groups and shares what they chose.

6. Describe how evaluating features of pterosaurs (prehistoric flying reptiles), bats, and birds can allow us to theorize how dragons could possibly fly.

7. Use real data tables from research papers to show relationships between variables, call on students to explain the graphs.

8. Explain wing loading; have students calculate wing loading based on dragons from popular media (such as using the weight of dragons from the movie, "How to Train Your Dragon").

9. Describe lift; show videos of animals with different strategies for producing lift.

10. Describe morphology; show anatomical structures of pterosaurs, bats, and birds to compare impact on flight mechanics.

11. Have students regroup to re-design their dragons, now applying the key properties learned in the session. Have them share their new dragons.

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OTSF TACTIC TO USE

Modeling

Biomechanics of flight, cont.

What OTSF Tactic will you use?

The major tactic will be constructing a model. Students will choose from an assortment of parts to assemble the most "physically possible" flying dragon in the beginning, which will assess prior knowledge. At the end, re-creating their dragon will show if any preconceptions changed or if they learned new information because of what they experienced in the session. Other tactics used throughout include questioning (having students explain their answers or interpret data given), kinesthetic activities (students can use their arms as wings to demonstrate if they understood how a wing beat changes based on the flight properties), and audience polling/think-pair-share (serves as checkpoints throughout the presentation to see if they are ready to move forward).

How will you adjust based on the feedback you might receive?

If the students explain their dragon models in the beginning very accurately, I can see if they can apply what they currently know to the real organisms I show before I explain them. If the students appear to be guessing on their dragons, then I will take more time to compare the properties. If students aren't engaging when I ask questions to the whole group, I may switch from asking questions of the whole room to using a think-pair-share style so that they can work through it with their partner.

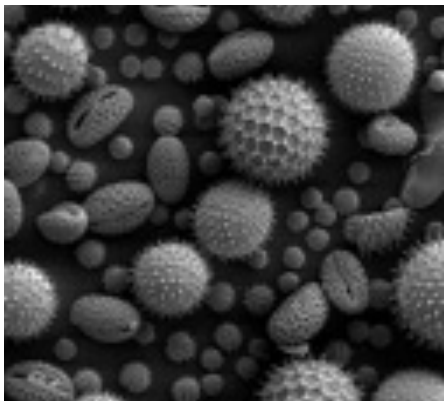
How would this help you reach your desired outcomes?

By using this dragon theme to explain flight biomechanics, the audience will:

(1) have a more memorable experience tied to the vocabulary words, which may aid in retention;

(2) have opportunities to create models, see videos, discuss with others, and answer audience polls so that the presentation isn't just a lecture straight through; and

(3) have a light-hearted and fun activity that adds an element of popular culture and creativity to the scientific concepts.



Nanoscience

AUTHOR

Corban Murphey, University of North Carolina at Chapel Hill Department of Chemistry

TOPIC

Nanoscience in the lab and the real world

SETTING

A day-long virtual visit to a middle school science classroom

AUDIENCE

5th-8th grade science students in North Carolina

OTSF TACTIC TO USE

Questioning

Polling

What are the desired outcomes for the engagement event?

- To understand the size of nanomaterials
- To realize nanomaterials are in many of the products we use every day
- To consider what everyday materials might look like on the nanoscale, and how different they might be

What will the audience do during the engagement event?

The audience will learn what "nano" means and see examples of nanomaterials in consumer products and the laboratory. They will also consider what other applications nanomaterials might be useful for. Lastly, they will play a game trying to match electron microscopy images to their zoomed-out counterparts.

What OTSF Tactic will you use?

1) Questioning 1—At the very beginning of the presentation, the scientist will gauge the audience's background by asking, "What do you know about nanoscience or nanotechnology?" Do they think it's science-fiction? Do they have any examples of real-life nanoscience before we start?

2) Questioning 2—After learning about the size scale of nanomaterials and the places one might find them, the scientist will begin a game of "What are we looking at?" Scanning electron microscopy (SEM) images of everyday, common objects will be displayed on the screen along with a simple question: what are we looking at? Depending on the audience, the presenter may wish to begin with a hint for what the answer is. For instance, with the flower pollen image in Figure 1, the presenter may start by saying "This can make you itchy." As participants offer their guesses, the presenter will help to steer them towards the correct answer, e.g. using "hot and cold" phrasing or saying things like "you're on the right track." If they guess right or hit a dead end, the presenter will reveal the zoomed-out version of the image, and move to the next one. This activity will encourage the participants to adjust and think outside the box because the images are so different from what they're used to seeing with the naked eye.

TOPIC

Corban Murphey, University of North Carolina at Chapel Hill Department of Chemistry

SETTING

A demonstration station at a large science museum's "Nano Days" festival.

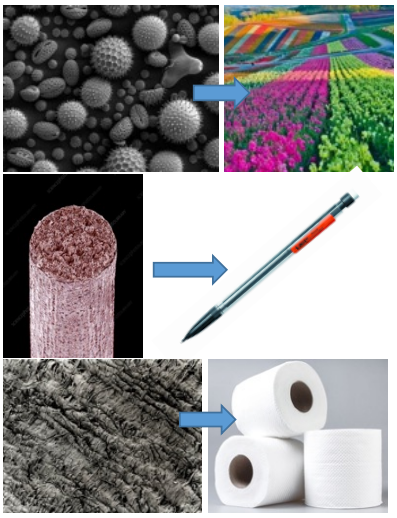
AUDIENCE

Urban middle school students on field trips. Groups of about 10-15 students at a time will visit the station at regular intervals.

OTSF TACTIC TO USE

Questioning

Polling



Some of the electron microscopy images the audience will be shown. The top left image is of flower pollen, middle-left is of pencil lead, and the and the bottom left is of toilet paper.

Nanoscience, cont.

How will you adjust based on the feedback you might receive?

1) After Questioning 1, if it is clear that the audience is familiar with the idea of nanoscience, the presenter can spend less time convincing the audience of its real-world legitimacy, and more time discussing the various applications of nanomaterials. If the audience is completely unfamiliar with the idea of "nano" itself, the presenter can more clearly emphasize the size scale nanomaterials exist in, and the variety of places you can find them in everyday products.

2) During Polling/Questioning 2, the presenter can hear the guesses come through and guide towards the right answer. They can also remind the audience of what they learned in the presentation-- things on the nanoscale often look very different than what we might think. For example, a guess for the pollen image in Figure 1 might be golf balls. The presenter might respond that though it may look that way, these are much smaller than a ball. Another audience member might guess burrs from a plant, to which the presenter may respond "Very close- these do come from plants, but think smaller!" Some of the guesses from the audience will be closer than others, but the presenter can encourage everyone by finding a way to guide them towards the right answer.

How would this help you reach your desired outcomes?

With Questioning (1), the presenter learns where the audience's collective mind is at regarding nanoscience. It is often viewed as a sci-fi, out-of-this-world area of research, and the Questioning (1) tactic gives the chance to debunk that viewpoint (if present) by both soliciting and showing real-world examples of nanomaterials all around them. The Polling/Questioning 2 tactic lets the presenter get an idea if the audience has entered the mindset of thinking small. If the guesses for the SEM images are off base, then the presenter can readjust and help to guide the audience towards the correct answer. Both of these feedback tactics will aid in the goals of the activity: to understand the size and widespread use of nanomaterials, and to consider how different everyday materials might look on the nanoscale.

Volcanoes in the Media

AUTHOR

Arianna Soldati, North Carolina State University, Marine, Earth, and Atmospheric Science Department

TOPIC

Volcano representation in the media.

SETTING

A public lecture taking place at a science museum café.

AUDIENCE

100+ science-interested adults with a range of volcano-related knowledge.

OTSF TACTIC TO USE

Questioning

Think, Pair, Share

What are the desired outcomes for the engagement event?

- Participants will improve their ability to discern fact from fiction in media depiction of volcanoes.
- Participants will learn some basic volcanology knowledge (e.g. how hot is lava, how different are explosive and effusive eruptions).

What will the audience do during the engagement event?

1. Participants will recall their personal interactions with volcanoes.

2. Participants will try their hands at identifying fact vs. myth for a few famous eruption scenes in Hollywood movies.

What OTSF Tactic will you use?

1. Questioning 1: Ask participants to share whether they have ever visited a volcano and/or an erupting volcano right at the beginning of the talk, and give them the opportunity to share a short memory.

2. Think, Pair, Share: Halfway through the talk, show the audience a frame or short clip from a popular disaster movie featuring volcanoes and ask them to discuss in pairs whether they think it is realistic or not, as well as to justify it based on elements identified in previously shared examples. Have a few people share out what they decided in their groups of two.

3. Questioning 2: Ask participants to share what media outlets they followed regarding recent volcano-related news.

How will you adjust based on the feedback you might receive?

1. Responses to the question will inform the speaker as to what degree of experiential knowledge participants have of volcanoes. If most of the audience has witnessed an eruption first hand, the speaker can focus on more challenging and nuanced examples from movies and news, otherwise they can stick with some basic information. Additionally, this information can help the speaker pair participants for the think, pair, share activity.

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AUDIENCE

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OTSF TACTIC TO USE

Questioning

Think, Pair, Share

Volcanoes in the Media, cont.

2. This activity will provide great feedback on whether the audience is learning from the movie clips shared by the speaker during the talk. Based on the results, more examples can be pulled for a specific type of volcanic activity (e.g. lava fountain; eruptive column) or hazard (e.g. pyroclastic flow; heat from lava flow) temperature and its effects), or the speaker can move on to a different eruption scenario. Understanding the reality of high volcanic temperatures for example appears to be especially challenging in this activity, as all of the examples are visual, whereas temperature is not. Therefore, it is helpful to keep multiple movie clips on hand in the slide deck.

3. The second question will give the speaker an idea of the level of interest and familiarity in the topic, and allow them to adjust recommendations for reputable media outlets that may require little to a lot of active searching of content and different levels of detail provided. The speaker prepares several "Sourcing Volcanic News" handouts in advance:

a. a list of everyday news outlets that publish short coverage of current events

b. a list of news outlets focused on long-form pieces

c.a list of primary sources and instructions on how to search and filter for the desired information.

The speaker shares the news resource(s) that is most appropriate for the audience comfort level based on the audience's response. A more challenging news resource is also offered to give the audience the opportunity to gain more in-depth knowledge of current volcanic events.

How would this help you reach your desired outcomes?

1. By exploring their own connection with the subject, the audience will engage with the material and better retain it.

2. By enabling peer-to-peer learning, the speaker will effectively build on existing group knowledge.

3. By leading the audience into applying what they just learned, the speaker will ensure that they are able to critically evaluate volcano-related news and media.

UNC

Using the Energy in Sound Waves

AUTHOR

Keerthi Anand, UNC Chapel Hill, Joint Dept. Of Biomedical Engineering, with NCSU

TOPIC

How can energy carried by soundwaves be manipulated to levitate and move small objects.

SETTING

A station at a science festival

AUDIENCE

Public with mixed age groups of middle school students to adults

OTSF TACTIC TO USE

Accomplish a Task

Questioning

What are the desired outcomes for the engagement event?

- Reiterate that sound is pressure waves through a medium and, sound at frequencies above our hearing range is called ultrasound.
- Learn what the public knows about the use of (ultra)sound in science, medicine, and technology.
- Allow audience to develop hands-on experiences with innovative acoustic levitation technology, where ultrasound is used to suspend and manipulate objects in mid-air, and learn about examples of real-world applications.

What will the audience do during the engagement event?

1. Based on audience member's prior experiences with sound, listen to a personalized explanation connecting their current knowledge of physics behind sound to acoustic levitation.

2. Observe an instrument that uses sound to levitate polystyrene particles and move the particles in a predetermined path.

3. Attempt to levitate multiple particles in acoustic fields using several smaller devices.

4. Use ultrasound to control a particle through an aerial obstacle course.

What OTSF Tactic will you use?

1. The audience will first be **questioned** on whether sound can travel in a vacuum like space. They will then be asked what is needed for us to be able to hear sound, and why we cannot hear certain sounds like a bat's call (ultrasound) or the devices nearby actively emitting sound waves.

2. After the initial exposure to the concepts behind acoustic levitation, audience will be asked to **accomplish the task** of inserting different sizes of polystyrene beads into an acoustic pressure field.

3. Visitors will attempt to insert the particles using their hands or tools provided, such as tweezers or a wire mesh. They will then be asked to determine what is the smallest and largest size of particle that can be successfully levitated. This opens avenues to various lines of **questioning** as they fail or succeed at the initial and subsequent tasks.

4. They will then **accomplish the task** of navigating the particle though the maze.

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SETTING

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AUDIENCE

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OTSF TACTIC TO USE

Accomplish a Task

Questioning

Using the Energy in Sound Waves, cont.

How will you adjust based on the feedback you might receive?

When the audience first sees an acoustic levitator and are asked how they think it works, they might respond with “fans” or “magnets”. After reiterating that the devices are using sound, the scientist could draw a parallel to how you can feel the vibrations when you stand next to boom boxes at concerts or when a loud car that’s blasting music drives by. That same energy can be controlled to generate a force at a specific location to keep an object from falling.

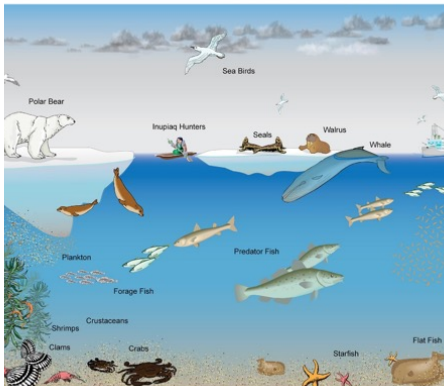
The audience might have had a sonogram or witnessed a family member get one. The topic can elicit discussion of how ultrasound can be used in medicine to create images, and compare/contrast ways it is similar or different from acoustic levitation.

Young children tend to use their fingers to pick up and insert the beads, and sometimes they are able to get the particle levitating because the small fingers don’t overly disturb the acoustic field. If an adult is present, the scientist may ask the adult to also attempt it with their fingers (and most likely fail), which can lead the conversation to how sound is reflected off objects with different densities. Reattempting this task with tweezers (which do not disturb the sound field) or a mesh (which allows sound to pass through) can teach the audience about how sound waves behave around different objects.

How would this help you reach your desired outcomes?

1. **Questioning** will help determine the audience member’s prior knowledge of sound and determine additional discussions to help them understand acoustic levitation. Scientists can link the principles behind the acoustic levitator to uses in pharmaceuticals, manufacturing, and non-contact experiments. Because sound exist as a spectrum, scientist can relate use of sound in different fields.

2. **Accomplishing a task** will allow members to make meaningful memories and generate genuine interest in science with sound.



NOAA NCDC

Marine Food Web

AUTHOR

Emily Nocito, University of Colorado Boulder, Environmental Studies

TOPIC

Marine Food Web (can go generic or specific e.g. Antarctic, Artic, coral reef)

SETTING

STEM Camp, 10-15 students. Time required is around 45 minutes

AUDIENCE

Elementary aged students between 3rd and 5th grade

OTSF TACTIC TO USE

Kinesthetic Activity
Drawing

What are the desired outcomes for the engagement event?

Students should be able to define some basic food web words (producers, herbivores, carnivores) and their placement within a food web (Drawing tactic) and understand what happens when different species are taken out of the food web (Kinesthetic tactic)

What will the audience do during the engagement event?

Students are given a word/picture bank of different marine species (kelp, plankton, fish, seal, penguin, shark, killer whale), colored pencils and a blank piece of paper. First, explain what each species is (fish, algae, marine mammal, etc.) to orient the students. Ask students to look at the bank of pictures and words and draw how they think the food web looks for that marine environment, defining food web (the way scientists show what-eats-what in an environment). Give students 10 minutes to draw out their food webs and ask if anyone wants to share their food web out loud. Then, drawing on a white board, map out the food web from bottom to top. This is when you will write out and define the words PRODUCERS, HERBIVORES, CARNIVORES and ask students to copy down onto their own sheets. Pose the following question to students while at the white board:

- Where would they put themselves in the food web?
- Where would they put the Sun in the food web?

After drawing, each student gets a card with a species from the food web. Students will get up and kinesthetically arrange themselves to the food web as seen in figure below, with producers on the bottom and going all the way up to carnivore. Ask students to hold hands (or use pieces of yarn or string if there are many students or not enough space) to show the linkages of the food web.

Then, ask one “species” to step away or “collapse” such as one might during the playful song London Bridge. For example, removing the fish would mean the student(s) playing the fish would collapse/fall down/step away, breaking the food web. They would stop holding the hand or yarn. Ask students what the species above them would do for food, eventually leading to other students collapsing as well. Do this for each ‘level’ to show that if (for example) kelp was to disappear it would eventually affect the shark, even though the shark does not eat kelp. You can do this activity in as many rounds as you want. At a minimum, remove at least one species from each level, then ask students to choose who gets removed, with a prediction of what will happen if that species is removed.

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Emily Nocito, University of Colorado Boulder, Environmental Studies

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AUDIENCE

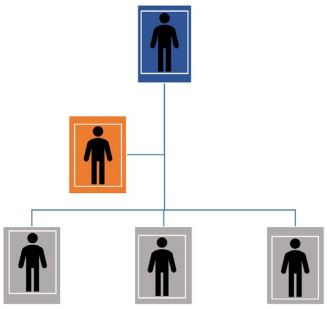
Elementary aged students between 3rd and 5th grade

OTSF TACTIC TO USE

Kinesthetic Activity

Drawing

Marine Food Web, cont.



xample of how participants can arrange themselves nto the food web. Carnivores at the top level (in lue), herbivores at the middle level (in orange), and roducers at the lower level (in grey). Note that the umber of participants can vary to meet the needs f your specific example. The linkages (in light blue) epresent how participants can hold hands

How will you adjust based on the feedback you might receive?

Students may ask where other species that they know of (seahorses, manatees, whales) etc. go on the food web. Don't ignore these questions and be prepared to possibly add them into the food web on the white board and the dancing food web if possible. Students may also need reminders during the kinesthetic activity about what different words mean, so be ready to positively reinforce definitions. If students are uncomfortable with the kinesthetic activity, allow them to assist you by helping their peers get into the food-web formation, and by suggesting what species to remove from the food web. If students need assistance to better understand what a food web is, ask them to tell you what they had for dinner the last night or their favorite food. Using that example, re-explain the key phrases and linkages while centering them at the top of the food web. For example, if a student's favorite food is a burger from McDonald's discuss the beef (cow) as an herbivore, who ate grass (producer), which needs sunlight to grow

How would this help you reach your desired outcomes?

The drawing aspect of this activity first introduces the key words associated with a food web and starts to gear students towards where species fit into the food web. Writing out the key words and their definitions, along with labeling the drawn-out species provides a take-home reminder of what a food web is and what it looks like and what the words mean both in terms of definition and with examples via the species. Students are also able to apply the food web concept to other topics, such as the food web of animals in their backyard or the food web of their family's diet.

The kinesthetic activity additionally reinforces the overall concept of a food web through forming and reforming, while also introducing what can happen if a species is removed. The movement of a "collapsing" food web, especially done when energetically such as through dancing, is a memorable one. It is also a simple enough activity that students can recreate with their siblings, families, etc. while reiterating what a food web is, and what happens when it collapses.

Characteristics of Bats Wings

AUTHOR

Joy O'Keefe, University of Illinois, Natural Resources and Environmental Sciences

TOPIC

Basics of bat biology and how to observe bats in nature

SETTING

An urban park known to have bat activity where a crowd can gather to stand near a sidewalk and with a walking path to listen for bats

AUDIENCE

25+ members of the community who signed up to attend the event; this could include people of all ages who are comfortable walking in a park at night.

OTSF TACTIC TO USE

Drawing

What are the desired outcomes for the engagement event?

For the participants to develop or enhance their appreciation for bats for their uniqueness and ecosystem services. To dispel some of the mystery around bats by allowing people to see and hear them and to encourage people to make observations in nature.

What will the audience do during the engagement event?

The audience will assemble for a "sidewalk talk" for the first 30 minutes of the event. During this talk, the scientist will employ several interactive OTSF tactics to assess knowledge of bats and to prepare the audience for the observations they'll make during the bat walk. Following this, the scientist will hand out some acoustic detectors that make the sounds of echolocating bats audible and will explain how these devices work. Then the group will do a "bat walk", which entails listening for bats with the devices and spotlighting bats in flight when they are observed.

What OTSF Tactic will you use?

The scientist will assemble the audience for the initial discussion in a place where there is a concrete sidewalk or another substrate that people can draw on. The scientist will provide the audience with many pieces of sidewalk chalk and will encourage everyone to draw a bat in motion, with the aim that each person will draw a bat's body and wings. This activity will take about five minutes, during which time members of the audience are likely to confer with each other on their drawings.

AUTHOR

Joy O'Keefe, University of Illinois, Natural Resources and Environmental Sciences

TOPIC

Basics of bat biology and how to observe bats in nature

SETTING

An urban park known to have bat activity where a crowd can gather to stand near a sidewalk and with a walking path to listen for bats

AUDIENCE

25+ members of the community who signed up to attend the event; this could include people of all ages who are comfortable walking in a park at night.

OTSF TACTIC TO USE

Drawing

Characteristics of Bats Wings, cont.

How will you adjust based on the feedback you might receive?

If the audience struggles with drawing a bat and its wings, then the scientist can describe the basic morphology of bat wings in more detail and can highlight the fact that bats are the only mammal capable of true powered flight. If the audience is adept at drawing bat wings and demonstrates an understanding of their basic structure, then the scientist can discuss more specifics about bat flight, such as flight speeds, how wing shape varies with foraging and migration strategies, and the ideas surrounding the evolution of wings.

How would this help you reach your desired outcomes?

The scientist will assess each of the drawings made by audience members, commenting on unique features they drew and correcting any misconceptions that are apparent in the drawings if needed. This will help to establish trust and to build a connection between the scientist and most of the audience members. After reviewing the drawings, the scientist will be able to further develop the audience's appreciation for flight in bats and how flight capabilities vary among bats. This will also prepare the audience for the observations they'll make after dark when they will see and hear bats foraging overhead.

Attitude about Bats

AUTHOR

Joy O'Keefe, University of Illinois, Natural Resources and Environmental Sciences

TOPIC

Basics of bat biology and how to observe bats in nature

SETTING

An urban park known to have bat activity where a crowd can gather to stand near a sidewalk and with a walking path to listen for bats

AUDIENCE

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OTSF TACTIC TO USE

Think, Pair, Share

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What OTSF Tactic will you use?

The scientist will assemble the audience for the initial discussion in an open space in the park. The scientist will ask each audience member to think of an adjective that describes bats. After about 30 seconds, the scientist will ask people to pair up to discuss their thoughts. Finally, the scientist will ask the audience to share the adjectives they listed and discussed.

How will you adjust based on the feedback you might receive?

This is an informative initial exercise to understand the basic notions that people in the audience have about bats. As the audience shares their chosen adjectives for bats, the scientist will be able to expand upon their responses. Some adjectives may lead to a discussion of myths about bats or about unique features of bats like their "hand wing".

How would this help you reach your desired outcomes?

This Think-Pair-Share prompts the audience to share their initial impressions of bats, gives the scientist an idea of what people in the audience know about bats, and begins to build some trust between audience members and the scientist, who should expand on their answers, affirming any truths about bats and gently dispelling any myths. By sharing interesting, factual information that builds upon the ideas shared by the audience, the scientist will be enhancing their understanding of the uniqueness of bats.

Classifying Galaxies

AUTHOR

Caroline Roberts, University of Iowa, Department of Physics and Astronomy

TOPIC

Learning about galaxies in our Universe.

SETTING

A virtual public lecture using Zoom technology that is a part of a university Physics and Astronomy department's public outreach.

AUDIENCE

About 50 guests from the general public: a mix of ages and educational backgrounds, including families and children, amateur astronomers, and college students.

OTSF TACTIC TO USE

Accomplish a Task

What are the desired outcomes for the engagement event?

The goals of the event were for audience members to learn what galaxies are and to debunk common misconceptions about galaxies, all while allowing guests to have a fun evening and end the event feeling as though they had an informative and enjoyable experience.

What will the audience do during the engagement event?

Guests learned about galaxies through an interactive lecture utilizing PowerPoint. The talk theme was focused on the question of 'Are there more stars in the sky or grains of sand on the Earth?' in a mystery format, where the audience was not given the answer at first but came to their own conclusion throughout the talk, being told the answer only at the end of the meeting.

What OTSF Tactic will you use?

To learn what guests knew about galaxy classification and to teach them to recognize the similarities between galaxies in our Universe, guests were divided into Zoom Breakout Rooms that were staffed by undergraduate student volunteers. In their small groups, guests were directed to view and manipulate 12 galaxy images on an internet Google Jamboard to drag and place in groups based on similarities and differences. The student volunteer leaders were trained to encourage dialogue and problem solving between the participants without giving away details of galaxy classification or implying that there were any correct answers. I visited each breakout room to obtain feedback on guests' knowledge and understanding.

AUTHOR

Caroline Roberts, University of Iowa, Department of Physics and Astronomy

TOPIC

Learning about galaxies in our Universe.

SETTING

A virtual public lecture using Zoom technology that is a part of a university Physics and Astronomy department's public outreach.

AUDIENCE

About 50 guests from the general public: a mix of ages and educational backgrounds, including families and children, amateur astronomers, and college students.

OTSF TACTIC TO USE

Accomplish a Task

Classifying Galaxies, cont.

How will you adjust based on the feedback you might receive?

After the task was completed, I had slides in my PowerPoint presentation prepared to respond to different scenarios with more or less guest understanding of similarities and differences between galaxy appearances. If participants' abilities to break the galaxies into correct classification groups was limited, I had more basic slides to go over the differences between spiral, elliptical, and irregular galaxies. If their understanding of the classifications was more advanced, I had slides prepared that covered Hubble's Tuning Fork diagram as well as the effect of orientation angle on galaxy appearance.

How would this help you reach your desired outcomes?

This tactic helped me reach my desired outcomes of helping my audience learn about galaxies and dispelling some common misconceptions my audience might hold, such as 'The Milky Way is the only galaxy' and 'There are only a few galaxies', and 'galaxies are all the same/are all spiral'. Zoom Breakout Rooms and Google Jamboards are fun technologies that allow guests to meet each other, aiding in the goal that participants have an enjoyable time.

Biology of Aging

AUTHOR

Brian F. Shmaefsky, Lone Star College-Kingwood, Environmental Science Department

TOPIC

Biology of Aging

SETTING

Two public lectures at a two community seniors centers

AUDIENCE

42 participants and Glazier Senior Center and 36 participants at the Academy of Lifelong Learning Center. Participants likely had no academic background on the scientific literature of human aging.

OTSF TACTIC TO USE

Think, Pair, Share

What are the desired outcomes for the engagement event?

- Participants will be able to recall the major biological factors that contribute to human aging.
- Participants will be able to recall the major environmental and dietary factors that contribute to human aging.
- Participants will be able to critique the effectiveness of common anti-aging therapies and remedies.

What will the audience do during the engagement event?

1. Begin with a question to the audience asking them to think about their perceptions of human aging.

2. Audience sees an image comparing a famous person in their 20s and in their 70s.

3. The audience is then asked the question “What are some common signs of aging?”

4. The audience divides into think-pair-share groups of two people to discuss the question.

5. Volunteers from the groups briefly describe the findings of the think-pair-share conversation to the whole audience.

6. After the group reports to the audience, the audience is asked if they found any items that were not mentioned by the groups that reported their findings.

7. The presentation concludes with a brief discussion on how scientists and gerontologists perceive human aging.

8. The discussion is followed by a brief question-and-answer session.

9. At end of session, volunteers from the audience are asked to briefly review their perceptions of aging.

AUTHOR

Brian F. Shmaefsky, Lone Star College-Kingwood, Environmental Science Department

TOPIC

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SETTING

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AUDIENCE

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OTSF TACTIC TO USE

Think, Pair, Share

Biology of Aging, cont.

What OTSF Tactic will you use?

The audience was prompted to limit their think-pair-share conversation to their personal observations of the signs of aging. They were also instructed to record the responses they had in common with their think-pair-share partner. The discussion following the reporting encouraged the audience to compare their observations to the perceptions of the scientific and gerontologist communities. A brief time was provided for the audience members to share their opinions about any similarities or differences in the aging viewpoints.

How will you adjust based on the feedback you might receive?

The audience feedback is used to discuss personal attitudes and misconceptions of the aging process. Much of the audiences' viewpoints of how we recognize aging are consistent with the perceptions of scientists and gerontologists. The session promoted a targeted discussion of how different societies may perceive aging and what causes us to have these perceptions. Two other brief think-pair-share sessions helped guide the content on the science of aging and the effectiveness of anti-aging strategies. Prior to using OTSF tactics in similar presentations, the biology on aging was done with the assumption that people had similar perceptions of aging and were unaware of the biological mechanisms of aging.

How would this help you reach your desired outcomes?

The primary goal of the biology of aging presentations for seniors is to make the audience aware of the pros and cons of anti-aging strategies used by gerontologists and marketed by commercial entities. The OTSF tactics improve the key desired outcome of the presentation by:

- The activity helps people understand misconceptions about aging that might affect their decisions on using anti-aging strategies.
- The activity assesses the audience's prior understanding of biological aging. which helps gage the level of detail needed to explain the effectiveness of anti-aging strategies.
- The activity helped streamline the amount of content that had to be presented to deliver informed discussions about anti-aging strategies.
- The activity improved audience engagement by valuing the knowledge people had about the topics covered in the presentation.