OPTIKS

Outreach for **P**rofessionals who **T**each in **I**nformal environments and **K**-12 **S**chools

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Table of Contents

Title**:** Training the Trainer in OPTIKS: **O**utreach for **P**rofessionals who **T**each in **I**nformal environments and **K**-12 **S**chools

Overview: It is common for industry professionals, faculty, and graduate students to conduct outreach to K-12 schools and in informal locations such as fairs, science centers, or open houses. But what are the most effective ways to engage participants in activities and how should the information be presented?

As part of this workshop, participants will learn how to most effectively present activities in optics and photonics that will maximize engagement while taking into account the audience and the location. They will also learn how to train others using the skills learned in this workshop.

Learning Outcomes:

Participants in the workshop will be able to:

1. Present information taking into account audience and location
2. Alter an activity to maximize engagement for their audience.
3. Recognize when a presentation is "over the heads" of a prospective audience.
4. Adapt their presentation so they "speak simply"
5. State the important factors that are required for effective presentations to varying audience
6. Plan to teach others the approaches learned in the workshop

Intended Audience: Industry professionals, graduate students or faculty who are interested in conducting outreach and training others how to conduct workshops

Course Level: Beginner, but those with some experience conducting some outreach.

Course Length: 4 hours

The Purpose of the Workshop

Teaching in a classroom involves a great deal of planning in developing lessons, designing activities, and delivering content so that students will learn. Likewise, in informal learning environments such as science centers, technology fairs, or exhibitions, your level of planning needs to take into account factors such as the audience, the environment and the amount of time you will interact with participants.

The goal of this workshop is to have you understand how to develop lessons and activities so that participants can become excited about optics and photonics. Ideally, we want participants to be engaged, have fun, and have a sense that they can pursue a career in optics and photonics.

You will want to engage participants so you minimize lecture and maximize the amount of time they are engaged in an activity. **Engagement** does not necessarily mean that the activity must be hands-on. Often it is. But at times it is not. Think about an optical illusion. This is not necessarily hands-on, but it is an engaging activity because it grabs the participants' interest and keep them involved. Questions that require students to think and come up with an answer that is not "black or white" or can get a group of participants to solve a problem are often engaging. But the activity needs to be at a cognitive level appropriate to the age.

Beware! You may think a topic is engaging for you. But is it engaging for the audience? Why do they care to know what you are telling them? What connection does it have to their lives?

For example, *nanotechnology* may be very interesting to a presenter, but what is it about nanotechnology that will make it interesting for the participants? Are there products they use that involve nanotechnology? Are there inspiring or "cool" discoveries that might pique their interest? What benefit does it have for society? How can you make a connection in the lives of the participants?

Examples of engaging activities:

- Finding what makes up light by looking through diffraction gratings.
- Using a lens to produce an image that is larger or smaller than an object.
- Trying to figure out why light from a light bulb spreads out but laser light does not.
- Showing optical illusions and have students brainstorm what they have in common.
- Do a Think-Pair-Share on how students think a wave travels from air into water.

What is common in the above activities?

Considering Audience and Location

Prior to attending an event whether in a classroom or in an informal setting such as a fair or science center, it is important to determine who is attending and the purpose. Here are some factors you should determine:

1. What is the setting? Is it a classroom, science center, fair, etc?
2. What is the format or environment? Is the space out in the open or do you have the ability to darken?
3. How much space will you have for demonstrations or activities?
4. How will you be able to interact with participants?
5. How many will be in attendance?
6. What are the ages of the participants?
7. How much time will you have?
8. Is there electricity?
9. Is there a budget? If so, how much?

Setting:
A classroom is called a **Formal Setting** because there is an organized structure of students lead by a teacher. We are most familiar with this way of learning because it is where we traditionally think learning occurs. There is the expectation that students are in the classroom to learn, be disciplined, and have structure. This setting may affect the type of presentation or activity you conduct. For example, it would be common for a presenter to have students complete a task or lab, and have worksheets that are provided to students. The students are expected to complete the activity and possibly have it scored by the presenter or the teacher. It may also be a place where more informal activities can be conducted. However, it is best to determine the expectation of the teacher in planning the activity.

<u>Characteristics</u>

- Longer form activities like labs with worksheets or demonstrations that develop one or two ideas.
- Questions are asked which require students to think, solve, collaborate, and develop answers.
- Activities tie to the curriculum.
- More time to dive deep into a concept or two (often 30 to 60 minutes or more).

On the other hand, an **Informal Setting** is one in which participants do not expect to learn or have a formal structure in which learning will take place. It is much more freeform and there will be multiple ages. Yet, learning occurs in these environments as well. Examples of informal learning includes science centers, fairs, or after school clubs. Since participants often don't attend these locations with the expectation that they will learn about optics and photonics, activities need to be designed differently from those in a formal setting. The activities are usually much more hands-on with less depth. There is often much less time to interact with participants, possibly on the order of only a minute or two.

<u>Characteristics:</u>

- Shorter form activities that may be related, but not necessarily.
- Must do something quick and fast to grab attention
- Questions should be of a form that allows for audience participation in which hands are raised or they call out the answers.
- Not a lot of time to develop a single concept, so ideas presented should be simple to communicate.

Considerations:
Not all informal settings are necessarily different from a classroom. For example, an after school club may have very formalized instructional programming. In this case, you would want to craft the activity to the expectations of the environment. Fairs and malls by definition have many people moving around and they often do not want to be engaged in an activity or demonstration beyond a few minutes. Take this into account when you are planning your activities.

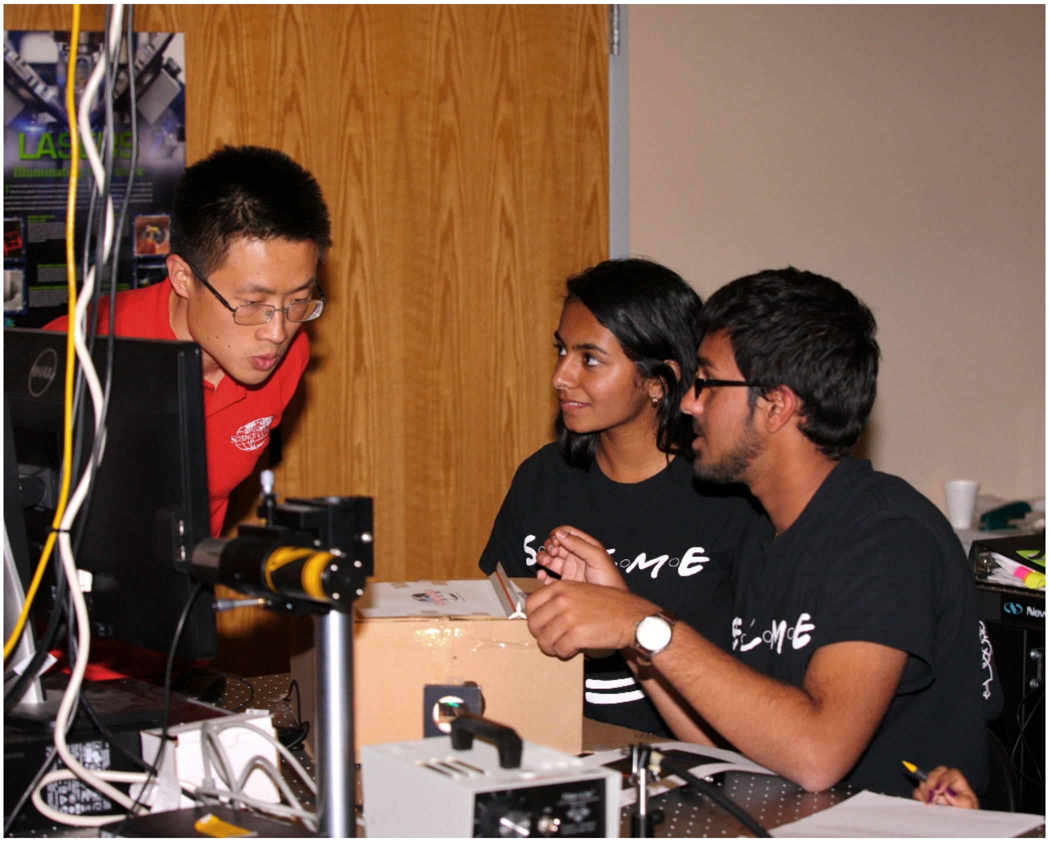
Format of Environment:
Before you plan the activity, know what the physical space will be like. If the activity is in a classroom, does it have windows? Can the room be darkened? This will impact the type of activities you can do. If you are conducting an activity in a location like a fair, it may be impossible to change the lighting in the room. You may also have limited space to setup a demonstration. Take this into account.

Space:
Check to see how much space you will have to conduct your activity. If you are limited to a table in which participants approach, you may want to elevate the demonstration so more can see. Limit these types of activities to simple things you can bring along.

Interaction with participants:
Much of this is tied to the space and format of the environment. The interaction will depend on how much space you have and the format. In classrooms, the interaction may be much more varied because you have extended period of time. At a location like a science center, the interaction may be confined to a demonstration for an audience. At a fair, it may be very short. Participants may approach a table to view a demonstration or take part in a small quick activity.

Numbers in attendance:
In a typical classroom, there may be only 20-30 students and the number of materials you bring could number less than 10 sets. Typically, you will have students in groups of 2-3. At other environments, if you doing a demonstration for a large audience, consider how everyone will be able to participate. In a classroom, if you are doing a demonstration, the devices used for a demonstration may be smaller since the participants are close. At a science center, in an auditorium, the same demonstrations may not be appropriate. If the devices you are using are too small, they may not be visible by everyone. Adjust the type of activity and the way it is conducted so it has maximum impact.

Ages of Participants:
Consider the age when planning the activity. This is far easier when you are conducting an activity in a classroom, where the ages are all the same. In an informal setting, the ages could be 5-95. If this is the case, consider an activity that everyone can enjoy. For example, at almost any age, seeing the spectrum through diffraction glasses are highly engaging. Most people do not understand how light is comprised of component colors. The types of questions you ask of participants may vary in such a situation, but the activity is similar for everyone.



Time:
The type of activity you do is dependent on the time available. In classrooms, you typically have 45 minutes to an hour. This allows for extended observation of physical phenomena along with time for students to record observations and prepare and analysis. For example, students may be asked to determine the types of images formed from concave and convex mirrors and describe the sizes of images, their positions, and orientations. However, at a fair, where you may only have a few minutes, it would be best to demonstrate a single large concave mirror, asking participants what type of image they see.

Electricity:
At many informal locations, electricity will not be readily available. Using light bulbs or power supplies for demonstrations will be problematic. This might also rule out the use of diffraction glasses to see spectra because you would not want the student to think they can stare at the sun. Instead, you will need to consider activities that are easy to use without power. Such example are demonstrations of lenses and mirrors or items that are powered with batteries.

Budget:
In many cases the budget is what is available from our company or university. Teachers will often have guest presenters because they lack the expertise or budget to fund supplies. However, the budget will dictate what you can do. If you have more funding, it may be possible to provide give-a-ways like diffraction glasses.

Engaging Girls

This early photo (circa 1908) of the young women flipping a circuit breaker and ironing may seem rather humorous, however, it is an indicator of the efforts made from early on in academia to engage women in science. In this example, newly invented home appliances were the catch. In the 1920's, enrollment in high school physics courses was low and to generate more interest, text books such as *Physics of the Home: A Textbook for Students of Home Economics* and *Household Physics* were published. The idea was to make physics and science more popular by making it relevant to the students' daily lives. For example, in Madalyn Avery's book, *Household Physics*, she included information on illumination, ray diagrams and wavelengths to show how to properly disperse light in a room. She thereby made the connection between physics knowledge and how a housewife could apply that knowledge in her home. *(Source: **Domesticating Physics**, Joanna Behrman; Physics Today 71, 5, (2018), published by American Institute of Physics)*

Moving forward to present day, studies continue to indicate women are underrepresented in physics and STEM careers. In 2015, women earned nearly 60% of all bachelor's degrees in the US but only 20% of the physics degrees. Cultural biases still continue to influence the involvement of women in science. Many biases are unintentional. Looking at the chart below of "standout" and "grindstone" words which may be used in letters of recommendation for men and women demonstrates how a student is encouraged in the classroom or as a potential job candidate through gender bias. *(Source: **Gender Matters**, Jennifer Blue; Physics Today 71, 3, (2018), published by American Institute of Physics)*

Standout Words (more often used to describe men)		Grindstone Words (more often used to describe women)	
Excellent	Terrific	Hardworking	Assiduous
Superb	Fabulous	Conscientious	Trustworthy
Outstanding	Magnificent	Dependable	Responsible
Unique	Remarkable	Meticulous	Methodical
Exceptional	Extraordinary	Thorough	Industrious
Unparalleled	Amazing	Diligent	Busy
Most	Supremely	Dedicated	Work
Wonderful	Unmatched	Careful	Persistent
		Reliable	Organized
		Effort	Disciplined

One approach to increasing the engagement of female students in science is to present outreach events for **girls only** (for example, there are summer camps for girls called "Coding is for Girls" and "Getting Girls into Coding.") In designing outreach for girls, it is important to take into account topics that are of interest to girls. After all, how often does a girl say "science is so boring. I will never need to know that."

Two documents published in the United Kingdom highlight the ways that we can design activities and materials so they are of interest to female students. They are: **WISE**, www.wisecampaign.org.uk, which focuses on increasing women involvement, engagement and employment in all areas of STEM and **PHABLABS,** www.phablabs.eu, which designs materials which target the natural way girls learn.

PHABLABS lessons and activities have been designed specifically for the optics and photonics community.

"People Like Me" is a resource developed by the **Wise** Campaign which allows girls to articulate their self-identity, using adjectives, and to map themselves onto roles that use science, technology or math where people like them are happy and successful. When planning lessons, they suggest taking into account the following:

- To encourage girls to consider careers in science, technology, engineering and math, a sense of 'fitting-in' can be reinforced by the careful choice of vocabulary and messages during lessons.
- Certain words can reinforce the 'Self-identity' vs. 'STEM-identity' conflict and put girls off studying STEM subjects, while other words can attract far more positive attention.

PHABLABS suggests when designing activities to be specifically interesting to females, they should incorporate the following:

- Activities that are **collaborative** – females thrive on team working and on projects that have a positive outcome for all involved.
- Activities that bring on a **feeling of success**. Females are motivated by success – any activity MUST ensure that girls come out feeling that they have been a success/done a good job.
- Activities that are **not 'elitist'** – there should be no implication that only 'brilliant people' do photonics
- **Role models that are 'normal'** especially if they have personal stories where they failed but still carried on
- **Activities that include Mum** – either on the day or via a flyer to take home to show Mum

The following table from PHABLABS shows the difference in activities that would be successful for a female vs a male student.

Females	Males
Design a house to keep people as safe as possible in an earthquake	Build a house to test to destruction on an earthquake table. The group with the house that falls down last wins
Design a 'seatbelt' to stop an egg on a trolley being smashed when the trolley hits the wall.	Build a trolley to go as fast as possible down a ramp to hit the wall hardest. The most spectacular crash wins.
Add colored lights to a soft toy that slowly go dim so that a child who is afraid of the dark can go to sleep happily.	Add colored lights to a toy to make it brighter – the groups with the brightest toy wins.
Add lights/music to a soft toy so that an elderly person with dementia is helped to remember their childhood	Ditto
Design a marble-run to link to all the other marble runs to see how far the marble will go before it falls off	Design a marble run – the marble that gets to the end fastest wins

SciGirls is a US-based transmedia effort providing resources for girls, educators and families through videos, an interactive website and hands-on activities to maximize the participation of girls in STEM.

SciGirls (pbskids.org/scigirls) is an award winning television show, website and educational outreach program. In partnership, there is ***SciGirls Connect*** (scigirlsconnect.org) which is a broad national outreach effort to support educators to engage girls in STEM.

In designing engaging outreach, SciGirls Connect using the SciGirls Seven Steps Method of proven Strategies for Engaging Girls in STEM:

1. Girls Benefit from Collaboration, especially when they can participate and communicate fairly.
2. Girls are motivated by projects they find personally relevant and meaningful.
3. Girls enjoy hands-on, open-ended projects and investigations
4. Girls are motivated when they can approach projects in their own way, applying their creativity, unique talents, and preferred learning styles.
5. Girls' confidence and performance improves in responses to specific, positive feedback on things they can control- such as effort, strategies and behaviors.
6. Girls gain confidence and trust in their own reasoning when encouraged to think critically.
7. Girls benefit from relationships with role models and mentors.

Using these steps any outreach activity can be adapted to be more engaging to girls. Using the **Seven Steps Method,** the following "Hover Craft" and "Owl Pellet" lessons are examples of how this can be accomplished.

Activity Makeover
Applying the SciGirls Seven

Pages 16 and 17 show how to take traditional science or engineering activities and apply the **SciGirls Seven**, making subtle shifts in how the activities are presented. In these examples, we model incorporating a few strategies at a time. (Refer to pages 7 and 8 for full explanations of each strategy.) You can do the same with your activities and watch your girls' confidence soar!

Miniature Hovercraft

Supplies for each group

- an empty thread spool
- a 4-inch square of cardboard
- white glue, or a hot-glue gun
- a sharpened pencil
- a balloon (12 inch, when inflated)

1) Glue the bottom of the empty spool to the center of the cardboard square.

2) Use the sharpened pencil to punch a hole in the cardboard that lines up with the center of the spool.

3) Blow up the balloon. Hold the bottom without tying it.

4) Get your partner to hold the spool for you. While pinching the neck of the balloon, stretch the bottom over the top of the spool, release the neck, and lift off!

5) Experiment with different sizes and shapes of cardboard to get the **best hover** out of your balloon hovercraft. Give your hovercraft a shove along a smooth tabletop, and see how far it goes.

Strategy 3
Have a table full of additional supplies to promote creative solutions to the hovercraft design: old CDs, water bottle caps of various shapes and sizes, an assortment of tape, scissors, push pins, paperboard cereal boxes, etc.

Strategy 4
Ask girls to write a story, poem, or song describing how hovercrafts are used to rescue families or animals in flooded coastal areas or along rivers.

Strategy 6
Once hovercrafts have been constructed and tested, change the focus from "best hover" to fastest craft, farthest hover, or maneuverability/ steering through a course. Ask girls to redesign their craft to meet the new challenge.

Strategy 7
Invite a rescue worker who may use hovercrafts or an engineer who designs them.

Supported by:
FOR GIRLS IN SCIENCE L'ORÉAL USA
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Activity Makeover continued

What's in an Owl Pellet?

Supplies for each group

- a commercially prepared owl pellet
- a magnifying glass
- tweezers
- 2 sheets of white office paper
- a bone identification chart of small rodent skeletons
- non-latex gloves

1) Practice excellent hygiene when handling the owl pellets. Keep hands away from eyes, nose, and mouth.

2) Carefully unwrap the owl pellet from its foil. Gently break it apart by hand.

3) Sift through the pellet, looking for bone pieces. Most pellets contain recognizable skull, jaw, leg, or rib bones from small rodents, such as a mouse or a vole. Use tweezers to remove bones from the pellet debris.

4) Lay out each bone on a clean sheet of white paper.

5) Count the number of bones in the pellet, and identify each by matching it to one on the chart.

6) Try laying the bones out in a rough skeleton arrangement. Parts of the skeleton may be missing; discuss why that might be.

7) Wash hands thoroughly when finished.

Strategy 1
Distribute only one glove per person. This not only saves on gloves, it encourages cooperation. One girl utilizes tweezers while the second holds the pellet.

Strategy 2
Talk about the types of owls that live in your area. Or, create a story emphasizing the importance of studying owl pellets. For example, "You're a veterinarian. A man brings in his pet owl, who got sick from something it ate the night before. By identifying the ingredients of the owl's last meal, you can help it recover."

Strategy 5
Some girls may be "grossed out" by owl pellets. Encourage them to participate by handling the pellet before dissection or picking up the bones to identify them after dissection. Patience with squeamish girls can empower them to get closer to the pellets. Offer words of praise, even for small steps toward participation.

Strategy 7
Invite a mentor from a nearby raptor center to bring a live owl and discuss its role in the food chain. Or take a field trip!

Hands-on Activity: Using the Seven Steps and the examples from the Hover Craft and Owl Pellet, can the UV Bead lesson become an engaging outreach activity for girls?

Ultraviolet (UV) Detecting Beads Lesson Plan

Ultraviolet (UV) light is an invisible type of light given off by the sun. UV rays can damage two of the body's vital organs: skin & eyes. This damage appears as a sunburn. When you have had a sunburn, the damage accumulates over time. You can't change the damage that has already happened but you can learn more about UV rays and how to protect yourself with sun safe behaviors. These UV beads contain a pigment that changes color once exposed to UV light. The beads will remain white when indoors or if shielded from UV light. Some bead colors change faster and more dramatically than others (purple).

- <u>Simple activities to do with the UV Beads:</u> Make a UV detecting bracelet. Thread 10 beads onto a length of the cord provided. Once the beads are exposed to some UV light, you may choose to trade some colors with a friend to get a better assortment. Try to arrange the colors so that 2 beads of the same color are not next to each other. Tie a knot on either side of the beads so they will stay in place and not slide around.

- <u>Test the effectiveness of clothing:</u> Cover bracelets with different fabrics—a thin cotton t-shirt, a jacket, some denim material, or artificial fibers (stretchy materials usually have some artificial fibers in them). Do the beads stay white? (Indicates total UV protection) Are the beads pale in color? (Some UV protection) Are the beads brightly colored? (Little or no UV protection) Covering clothing is always the best way to protect your skin from UV rays.

- <u>Test the effectiveness of sunscreen:</u> Teacher Activity: Coat several beads with different Sun Protection Factor (SPF) sunscreens—SPF 15, SPF 30, SPF 50+. Expose the beads to UV rays. Observe which set of beads changes most dramatically—the paler it becomes the more it has been protected. Which SPF protects best? Do different brands of the same SPF number protect differently?

- <u>Measure the sun's UV rays</u> on different colored beads at different times of the day. You will find that the beads change color much faster at noontime than in the late afternoon. To add another twist, take your beads outside at the same time of the day but under different weather conditions. Does cloud cover change the amount of UV light that reaches both the beads and your skin?

- <u>Investigate UV absorption:</u> Place different transparent filters between UV light and the beads. Try regular eyeglasses, sunglasses, and UV absorbing window film (if you have any). You will find that the front windshield of most vehicles absorbs some UV light but that most side windows do not have this protection. Encourage students to wear their UV bracelet on a regular basis to remind them that when the beads are brightly colored they need to cover up with clothes, a hat, and sunglasses, apply sunscreen SPF 30+ and seek shade.

Modifying Cookbook Activities into Inquiry Activities

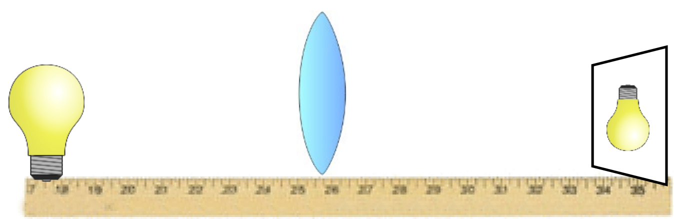
Engaging activities incorporate aspects that draw participants' attention, requiring them to think, problem solve, or explore. Many times, engaging activities are hands-on, although they do not have to be.

Likewise, there are many laboratory activities that are found in textbooks that are not engaging. Many of these are "cookbook" style labs that require students to follow a set of steps to solve a problem or collect data. The problem is that the procedures, while making the lab activity easy for students to follow, mask learning or cover up inherent misconceptions students may have.

<u>Consider the following activity:</u>

Students are given a lab activity that has specific steps which require students to place a light bulb on the left, a mirror in the middle and a card on the right. The students are asked to produce an image on the card.

What is the problem with this setup and procedures?



<u>Now consider the following:</u>

The teacher gives the students a lens, light bulb and index card. No procedures are provided. Students are asked "How can you produce an image that is larger, smaller, and the same size as the object."

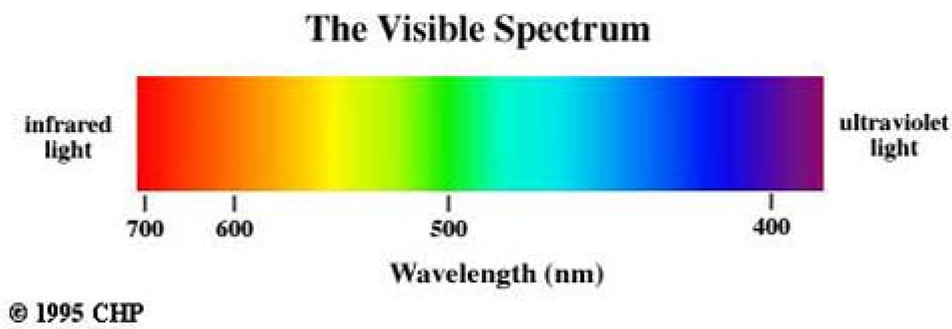
How is this different from the first example? How much more or less engaging is it?

Comparing Activities
Engaging activities often start with a problem to solve, an interesting question to answer, or a challenge to figure out. Yet, many activities conducted in outreach events are either didactic or contain a fair number of directions. Examine the next two lessons. Which of the following have a higher degree of engagement?

Use the following T chart to compare and contrast the two lessons. Be prepared to discuss with others.

Compare: What do they have in common?	Contrast: What are their differences?

Rainbow Lab



Purpose: To use spectroscopy to better understand the electromagnetic radiation spectrum (EMR).

Procedure: Follow the instructions of your teacher and observe all five spectral tubes using the hand spectroscope. Perform each of the tasks and answer all questions completely with illustrations and equations. **(H)** is for Physics Honors only!

Equipment: spectroscope, spectral tubes, goose chart, iPad, Google, The Elements App

Tasks:

1. Each team obtains a spectroscope from your teacher.
2. Look through the spectroscope at the fluorescent light to calibrate the scope.
3. Look at the five spectral tubes. Record on your data sheet the element, colors, and wavelength of each tube. Follow the safety precautions told to you by your teacher.
4. Make a data table **for each element** listing the frequencies and wavelengths of the **two brightest lines** found during the observation of each tube.
5. **(H)** Go to the following web site:

   http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/atspect.html#c1

   Compare the wavelengths for the two strong lines for each of your known elements (as shown on the web site) to your two strongest experimental lines. Show the comparisons on a spectral window similar to the one on your data table using wavelength for the measurement. Then, for the two brightest lines **in each tube**, give a **percent error** from your experimental data to the actual data from the web site.

Questions:
1. What are the frequencies of the brightest lines of each of your tubes (Calculate it!)?
2. Which elements of your selection, if any, have the same frequency for the brightest line?
3. What causes the different colors that you see for each bright line in the spectrum?
4. **(H)** Determine the **energy** for the brightest line in each of your tubes.
5. **(H)** What is the **mass equivalent** for the energy in each of the lines in #4? Use a table for questions 4 and 5.

Sources: http://www.cpalms.org/Public/PreviewResourceLesson/Preview/28793
http://www.cpalms.org/uploads/Resources/final/28793/Document/3366/Rainbow%20Lab%20HO.doc

How Can Light Be A Fingerprint?

Description: Students will examine the spectra of gases to determine their composition.

Student Materials (per group):

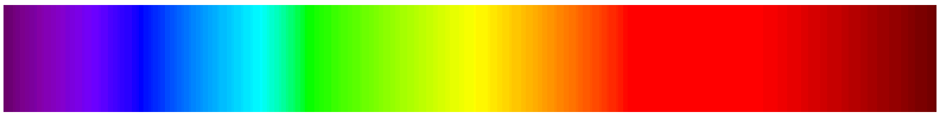
- ☐ Diffraction Gratings

Additional Teacher Materials:

- ☐ He, Ne, H_2, O_2, Kr Spectral Tubes
- ☐ Spectral Tube Power Supply

Background and Misconceptions:

When light is viewed through a diffraction grating, the light spreads out into its composite colors. Incandescent light bulbs emit a continuous spectrum, a viewer will see a spectrum similar to the one below.



Continuous Spectrum

Light can be used to identify particular gases, similar to using DNA or fingerprints. Gases that are composed of one element or molecule will emit a spectrum that is not continuous. The light is emitted by first sending energy through a gas that excites the electrons causing specific wavelengths of light to be given off. Through a diffraction grating, the emission spectrum will appear as a series of discrete lines at specific points along the electromagnetic spectrum. For example, the emission spectrum for helium appears below.

Helium Spectrum

Astronomers use this process to examine a star's spectra and determine the composition of the star. Keep in mind that a star is composed of many elements. Each element's spectra overlap with each other, making the work of the astronomer a bit more difficult in unraveling the star's composition. It also takes some training to become expert at matching the spectra seen through the diffraction gratings with those that are standard. Often, the diffraction gratings do not represent all the lines clearly.

Teacher Guided Questions to Inquiry: ***Use these questions to get the students started on their own inquiry!***

1. How can you identify the gases based on the spectrum you see with the diffraction gratings?
2. How can the spectrum be used to identify the composition of stars?
3. What will happen if the spectrum contains several gases?

Additional Hints:

- Use diffraction grating glasses that can be purchased in bulk for less than $1 at many online stores.
- When using the power supply and spectral tubes, use great caution. The power supply uses very high voltage to energize the spectral tubes and students should not touch them.
- This lab can be turned into a fun quick activity in which the students try to determine which element is contained in the tube.
- The student worksheets that contain the emission spectra must be printed in color. They can be laminated to be used repeatedly.

How Can Light Be A Fingerprint?
TEACHER ANSWER SHEET

Questions:

1. How easy is it to identify each gas? How important is it to be trained in identifying the gas?

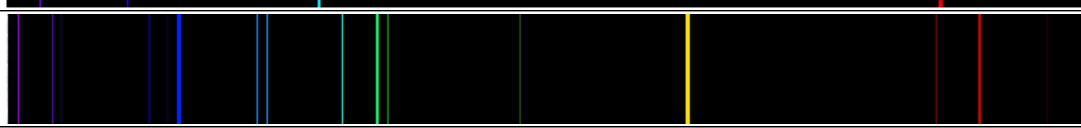
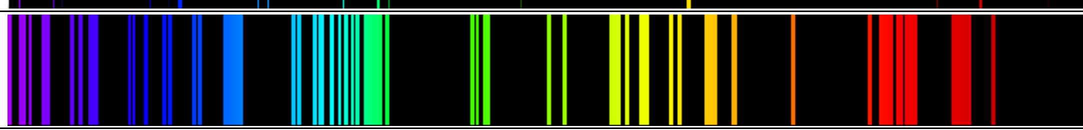
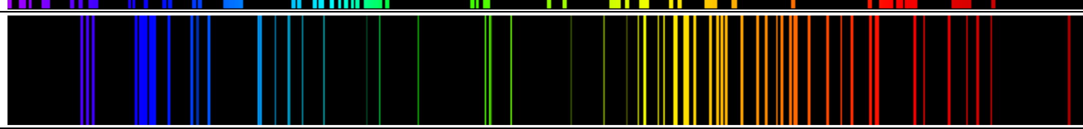
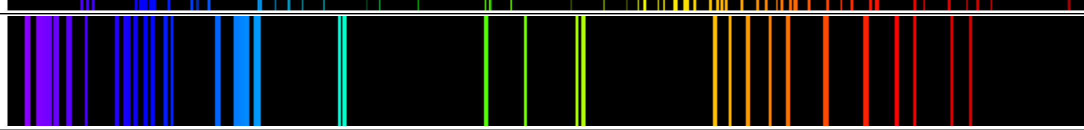
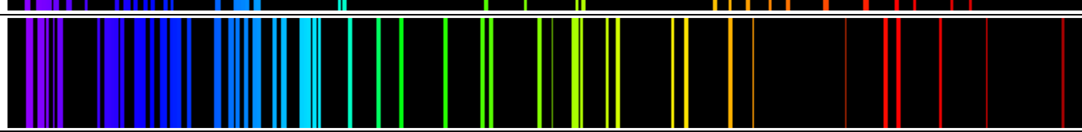
   It can be quite difficult since the diffraction grating may not show all the lines clearly. It is very important to be trained, just as police are trained to examine and match fingerprints.

2. Stars are made up of many elements. How do you think the spectrum might appear if there are three elements in a star?

   The spectra from the three elements would overlap producing a much more complicated spectra. The spectra would have to be disassembled to determine which elements are contained in the star.

3. Why is using a spectrum to identify gases important?

   It allows scientists and astronomers to identify elements, atoms, and molecules using light without necessarily having a sample in their labs. For example, it is impossible to go get a sample of star, but the spectra allows astronomers to discover the composition of a star.

Tube Number	Spectrum
Hydrogen	
Helium	
Nitrogen	
Neon	
Oxygen	
Krypton	

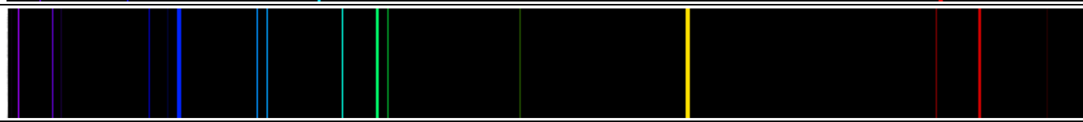
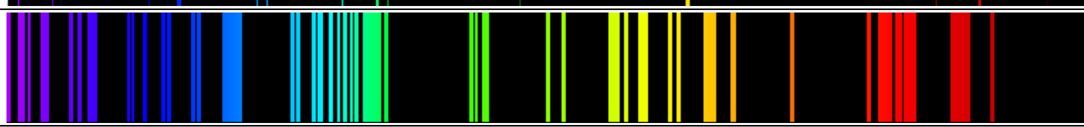
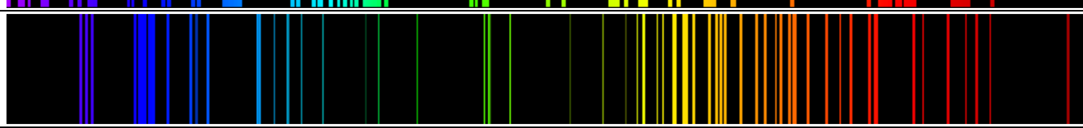
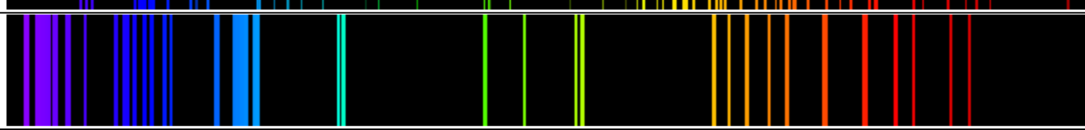
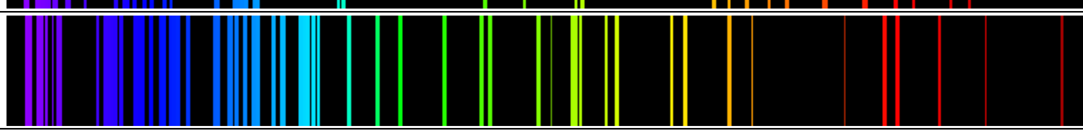
How Can Light Be a Fingerprint?

Name ____ **Date** ____________________

Description: Light can be made up of many different colors, but when examining different gases, it is possible to spread the light out and view its spectrum. The spectrum of a gas is similar to a person's fingerprint because it uniquely identifies it. In this experiment you are going to try to determine the type of gas you are viewing.

Materials: Spectral Tubes Diffraction Grating Power Supply

Procedures:
1. Use the diffraction grating to view each gases' spectrum.
2. Using the chart below, try to identify the gas.

Tube Number	Spectrum
	
	
	
	
	
	

Questions:
1. How easy is it to identify each gas? How important is it to be trained in identifying the gas?

2. Stars are made up of many elements. How do you think the spectrum might appear if there are three elements in a star?

3. Why is using a spectrum to identify gases important?

Highly Engaging Lessons

There are many excellent textbook laboratory activities, yet few are designed to engage students in the scientific process. Many require a set of "cookbook" steps that help with the efficiency of classroom instruction but also remove the rather sloppy process that goes into the development of thinking and problem solving.

Look at the following two activities. Compare and contrast the two and describe the level of engagement students may have.

Compare: What do they have in common	**Contrast: What are their differences?**

Lab: The Inverse Squared Law   Name _______________________
Date _________________   Physics   Period ___________

Background: Light travels away from a light source as a sphere. Let's say you shine a light on a card at a distance of one meter. In this example, the amount of light striking it is 400 lumens. (A lumen is a measure of light intensity.) If we move the card to two meters the amount of light striking the card will only be 100 lumens. If we move the card to 4 meters (so it is now 4 times farther way than it was when it was at 1 meter) the amount of light striking the card is only 25 lumens. The light does not decrease in a linear way. The light follows what we call the INVERSE SQUARED LAW OF LIGHT. We use the following formula to explain this:

$$I = \frac{1}{r^2}$$

I = intensity of light.
r = distance from light source.

According to this law, if you DOUBLE THE DISTANCE, R, you have 1/4 the light. If you move the card 4 TIMES farther away, you have 1/16th of the light.

During this lab, you will be investigating the relationship between light intensity and distance for a light bulb.

Identify:

Independent Variable (What you directly control)		Dependent Variable (What you are looking for)	

Materials: Ring Stand   Foam-core Boards   Light bulb   Meter stick

Procedures:

1. Place the large foam-core board against the ring stand. The ring stand will support it. Make sure the side with 16 squares is facing the bulb. Try to place the board so that it is completely vertical. Place the meter stick on the table so that the 100 cm mark is against the foam-core board. At the other end of the meter stick, line up the CENTER of the light bulb with the zero mark on the meter stick.

2. Hold the smaller foam-core board (shadow-caster) in front of the bulb so that the shadow cast on the larger board completely covers the board, but does not overlap past the board. Move the card back and forth until you get a perfect fit of the shadow size on the larger board. Measure this distance on from the light bulb to the shadow-caster. Also, notice the number of squares covered on the larger board. Record both numbers on the table below.

3. Determine the ration of the single shadow-caster (which is the same size as one of the squares on the board) to the number of squares covered. **Report this ratio as a fraction!**

4. Double the distance from the light bulb to the shadow-caster. For example, if you first distance is 10 cm, move the shadow-caster to 20 cm. Record this new distance and determine the number of squares covered. Also determine the ratio.

5. Repeat the steps again, but move the shadow-caster to a position that is THREE times as far away from the light bulb as compared to the ORIGINAL position. For this, you will need to turn the board to the opposite side to record your measurements. This is the side with 9 squares.

6. Repeat the steps again, but move the shadow-caster to a position that is FOUR times as far away from the light bulb as compared to the ORIGINAL position. For this, you will need to turn the board to the original side to record your measurements. This is the side with 16 squares.
7. In the final column of the table below, use the inverse squared law to determine the amount of light (or in this case shadow) that is on the board from each of the distances. Use the formulas below:

$$r = \frac{\text{Number of times the distance}}{\text{Original Distance}} \longrightarrow I = \frac{1}{r^2}$$

	Distance from light bulb to shadow-caster. (cm)	Number of squares covered by the shadow-caster.	Ratio of shadow-caster to the number of squares covered.	Intensity of light at distance **r**.
Original distance				
2X the distance				
3X the distance				
4X the distance				

Questions:
1. As you move the shadow-caster farther away from the bulb, what happens, and by what amount does the size of the shadow change? In other words, if you double the distance between the bulb and the shadow-caster, but what amount does the shadow change?

2. Why does the intensity of light change with distance?

3. Light leaves a source, such as a light bulb, traveling in all directions. Therefore at any instant, we can describe a sphere of light coming from the bulb. What is the relationship between this sphere of light and the inverse squared law you have examined in this lab.

4. Using graphical analysis, create a graph for your group. Plot the independent variable against the dependent variable. Explain the meaning of the graph produced.

Inverse Squared Law

CONCEPT/BACKGROUND INFORMATION:

Music can be very loud if you are standing next to a speaker at a concert, but as you move away from it, the music becomes softer. As a spacecraft moves away from earth, the pull of gravity diminishes. When you look at a light, it gets much brighter as you move closer to it. Each of these situations are related with a special rule called the Inverse Square Law.

The inverse squared law explains how energy changes with distance. If you are standing 1 meter away from a light bulb and then move to a position that is 2 meters away, we can predict the decrease in energy experienced by a person viewing the bulb. It is common to believe that if you double the distance from the light bulb, there would be ½ as much light. However, light does not just spread out in ONE direction (or in other words 1 dimension) but it spreads out in TWO directions and does so as if you are observing on the surface of a sphere. Therefore, light decreases as the inverse of the square of the distance and is summarized mathematically as the following:

$1/d^2$

When you double your distance, the light energy will be ¼ as intense. But be careful! When this is explained to students, they should understand that the relative light intensity decreases by ¼ when the distance is doubled. To determine the absolute value of the intensity of light, one would need to measure the intensity at 1 meter and then use the inverse squared law to calculate the intensity at two meters. If the original light bulb was 1000 lumens, then at 2 meters, there would be 250 lumens, or ¼ (1000 lumens) = 250 lumens.

If you tripled the distance, then $1/3^2$ or 1/9 the intensity; the light at 3 meters would be 1/9th as bright.

If, on the other hand, you DECREASED the distance from the light bulb, you would go from 1 meter to 0.5 m. Then you would have $1/(1/2)^2$ or 4 times as intense.

One other note: Our eyes are easily fooled by changes in intensity so it is not easy to perceive light changes accurately. If you ask the students to state what they observe, the observations would not match the measurements from instruments. There is a difference between brightness (what our eyes think they see) and intensity (how much light is released from a bulb.)

The inverse squared law applies to all physical phenomenon that propagates as a sphere, such as light, sound, gravity, electrical fields, magnetism.

It is important to introduce this concept first because students will be introduced to Newton's Law of Universal Gravitation: $F= G\ m_1m_2/r^2$, and will have the most difficult with the inverse square part of this concept.

MATERIALS NEEDED:

TEACHER	STUDENT
Lab sheets	Lab sheets Light Bulb Foam core or poster board Smaller 1/16 piece of poster board Meter stick Ruler

TEACHING TIPS:

Ask the students to determine how large of a shadow covers the large card when the small card is held in front of a light bulb if small changes are made to the position of the small card with respect to the light bulb and large card. Make sure that they don't over-cover the large card. In other words, if you move the smaller card close the light bulb, the shadow that is cast is much larger than the card. You want to watch to make sure that the shadow cast by the small card is just the size of the larger card.

Although more expensive, foam core board is more durable and is easier to stand up than poster board. Foam core can be found at most office supply stores.

(Personal observations/Notes for next time)

ACTIVITY

When you place a small card in front of the light bulb, how big is the shadow that is created? (Students will likely state that the shadow is bigger or smaller, depending on how far it is cast.)

What will happen to the size of the shadow as you change the position?

Predict: What will happen if I start the small card at 25 cm, then move it to 50 cm? In other words, I double the distance.

Challenge the students to use only the materials given, to find the places where the shadow is the same size as the card and where the shadow is covering ¼ of the large poster board.

Teacher Notes:

Have students conduct the activity described above. Do not give them much assistance. Make sure they record the position where the large card is completely in shadow, and the position where the card is only ¼ in shadow. The included data sheet will be excellent for students to use.

After students have collected the data, record each group's data on the board or overhead and have them find a pattern. You may want to point out groups whose data is not "correct" and have a discussion on experimental error.

Sample data table for board:

Group	Position where shadow was completely covering card:	Position where shadow was covering only ¼ of card.	Relative change of position (Double, half, three times…)

CONCEPT

Students should discover that as you double the distance, the amount of card that is covered is ¼ as much as at the first position. They may have thought that if you double the distance, there is only ½ covered. Ask them to predict what would happen if you tripled the distance. They should state that it would be $1/9^{th}$ as much.

Introduce the inverse squared law of light. Show the formula from the background and work out the problem. Keep in mind that you should NOT introduce the formula first. Wait until after they do the minilab.

VOCABULARY AND READING

Hand out the worksheet called Activity: Inverse Squared Law which provides examples of applications of the inverse squared law including light, gravity and electric field. Then, extend to Newton's Law of Universal Gravitation: $F= G\ m_1 m_2/r^2$

This law incorporates the inverse squared law. If you double the distance between two planets, a planet and a moon, or a planet and a person, the amount of gravity that is felt decreases by ¼ . If you double the mass of either object, then the force of gravity doubles.

Lab: What's In A Shadow

Name ___________________

Date ___________________

Period______________

Background: In this lab, you will find out how much the size of a shadow changes. We are all familiar with shadows, but what happens when you change the distance between the object making the shadow and the surface on which the shadow falls.

Predict: What will happen to the size of the shadow as you change the position? Be specific. Use statements like: *If I double the distance then….*

Here is the challenge to solve: First, find the position where the shadow completely covers the large card. Then, where is the card only ¼ covered. Record your measurements below.

Position where shadow was completely covering card:	Position where shadow was covering only ¼ of card.	Relative change of position (Double, half, three times…)

Questions:

1. If your shadow caster was originally at 25 cm and the shadow completely covered the large card and then you moved it to 50 cm, how much of the large card is covered? Did this match your predictions?

2. What is a general rule to explain your observations?

3. Using your general rule, what happens if you moved your shadow caster to 75 cm (three times as far away as when you started)? Is your general rule correct?

Highly Engaging Lessons: ABC-CBV-RAL

In the 1980s, the Biological Sciences Curriculum Study, now known as BSCS Science Learning, initiated a research-based lesson plan model designed to engage students in learning, uncover misconceptions, and improve student outcomes. Called the 5E model, it serves as the foundation for inquiry-based learning and helps for students to establish relationships between what they already know, what they will learn, and the ways that teachers can assess their learning.

The model is summarized here from "The BSCS 5E Instructional Model: Origins and Effectiveness, Executive Summary" July 2006:

> **Engagement**
> The teacher or a curriculum task accesses the learners' prior knowledge and helps them become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge. The activity should make connections between past and present learning experiences, expose prior conceptions, and organize students' thinking toward the learning outcomes of current activities.
>
> **Exploration**
> Exploration experiences provide students with a common base of activities within which current concepts (i.e., misconceptions), processes, and skills are identified and conceptual change is facilitated. Learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions and possibilities, and design and conduct a preliminary investigation.
>
> **Explanation**
> The explanation phase focuses students' attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. This phase also provides opportunities for teachers to directly introduce a concept, process, or skill. Learners explain their understanding of the concept. An explanation from the teacher or the curriculum may guide them toward a deeper understanding, which is a critical part of this phase.
>
> **Elaboration**
> Teachers challenge and extend students' conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept by conducting additional activities.
>
> **Evaluation**
> The evaluation phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives.
>
> Source: https://bscs.org/sites/default/files/_media/about/downloads/BSCS_5E_Executive_Summary.pdf

While this model is highly effective at engaging students in inquiry based learning, it can be challenging to use in outreach activities because it is dependent on conducting the lesson, with assessment, over a period of time.

Instead, a newer model can be used that is more effective in helping design activities which are inquiry-based. It is known at ABC-CBV-R; Activity Before Concept, Concept Before Vocabulary, Reading At Last.

Engaging students in an interesting lesson first, prior to introducing a concept, not only captures their attention, but also creates conditions in which they must apply critical thinking and problem solving skills. They not only use the lab as a verification of previously learned concepts, but also as an exploration that leads to new knowledge. **Activity Before Concept** (ABC) has the goal of engaging students in meaningful ways that require deep and complex thought and this experience is used to provide meaning to learn a concept to be introduced later. For example, by using a guided inquiry mode of instruction, students are asked to solve a question without a prescriptive set of procedures.

After a deep and meaningful experience in the laboratory, students have a much better understanding of concepts to follow and through guided facilitation, they can uncover scientific concepts on their own. This connection between activity and concept is vital. Very often, discussions about the laboratory activity and the data collection process are longer than the lab itself. In many science classrooms, teachers spend a great deal of time conducting a lab, but little time in allowing students to process the results and discuss. This discussion is vital to deep understanding of the scientific concepts.

Teachers then introduce vocabulary, but only after a thorough discussion of the concepts. While traditional teachers often feel that students must be presented first with vocabulary before they can introduce a concept and conduct a laboratory activity, introducing vocabulary after the concept is discussed is most appropriate because students have constructed meaning from their data, but need words and definitions to completely develop their discoveries and communicate with others in a common agreed upon language, much in the same way that we use the metric system as an agreed upon measurement system. This is called **Concept Before Vocabulary** (CBV) and this further deepens the learning process because students can associate meaning and their experiences with the new vocabulary and in turn the vocabulary is connected to the concepts.

If students do not read with meaning and have some experience with the subject that they are reading, they are unlikely to retain and understand what they read. Therefore, students read passages about the concepts that have been introduced at the end, not at the beginning, because they have had a rich experience throughout this learning process. This is called **Reading At Last** (RAL). Research supports that all reading activities should include a pre-reading activity, a during-reading activity and a post-reading activity. While it is common for traditional teachers to require students to read their text prior to doing a laboratory activity, the laboratory activity in our model becomes the pre-reading activity. This provides the initiative for the students to read more about the concepts that were uncovered in the activity and follow-up discussion. The reading passage is now firmly connected to an experience and student interest and retention follows.

Guided inquiry simply reorders the normal instruction that traditional teachers may follow so that the learning process is more natural and innate and it requires that the students are more active in their learning, while creating a need to satisfy natural curiosity about content, vocabulary, and reading. This process answers the question "Why do I need to learn this and where will I ever use it?"

Knowing this model, attempt to come up with a plan for adapting a lesson from the traditional cookbook model to one that uses the 5E Model:

Activity Before Concept
Concept Before Vocabulary
Vocabulary
Reading

Speaking Simply

It is commonly heard that you need to "dumb down" material or concepts for those who are younger or outside of your field. But consider the implied message that is communicated when using those terms "dumbed down." It connotes that the person who is learning the materials is not intelligent or is incapable of understanding the material. Instead, they may not have ever been exposed to the concepts being taught. Consider how difficult it may be for a person with a Ph.D. in Literature to understand basic physics concepts and vice versa. It has little to do with intelligence and more to do with the different fields of study.

When planning a lesson, instead consider how you will "speak simply." Science, politics, education, and medicine have specific terms that are used commonly, but without knowledge of those terms, a person outside the field will find it difficult to understand a conversation.

When planning an activity, consider the following:

- Who is the audience?
- What are their backgrounds?
- How deep is their scientific of knowledge of optics?
- What types of activities have then engaged in previously?

As you prepare the lessons, consider using terms that are more common across as many disciplines first, and then use experiences in the activity have them learn new content. For example, an audience may not be aware of refraction of light through a lens. The term "refraction" has no meaning to them. Prior to an experiment, you may ask them to describe what happens when light goes through a lens. Participants may say light bends or focuses. Later, after participants experiment, you can use more complex terminology that is specifically tied to the activity.

Speaking simply often requires practice since those who are in the field of optics and photonics naturally use terminology such as "phase transition," "nonlinear," or "waveguide."

Come up with a list of terms that might often be used in your research field and find a way to describe using simpler terminology:

Research Terminology	Speaking Simply

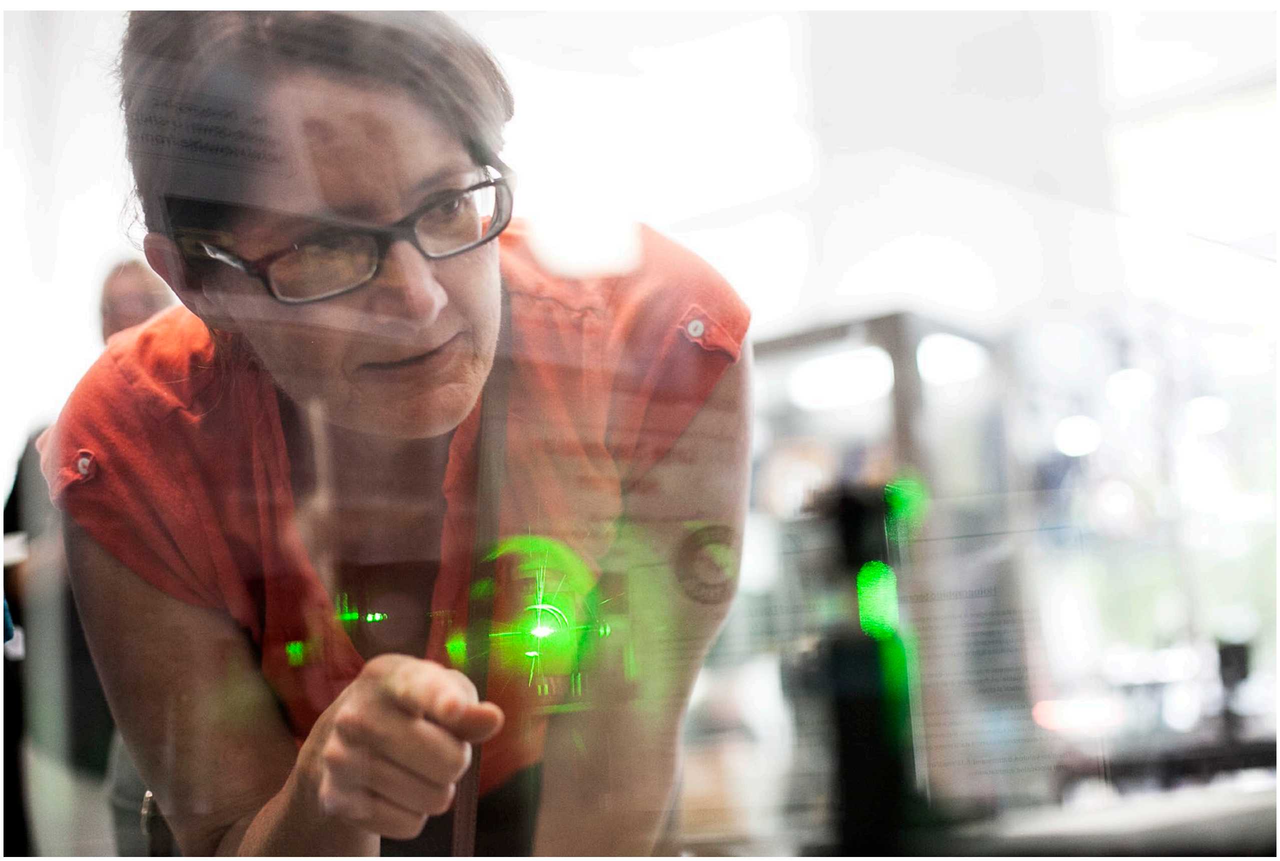
Teaching Others: What goes into a workshop?

Part of this workshop is to learn how to engage participants in their own learning and create "why do I want to know this" within the individual. The same should apply if you conduct this workshop with others. Your job is to model all the engagement techniques conducted during this workshop.

Often, teachers or presenters are reluctant to use an inquiry based model because they say they don't know all the possible answers which may come up from the various questions. The best answer to a question you don't know is "I don't know but lets try some things to find out." And use this as a jumping off point for additional learning. This is the best model for participants to see in a presenter. When they see that you are comfortable with your lack of knowledge about a question and are unafraid to explore more, they will have more confidence in their exploration.

<u>What should you do to prepare for a workshop?</u>

- Consider the amount of time you have and plan accordingly.
- Prepare information, handouts, or worksheets for participants, but don't overdo it. The workshop should not be overly scripted because this defeats the purpose of learning about inquiry and engagement.
- Gather supplies and materials and have them organized so the workshop follows.
- Try to determine the backgrounds of the audience in advance.
- Always do activities that use an inquiry model. Use the activities to engage them in the concept being introduced.



Interactive Techniques

While there are many more activities that are used in the classrooms, these techniques, are the most useful when engaging participants in formal and informal settings. The very nature of these assessments drives interactivity and brings several benefits. Students are revived from their passivity of merely listening to a lecture and instead become attentive and engaged, two prerequisites for effective learning. These techniques are often perceived as "fun", yet they are frequently more effective than lectures at enabling student learning.

Circle any that appear interesting to you. Not all techniques listed here will have universal appeal, with factors such as your teaching style and personality influencing which choices may be right for you.

1. **Misconception Check** – Discover class's preconceptions. Useful for starting new chapters.
2. **Categorizing Grid** – Hand out rectangles divided into cells and a jumbled listing of terms that need to be categorized by row and column.
3. **Defining Features Matrix** – Hand out a simple table where students decide if a defining feature is PRESENT or ABSENT. For instance, they might have to read through several descriptions of theories and decide if each refers to behaviorist or constructivist models of learning.
4. **Pro and Con Grid** – Students list out the pros and cons for a given subject.
5. **Approximate Analogies** – Students provide the second half of an analogy (A is to B as X is to Y).
6. **Applications Cards** – Students write on a card a real-world application of a concept or principle they just learned.
7. **Classroom Opinion Polls** – Informal hand-raising suffices to test the waters before a controversial subject.
8. **Everyday Ethical Dilemmas** – Present an abbreviated case study with an ethical dilemma related to the discipline being studied.
9. **Drawing for Understanding** – Students illustrate an abstract concept or idea. Comparing drawings around the room can clear up misconceptions.
10. **Pass the Chalk** – Provide chalk or a soft toy; whoever has it must answer your next question, and they pass it on to the student of their choice.
11. **Using Pictures** – Show a picture and ask students to write about it using terms from lecture, or to name the processes and concepts shown.
12. **Student Pictures** – Ask students to bring their own pictures from home to illustrate a specific concept.
13. **Choral Response** – Ask a one-word answer to the class at large; volume of answer will suggest degree of comprehension.
14. **Total Physical Response (TPR)** – Students either stand or sit to indicate their binary answers, such as True/False, to the instructor's questions.
15. **Think-Pair-Share** – Students share and compare possible answers to a question with a partner before addressing the larger class.
16. **Line Dance** – Students line up according to their level of agreement on a controversial subject: strong agreement on one side, strong disagreement on the other.

17. **Four Corners** – Put up a different topic in each corner of the room and ask students to pick one, write their ideas about it down, then head to "their" corner and discuss opinions with others who also chose this topic.
18. **Think Break** – Ask a rhetorical question, and then allow 20 seconds for students to think about the problem before you go on to explain. This technique encourages students to take part in the problem-solving process even when discussion isn't feasible. Having students write something down (while you write an answer also) helps assure that they will in fact work on the problem.
19. **Optimist/Pessimist** – In pairs, students take opposite emotional sides of a conversation. This technique can be applied to case studies and problem solving as well.
20. **Pop Culture** – Infuse your lectures, case studies, sample word problems for use during class with current events from the pop culture world. Rather than citing statistics for housing construction, for instance, illustrate the same statistical concept you are teaching by inventing statistics about something students gossip about, like how often a certain pop star appears in public without make-up.
21. **Opposites** – Instructor lists out one or more concepts, for which students must come up with an antonym, and then defend their choice.
22. **Ranking Alternatives** – Teacher gives a situation, everyone thinks up as many alternative courses of action (or explanations of the situation) as possible. Compile list. In groups, now rank them by preference.
23. **Imaginary Show and Tell** – Students pretend they have brought an object relevant to current discussion, and "display" it to the class while talking about its properties.
24. **Movie Application** – In groups, students discuss examples of movies that made use of a concept or event discussed in class, trying to identify at least one way the movie-makers got it right, and one way they got it wrong.
25. **Pictionary** – For important concepts and especially terms, have students play pictionary: one draws images only, the rest must guess the term.
26. **Super-Password** – Also for concepts and terms; one student tries to get his partner to say the key term by circumlocution, and cannot say any of the "forbidden words" on a card prepared ahead of time.
27. **Find the Company** – Students search the Internet for a corporation that makes use of concepts/ideas from class, and must defend their choice in the next class session.
28. **Six Degrees of "RNA Transcription Errors"** – Like the parlor game "Six Degrees of Kevin Bacon" (in which actors are linked by joint projects), you provide groups with a conceptual start point and challenge them to leap to a given concept in six moves or fewer. One student judge in each group determines if each leap is fair and records the nature of the leaps for reporting back to the class.
29. **Word of the Day** – Select an important term and highlight it throughout the class session, working it into as many concepts as possible. Challenge students to do the same in their interactive activities.
30. **Group-Decided Question** – Stop class, group students into fours, ask them to take five minutes to decide on the one question they think is crucial for you to answer right now.
31. **Truth Statements** – Either to introduce a topic or check comprehension, ask individuals to list out "It is true that..." statements on the topic being discussed. The ensuing discussion might illustrate how ambiguous knowledge is sometimes.
32. **Brainstorming on the Board** – Students call out concepts and terms related to a topic about to be introduced; the instructor writes them on the board. If possible, group them into categories as you record the responses. Works to gauge pre-existing knowledge and focus attention on the subject.

Sources:

Thomas A. Angelo/K. Patricia Cross, Classroom Assessment Techniques. 2nd Edition. Jossey-Bass: San Francisco, 1993.

Alison Morrison-Shetlar/Mary Marwitz, Teaching Creatively: Ideas in Action. Outernet: Eden Prairie, 2001.

Additional materials provided by Kevin Yee and Lori Mumpower

Checklist for Preparing Outreach Activities

- ☐ Determine the setting – formal or informal?
- ☐ What is the format?
- ☐ How much space will you have?
- ☐ How can you interact with participants?
- ☐ How many will be in attendance?
- ☐ Who is your audience?
- ☐ How much time will you have for individual activities and overall?
- ☐ Is there electricity?
- ☐ What is the budget like?
- ☐ How will you explain the activity using simple language?
- ☐ Is the activity relevant to the audience?
- ☐ Do you have enough supplies?
- ☐ How will it be transported?
- ☐ What other items will you have on display, such as banner, signage, handouts?
- ☐ Will the items be organized for rapid deployment?

Suggested General Materials

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<tr>
<td>Large Plastic Storage Containers such as a Rubbermaid Tote Storage</td>
<td>Plastic Shoe Boxes with lid such as Sterilite Storage Box with Lid</td>
<td>Plastic Storage Bags such as Ziploc Gallon Bags</td>
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<tr>
<td>Extension Cords</td>
<td>Power Strips</td>
<td>Scissors and Tape</td>
</tr>
<tr>
<td></td>
<td colspan="2"></td>
</tr>
<tr>
<td>Foldable Hand Truck</td>
<td colspan="2">Lamp Holder, Ceiling Box, and 6 Foot Extension Cord
To build your own lamps.
(Cut off female end of extension cord, strip the two lead wires. Thread through the openings on side of Ceiling Box and connect to the terminals on the Lamp Holder. Screw to the Ceiling Box)</td>
</tr>
</table>

Contact Information and Resources

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Resources available on our website or email Mike McKee:

- Lesson Plans: Light: A Lab Manual for Teachers
- A Primer on Photonics: Bachelor of Science in Photonic Science and Engineering: A Degree for the 21st Century
- Information about Photonics: http://optics.creol.ucf.edu
- A Photonics Competition: http://competition.creol.ucf.edu
- Posters for Teachers


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