The National Optical Astronomy Observatory's

International Year of Light 2015 Quality Lighting Teaching Kit

Instructor Guide

Presented by

NOAO

INTERNATIONAL YEAR OF LIGHT 2015

In partnership with

IAU

INTERNATIONAL YEAR OF LIGHT 2015

COSMIC LIGHT

SPIE. cie

OSA The Optical Society

ida INTERNATIONAL DARK-SKY ASSOCIATION

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About the IYL2015 Quality Lighting Teaching Kit: Enlightening our Future with Responsible Lighting

History

The International Year of Light and Light-Based Technologies 2015 (IYL2015) is a United Nations sanctioned global initiative to "highlight to the citizens of the world the importance of light and optical technologies in their lives, for their futures, and for the development of society" (www.light2015.org/Home/About.html). IYL2015 has six (6) main themes. The Quality Lighting Teaching Kit (hereafter, the QLT Kit) is a cornerstone project of the Cosmic Light theme. Cosmic Light explores how light of all types is used by and affects astronomers. One of the key ways that astronomers are affected by light is by light pollution. The QLT Kit not only raises awareness of light pollution and its effects on astronomers, but it shows that light pollution is an issue of importance for everyone and that it has real, tractable solutions.

This kit was developed by the Education and Public Outreach Department of the National Optical Astronomy Observatory (NOAO) in Tucson, Arizona, United States. NOAO is the US national observatory operated by the Association of Universities for Research in Astronomy, Inc. (AURA) under cooperative agreement with the National Science Foundation (NSF). The development of this kit was supported by grants from the International Astronomical Union (IAU) and the Optical Society of America (OSA). Partners in the project are the IAU, OSA, the International Society for Optics and Photonics (SPIE), the International Commission on Illumination (CIE), and the International Dark-Sky Association (IDA).

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Central Ideas

Light pollution is a solvable problem, and reducing light pollution is attainable. Even though outdoor lighting is necessary, it can be used and implemented in responsible ways that reduce light pollution and its effects.

Essential Questions

The following fundamental questions should guide student thinking throughout all activities:

- What is light pollution?
- What is quality lighting?
- How can we achieve quality lighting?
- How can we solve the three basic types of light pollution?
- How can we be more energy efficient with lighting?
- How can we minimize light pollution? How can *I* make a difference?

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Learning Objectives and Outcomes

By the end of these activities, students will be able to:

- apply what they've learned about light pollution to design solutions to modern, outdoor lighting problems.
- identify and define the three kinds of light pollution (glare, sky glow, light trespass) and demonstrate them in a model setting.
- demonstrate ways to minimize light pollution in real applications.
- describe the effects light pollution has on human health, safety, and the environment/wildlife.
- compare different kinds of outdoor lighting.

Broader learning goals include:

- reading information critically to extract essential points.
- synthesizing information from a variety of sources and media.
- determining an underlying, broader problem from specifics.
- weighing pros and cons and ideas and solutions.
- thinking critically about implications and impacts of solutions.
- working as a team and working with other teams.
- giving constructive feedback.

Grade Level

The QLT Kit is designed for students in US grades 6-10 (ages 12-16). However, the activities can easily be adjusted for use through the undergraduate (college, university) level. Adjusting the activities to be used in lower grades (elementary, primary) may be difficult due to the nature of several of the activities.

Educational Standards

The activities in this kit fulfill the following Next Generation Science Standards (NGSS) for middle (MS) and high (HS) school in the USA. More details about these standards can be found at www.nextgenscience.org/search-standards.

- MS-ESS3-3
- MS-ETS1-1
- MS-ETS1-2
- MS-ETS1-3
- HS-ESS3-2
- HS-ESS3-4
- HS-ETS1-1
- HS-ETS1-2
- HS-ETS1-3

The kit also meets the following International Technology and Engineering Educators Association standards. More details about these standards can be found at www.iteea.org/TAA/PDFs/Execsum.pdf.

Middle School

- The Effects of Technology on the Environment
  - Environmental vs. economic concerns
- The Attributes of Design
  - Design leads to useful products and systems
  - There is no perfect design
  - Requirements

- Engineering Design
  - Iteration
  - Brainstorming
  - Modeling, testing, evaluating, and modifying
- Apply Design Processes
  - Apply design process
  - Identify criteria and constraints
  - Model a solution to a problem
  - Test and evaluate
- Use and Maintain Technological Products and Systems
  - Use computers or calculators

High School

- The Effects of Technology on the Environment
  - Conservation
  - Reduce resource use
  - Reduce negative consequences of technology
  - Decisions and trade-offs
- The Attributes of Design
  - The design process
  - Design problems are usually not clear
  - Designs need to be refined
  - Requirements
- Apply Design Processes
  - Identify a design problem
  - Identify criteria and constraints
  - Refine the design
  - Evaluate the design
  - Reevaluate the final solution(s)
- Use and Maintain Technological Products and Systems
  - Document and communicate processes and procedures

The kit satisfies the following Common Core English Language Arts Science and Technical Subjects Standards for the USA. More information about these standards can be found at www.corestandards.org/ELA-Literacy/RST/introduction/.

- CCSS.ELA-LITERACY.RST.6-8.1
- CCSS.ELA-LITERACY.RST.6-8.2
- CCSS.ELA-LITERACY.RST.6-8.3
- CCSS.ELA-LITERACY.RST.6-8.4
- CCSS.ELA-LITERACY.RST.6-8.9
- CCSS.ELA-LITERACY.RST.9-10.1
- CCSS.ELA-LITERACY.RST.9-10.2
- CCSS.ELA-LITERACY.RST.9-10.3
- CCSS.ELA-LITERACY.RST.9-10.4
- CCSS.ELA-LITERACY.RST.9-10.9
- CCSS.ELA-LITERACY.RST.11-12.2
- CCSS.ELA-LITERACY.RST.11-12.3
- CCSS.ELA-LITERACY.RST.11-12.4
- CCSS.ELA-LITERACY.RST.11-12.7
- CCSS.ELA-LITERACY.RST.11-12.8
- CCSS.ELA-LITERACY.RST.11-12.9

The energy activity in particular satisfies the following Common Core Math Standards for the USA. More information about these standards can be found at www.corestandards.org/Math/.

- CCSS.MATH.CONTENT.7.NS.A.3
- CCSS.MATH.CONTENT.HSN.Q.A.1

The City of the Future Essay Contest satisfies the following Common Core English Language Arts Writing Standards. More information about these standards can be found at www.corestandards.org/ELA-Literacy/WHST/introduction/.

- CCSS.ELA-LITERACY.WHST.6-8.1
- CCSS.ELA-LITERACY.WHST.6-8.4
- CCSS.ELA-LITERACY.WHST.6-8.6
- CCSS.ELA-LITERACY.WHST.6-8.7
- CCSS.ELA-LITERACY.WHST.6-8.9
- CCSS.ELA-LITERACY.WHST.9-10.1
- CCSS.ELA-LITERACY.WHST.9-10.4
- CCSS.ELA-LITERACY.WHST.9-10.6
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- CCSS.ELA-LITERACY.WHST.11-12.1
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- CCSS.ELA-LITERACY.WHST.11-12.7
- CCSS.ELA-LITERACY.WHST.11-12.9

Adaptations for After-School Use
This Instructor Guide will be directed toward use in a traditional classroom. However, this can be easily adapted for use in an after-school or club environment. One way to do this is to have all students tackle each of the problem areas over the course of several meetings.

Diagnostic Assessment

For the Students
The diagnostic assessment consists of online (or paper version) pre- and post-assessments for the students. How to access the online surveys (or copies of the paper versions) will be emailed to the instructors. The assessments provide a way to evaluate student understanding and growth as a result of the lesson. Written surveys for both the pre- and post-assessments must be sent back either electronically (after scanning) to cwalker@noao.edu or by mail to Connie Walker, NOAO, 950 N Cherry Ave, Tucson AZ 85719, USA within a week after they were given.

Estimated Time Needed
The pre- and post-assessments should take no more than 15 minutes apiece. The pre-assessment should be done at least a day before the start of the activity. The post-assessment should be done at most a day after the final presentations.

Sequence
The instructor should hand out the pre-assessment and allow the students time to complete the assessment before beginning the activity. The same should be done for the post-assessment after the final presentations.

For the Instructors
There will also be a post-survey for the instructors to be taken after instruction is complete. Written surveys for the instructors can be completed online or on paper. If written, surveys must be sent back either electronically (after scanning) to cwalker@noao.edu or by mail to Connie Walker, NOAO, 950 N Cherry Ave, Tucson AZ 85719, USA within a week after they were taken.

Introducing the Activity

Before You Begin

Before beginning the lesson, there is some basic set up. This will include:

- Reading through this instructor guide in its entirety.
- Covering the windows of the room with black trash bags to darken the room as much as possible.
- Constructing the house, which will be used for the Light Trespass case study. Cut along the dotted lines and fold on the solid lines. Tape the flaps on the interior of the house to make it sturdy.
- Posting the ten (10) posters around the room where there are visible and accessible to the students.
- Putting batteries in all of the flashlights, the lux meter, and in the star projector. Batteries are included in the kit.
- Gathering materials for the students including pencils, markers, colored pencils, paper, tape, etc.
- Optional: printing out the *Problem Solving Sheets* (on the flash drive). These sheets will help the students organize their thoughts, but are not necessary. If the students use science journals the same information can be recorded there.

Optional Pre-Activities

One way to introduce this activity is to have the students take pictures of outdoor lights at night where they live before the activities are started. Questions for the students to think about while they take pictures include:

- What is the purpose of outdoor lights at night?
- How are the lights near where I live similar or different to one another?
- Is there anything I like about the lights? Is there anything I dislike?

While this activity may not be possible in all areas, another option is for the instructor to take pictures and show them to the class. Additionally, pictures of different kinds of outdoor lights can be found online. This is an optional part of the activity, but it can lead to a useful discussion about light pollution when introducing the activity. This should be done a few days before the start of the activity and the results discussed before the activity is introduced.

Another way to introduce the activity is to have the students participate in Globe at Night (www.globeatnight.org). Globe at Night is an international citizen science program to measure light pollution across the world. Using a pre-assigned constellation during certain times of the month, students will match the constellation they see in the sky to one of the provided charts. Simply put, the more stars in that constellation they can see, the darker that area is and the less light pollution there is. More information and materials can be found on Globe at Night's website. While, again, this may not be possible to do in all areas, it is another optional way to introduce the project.

Estimated Time Needed

The introduction will take about 45 minutes or one traditional class period.

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Introducing the Premise

Introducing the activity properly is crucial to the students' understanding. This challenge is modeled in a problem-based learning style, meaning that after the challenge is introduced and posed, the instructor will take on a role of a moderator, stepping in only when the students have questions or are stuck; this is very much a student-centric activity. For more information on problem-based learning, see the supplemental links at the end of this document.

The premise of this activity is that the instructor is the mayor of a fictitious city in which the students live. The mayor has been receiving complaints from citizens of the city, which all have to do with the lights in the city (See the *Issues Poster*). The students have been assembled into a task force to determine the underlying problem expressed in the complaints as well as to come up with feasible solutions to those problems. The complaints have been sorted into the following six (6) categories:

1. Energy
2. Safety
3. Glare
4. Animals
5. Night Sky
6. Light Trespass

The case studies above have been ranked from hardest to easiest. When dividing into groups, it may be worth keeping in mind that the Energy case study may be more challenging and time consuming for certain students than for others. While the energy case study is one of the more rewarding case studies, the instructor may wish to not assign it.

Once the groups have been assigned, draw their attention to the *Our Globe at Night Poster*. This poster shows the world at night from space. Have the students find their city on the poster. Was it easy or difficult to find their city? Why? Which areas are bright and which are dark? What is this light being used for (if anything)?

General Sequence

On the *Issues Poster*, there are complaints from citizens that are specific to each case study. Each student group will have a unique case study poster with information and instructions specific to that group. They will also each have a box and/or clear envelope with materials that will be used in the "Now Try This!" section of their poster. In working to determine and solve the problems, the students should follow the steps as outlined on the *Problem Solving Poster*. Each group should:

1. • Read the complaints from the *Issues Poster* that pertain to their case study. Students should write down the issues voiced in the complaints.
2. • Read the information presented in their poster. The "Now Try This!" section gives instructions for an experiment, game, or activity to complete in order to gain more understanding of the problem they are presented with. They should use the materials in their box and/or envelope to complete this activity. Specific details for each group's activity are listed in the following section.
3. • Write down a statement of the problem based on the issues raised in the complaints, the information presented in the poster, and the results of their activity. There may be more

than one problem; however, the problems should capture as many of the issues as possible.

4. • Brainstorm solutions to their problem. The students should carefully consider the implications (both positive and negative) of their solutions as well as any exceptions where their solutions may not work.
5. • Determine if there is any other information they need to better understand the problem or have better solutions. This may involve re-reading the information in their poster, re-doing their activity, or using the links provided at the end of this document or key ideas from the poster to research more about their problem.

The above steps are color coded to correspond to the steps in the *Problem Solving Poster*. On the flash drive, there are optional worksheets (*Problem_Solving_Sheets.pdf*) that are color coded for each step should the instructor wish to use them. They are simply to help the students organize their thoughts.

Case Study Activities

In addition to the *Issues Poster* and each group's case study poster, there is a box and/or envelope with an activity, experiment, or game in order to gain additional insight into the issues, problem, or solutions. Instructions for each group's activity can be found in the "Now Try This!" section of their poster. Additional information and background is provided below. Please note that files for handouts & posters are also provided on the flash drive in the General Supplies box.

Estimated Time Needed

The time needed for the students to complete their research, experiments, and to generate solutions will vary depending on the age and ability of the class. At least two traditional class periods (equivalent to two hours) should be allocated to this portion of the program.

Energy

Materials provided (in a clear plastic envelope) in the kit (unless otherwise noted) include:

- *Energy Calculation Mat* (in the poster tube)
- *Energy Calculation Worksheet* handout
- *Energy Calculation Worksheet* page 10 (to replace the "Start Here" section on the Second Side of the *Energy Calculation Mat*
- *Types of Lights* handout
- Wet erase markers
- Houston at night sheet

Additional materials needed include:

- Colored markers, crayons, or pencils

The energy activity is the most challenging. Students in this group should be carefully selected.

In this activity, students are given an aerial nighttime view of Houston, Texas, USA with a grid superimposed on top (if additional sheets need to be printing, they must be in color). There are three different colors of lights shown in the image: white (along the highways), yellow (the blobs on the right side, these are oil refineries), and brown (everywhere else). The students will count the number of squares of each colored light to determine how much energy, cost, and carbon

footprint this city uses and wastes each night. These values accurately reflect the actual energy usage of Houston as well as the type of lights currently used.

Afterwards, they will use the *Types of Lights* handout to determine a more energy efficient scenario by changing the types and/or wattages of the lights or by implementing timers or motion sensors to limit the amount of time the lights are on. If time is limited, this part may be omitted and replaced with a discussion among the students about how they would make the scenario more energy efficient.

All of these calculations can be done on the double-sided *Energy Calculation Mat*, which can be written on using the wet erase markers. Or handouts (*Energy_Calculation_Worksheet.pdf*), mirroring the *Energy Calculation Mat*, can be used as well.

Safety

Materials provided in the kit include:

- Lux meter (battery inside) (in the main container)
- Recommended Light Levels file (on flash drive: *LightLevels_indoor+outdoor.pdf*)

It is a common misconception that more light is safer; however, this is not always true. While light is needed to see and be safe at night, poorly designed or placed lights can actually be less safe! Poorly shielded or glaring lights provide areas for criminals to hide; criminals also exploit the false sense of security people feel in overly lit areas. In this activity, students will use a lux meter to measure light levels of different scenarios and compare their results to standardized lighting levels.

More detailed standardized lighting levels (in addition to that on the poster) can be found in the brightness level tables for indoor and outdoor lighting located in a file on the flash drive labeled "*LightLevels_outdoor+indoor.pdf*". It is an instructor resource with information that can be provided to the students at the instructor's (Mayor's) discretion. It offers lighting level comparisons to natural sources outdoors, to roadways, sidewalks, and intersections, to recommended light levels indoors (such as in a workplace).

When students are measuring light levels from different light sources using the luxmeter, they can choose whatever distances they wish, as long as they use the same distances for as many light source as possible (for comparison). The student or instructor will be responsible for making tables to record measurements.

Glare

Materials provided (in a blue-lid, Ziploc box) in the kit (unless otherwise noted) include:

- Mini-Maglite (batteries in package)
- Flashlight and 2 D batteries
- Book light (batteries inside)
- Four (4) inkjet transparencies on a ring
- Tape measure
- Eye chart (at the bottom of the kit)

Additional materials needed include:

- Tape (to hang the eye chart)

One of the three main types of light pollution is glare, which is caused by an exposed bulb. The bulb is overly bright and can severely impair vision, especially while driving at night. Glare is worse for older adults with aging eyes. Nearly everyone over the age of 60 has cataracts to some degree. Cataracts cloud the lens inside the eye causing blurriness and yellowing of images. The clouding also means that light scatters more inside the lens. In addition, as the eyes age, the pupil can lose some of its ability to dilate or contract under changing lighting conditions. When a glaring light enters the pupil in an aging eye, the pupil may not contract and can let too much light in. This can be both painful and unsafe. Therefore, glare is much more of a problem for aging eyes.

In this activity, the students will explore glare from a "headlight" (the Mini-Maglite) at night (in a darkened room). They will try to read the eye chart posted 20 feet (6 meters) away. In the United States, "perfect" or 20/20 vision means that the person can read line 8 from 20 feet away. Students will explore how glare affects their reading ability. The transparencies will simulate varying degrees of cataracts from very mild to severe. The students will then explore how cataracts (both with and without a glaring light) can impair their reading ability.

For this activity, the cap (reflector) should be kept on the Mini-Maglite. (Please note that if the reflector is removed, the bulb is *very* hot.) When shining the light toward the other students' eyes, the reflector should be adjusted to minimize the size of the spot of light is makes. In addition, the large flashlight should be positioned so that the eye chart is uniformly illuminated in the darkened room. The instructor may need to assist with these items.

Two "*Going Further*" ideas could include: 1) adding "BluBlocker" glasses to the experiment, or 2) adding a basketball hoop to the experiment. The basketball hoop would be used to challenge the students to make a basket with a NERF ball at 20 feet while the inkjet transparencies were held in front of the eyes and someone shined the Mini-Maglite toward their eyes.

Animals

Materials provided (in the clear plastic envelope) in the kit (unless otherwise noted) include:

- Game board (at the bottom of the kit)
- Game pieces (buttons)
- Two deck of game cards (Migration Cards and Nesting Cards)
- A dice
- Instruction sheet
- *Kirkland's Warblers Facts* sheet

Students in this group will explore how light pollution affects animals, specifically birds. They will play a game in which they are Kirtland's Warblers, which migrate from the Bahamas to the Great Lakes region of the United States and back again. Along the way, they fly through many major cities. Each year, up to 1 billion birds are killed by crashing into buildings in North America alone. Lit buildings at night cause many of these deaths and injuries. Birds and other

animals use the sun or stars to navigate, and the lights can confuse the animals causing them to circle the building and collapse from exhaustion. In addition, lights can cause eggs to hatch earlier than they would otherwise. All of these issues are explored in the game. After the students have played the game, they should look at any cards they did not use and discuss what happened.

A great "*Going Further*" idea is to have the students research and design a game centered on where they live and on an animal that is threatened by light pollution.

Night Sky

Materials provided (in a blue-lid, Ziploc box) in the kit (unless otherwise noted) include:

- Mini-Maglite (batteries in package)
- Book light (batteries included)
- Ping pong ball (with a small hole for Maglite bulb)
- Black PVC cap
- Black construction paper (2 pieces)
- Star Master projector (in main container) and 3 AA batteries
- Aluminum foil (in main container)
- 4"x4"x4" white box (substitute star projector)
- "*Planetarium Box Construction*" instructions (on flash drive)

Possible materials needed include:

- White paper (standard size)
- Thimble, sewing needle and thumb tack for white "Planetarium" box
- Black electrical tape for white "Planetarium" box

The second major type of light pollution is sky glow, in which lights from a city shine up into the sky. This light scatters off of dust, water, smog, clouds, and other things in the atmosphere creating a light dome or glow over the city. Sky glow washes out the stars from view; as a result, most people in cities have never seen a dark night sky. The dark night sky has inspired the arts, literature, philosophy, and many other areas of our cultural heritage.

In this activity, the students will use the star projector to determine how different kinds of lights and shields affect the number of stars that can seen. The star projector has two buttons on the side called "LED" and "Stars". One of the two buttons will turn on the white lights, and the second button activates colored lights. Only the white light button should be used. When the white light is on, the only stars the students need to focus on are the ones within the circle at the top of the projector. To see the stars, the students should hold a sheet of white paper a few inches above the box so that the entire circle is as big as possible on the paper and the stars are sharply in focus. The students can then try the different kinds of lights and shields as described in the "Now Try This!" section of their poster to see the effects on the night sky and come up with possible solutions to mitigate the effect of light pollution.

Start with no light and have the students count the stars within the circle. Then have a light as close as possible to the Star Master projector. Keep the same procedure for what ever light or different configuration with the light is used. For instance, use the same distances away from the

source for each light (perhaps against the Star Master and 3" away) and different configuration (e.g., place the book light level, place the book light at 45 degrees, use the globe light with ping pong ball, use the globe light without ping pong ball, use the PVC cap and then the aluminum foil as shields on any of the previous four configurations). (The PVC cap is hard to use with the book light.) Have the students make a table with these parameters (light used, light configuration, shielded or not, distance, etc.), so they can comparatively record how many stars they estimate in each circumstance. What conclusions do they draw from the amount of light and the number of stars? How would they solve the problem?

Please note that when the reflector is removed from the Mini-Maglite, the light will stay on and the bulb gets *very* hot. Therefore, the instructor should remove the cap and put the ping pong ball over the exposed bulb (via a little hole in the ping pong ball). The reflector can then be used as a stand.

When turning the Star Master projector on and off, it should be handled by the instructor as well, as it is not robust. As a back-up, a 4"x4"x4" white box is included in the kit along with a template for the constellation field of Orion and directions to poke holes for stars in the box's lid. (The instructions are in a file called QLTkit_*PlanetariumBoxConstruction.pdf* on the flash drive.)

Light Trespass

Materials provided (in a blue-lid, Ziploc box an a clear plastic envelope) in the kit (unless otherwise noted) include:

- Mini-Maglite and batteries
- Book light and batteries
- Ping pong ball
- Black PVC cap
- City mats (3 sheets)
- House mat (assembly needed)
- Plastic figurine of a person
- Aluminum foil (in the main container of the kit)

The third type of light pollution is light trespass, where light goes where it is not needed, wanted, or intended. The most common example of light trespass is a streetlight shining into a window at night. This can make sleeping (even with curtains or blinds) difficult. The light is not shining where it is supposed to and is trespassing on other property. Light at night, in particular, can have health effects on humans. Blue light (which is common in most LEDs) is especially bad because blue light at night inhibits the production of melatonin. Melatonin is a hormone, which is only replenished when asleep in the dark. Other sources of blue light such as computer, tablet, and cell phone screens before bed also inhibit melatonin production.

In this activity, the students will have a 40:1 scale model of a street, complete with a house, a person, a streetlight with a slight drop-down Cobra lens (the booklight) and a globe light (Mini-Maglight with the ping pong ball).

Keep the same procedure for what ever light or different configuration with the light is used. To start, set one light at a time across the street from the window of the house. Use the same distances away from the source for each light and different configuration (e.g., place the book light level, place the book light at 45 degrees, use the globe light with ping pong ball, use the globe light without ping pong ball, use the PVC cap and then the aluminum foil as shields on any of the previous four configurations). (The PVC cap is hard to use with the book light.) Have the students make a table with these parameters (light used, light configuration, shielded or not, distance, etc). Students can repeat the process with a second (closer) distance from the window of the house.

The students should try to recreate the problems voiced in the complaints poster and experiment with the position and angle of the light. They should then come up with solutions to keep the light task-oriented (e.g., find ways to shine the light where needed) and mitigate light trespass (e.g., find ways not to shine light where it's not needed).

Please note that when the reflector is removed from the Mini-Maglite, the light will stay on and the bulb gets *very* hot. Therefore, the instructor should remove the cap and put the ping pong ball over the exposed bulb (via a little hole in the ping pong ball). Use the reflector as a stand.

Presentations

A key component of problem-based learning is presenting methods and findings to an audience. After the students have completed their research and activities, determined their questions and problem, have come up with solutions and recommendations, and have analyzed the implications of their solutions, they should present this information to the other groups. Presentations can take many forms. Some ideas are:

- Oral or powerpoint presentations
- Posters
- Videos
- Skits
- Songs
- Brochure or pamphlet

Presentations should be between 5 and 10 minutes per group, plus time for questions. Students from other groups should ask thoughtful questions and give constructive feedback. A sample rubric for presentations can be found on the flash drive (*Rubric_Presentation.pdf*).

After all groups have presented, the instructor should lead a discussion in which the groups meld their ideas together. How were their ideas similar or different? Are there new ideas? How are the problems similar or different? How can the solutions be used for efficient city-wide planning for street lights?

After the presentations and discussion have concluded, the post-assessment should be given as previously described. This can be used to assess student understanding and growth during the project. More time may be needed for the post-assessment, as answers should be more thoughtful and complete.

City of the Future Essay Contest

A great follow up activity is to take what the students have learned about the problems and solutions of light pollution today and apply them to a city in the future. This portion of the activity will allow students to be as creative as they want in determining if the issues of today will still be issues 50 or 100 years from now. To introduce this portion, the teacher should draw the students' attention to the *City of the Future Poster*, which depicts an artist's concept of a futuristic city. What is similar about a city today? What's different?

In this portion, the students will write an essay describing the issues, problems, and solutions to lighting in this future city. Specific questions to address can include:

- Are the issues presented in the *Issues Poster* still relevant? Why or why not?
- Are the problems of lighting today still problems in the future? Why or why not?
- Are there new problems? How might those problems be solved in different ways?

The length of the essay can be determined by the instructor. There is a sample rubric provided on the flash drive (*Rubric_Essay_Contest.pdf*).

This can easily be turned into an essay contest between classmates. In addition, the instructor may send the winning essay from their class to the QLT Kit program director, Connie Walker (cwalker@noao.edu), to be entered into an overall essay contest featuring submissions from students around the world.

Resources for Going Further

Case Study References

The following links were used in creating the posters and may provide additional information for students.

Energy

- www.darksky.org/light-pollution-topics/energy-waste
- www.energy.gov/articles/how-much-do-you-spend

Safety

- www.darksky.org/light-pollution-topics/lighting-crime-safety
- www.physics.fau.edu/observatory/lightpol-security.html
- www.darksky.org/assets/documents/ida_safety_brochure.pdf
- www.bsl.lacity.org/downloads/business/BSLDesignStandardsAndGuidelines0507Web.pdf

Glare

- www.darksky.org/assets/documents/ida_human-health_brochure.pdf
- www.lrc.rpi.edu/programs/nlpip/lightinganswers/lightpollution/glare.asp
- www.nei.nih.gov/health/cataract/cataract_facts

Animals

- www.darksky.org/assets/documents/ida_wildlife_brochure.pdf
- www.flap.org/faqs.php
- www.darksky.org/about-ida/faqs#8
- www.darksky.org/assets/documents/PG2-wildlife-bw.pdf

Night Sky

- www.darksky.org/light-pollution-topics/night-sky-heritage
- www.mthamilton.ucolick.org/public/lighting/Pollution2.html
- www.darksky.org/about-ida/faqs#7

Light Trespass

- www.darksky.org/assets/documents/ida_human-health_brochure.pdf
- www.darksky.org/about-ida/faqs#9
- www.lighttrespass.com/index.html

Problem-Based Learning Resources

Problem-based (or project-based) learning puts the student at the center of the lesson during which they explore real-world issues. Below are some resources for instructors to learn more about this method. There are also links about engineering design, iterative processes, and giving constructive feedback.

- www.edutopia.org/project-based-learning
- www.edutopia.org/video/five-keys-rigorous-project-based-learning
- www.bie.org/Merchant2/merchant.mvc?Screen=PROD&Product_Code=PH&Category_Code=
- www.sciencebuddies.org/engineering-design-process/engineering-design-process-steps.shtml#keyinfo
- www.studygs.net/pbl.htm
- www.vimeo.com/38247060

Multimedia

- Borrowed Light Video
  - "The last patron of an abandoned observatory takes on an impossible task to show the surrounding city something incredible. A short animation about conflicting existences, natural wonders, and petty theft on a grand scale."
  - Available at www.vimeo.com/67419875
- Losing the Dark downloads
  - www.darksky.org/night-sky-conservation/290
  - Available in 18 languages
- Need-Less Light Pollution Simulator
  - www.need-less.org.uk/index.htm#lpsimulator
  - Scroll down the page

The City Dark
This DVD is included in the kit. The following sections correspond to some of the case studies:

Title of Section	Start Time	Corresponding Case Study	Description
Islands of Dark	13 min 57 sec	Night Sky	"Islands of Dark" discusses the effects of light pollution on astronomy.
Nature and the Night	21 min 35 sec	Animals	"Nature and the Night" discusses the effects of light pollution on wildlife.
Night's Shift	31 min 5 sec	Light Trespass	"Night's Shift" discusses the effects of light pollution on health.
Why We Light	40 min 8 sec	Safety	"Why We Light" discusses outdoor lighting and its relation to crime levels.
Astrofilia	44 min 30 sec	Energy	"Astrofilia" discusses ways in which light pollution & energy consumption can be reduced.

IYL2015 Links

- IYL2015:
  - Website: www.light2015.org
  - Facebook: www.facebook.com/IYLight2015
  - Twitter: www.twitter.com/IYL2015
  - Blog: www.light2015blog.org/
- Cosmic Light:
  - Webpage: www.light2015.org/Home/CosmicLight.html
- Dark Skies Awareness:
  - Webpage: www.light2015.org/Home/CosmicLight/Dark-Skies-Awareness.html

Light Pollution and Dark Skies Links

- The International Dark-Sky Association
  - Website: www.darksky.org
  - Facebook: www.facebook.com/IDAdarksky?fref=ts
  - Twitter: www.twitter.com/intldarksky
- Globe at Night
  - Website: www.globeatnight.org
  - Facebook: www.facebook.com/GlobeatNight
  - Twitter: www.twitter.com/GlobeatNight
  - Newsletter: www.globeatnight.org/newsletter/
  - Podcasts: http://cosmoquest.org/x/365daysofastronomy/meet-our-podcasters/globe-at-night/
  - Other dark skies activities: www.globeatnight.org/dsr/ and www.noao.edu/education/iyl-focus/

References for the Posters

These links were used in creating the posters and may provide additional information for students.

Problem Solving

- www.studygs.net/pbl.htm

Energy

- www.darksky.org/light-pollution-topics/energy-waste
- www.energy.gov/articles/how-much-do-you-spend

Safety

- www.darksky.org/light-pollution-topics/lighting-crime-safety
- www.physics.fau.edu/observatory/lightpol-security.html
- www.darksky.org/assets/documents/ida_safety_brochure.pdf
- bsl.lacity.org/downloads/business/BSLDesignStandardsAndGuidelines0507Web.pdf

Glare

- www.darksky.org/assets/documents/ida_human-health_brochure.pdf
- www.lrc.rpi.edu/programs/nlpip/lightinganswers/lightpollution/glare.asp
- www.nei.nih.gov/health/cataract/cataract_facts

Animals

- www.darksky.org/assets/documents/ida_wildlife_brochure.pdf
- www.flap.org/faqs.php
- www.darksky.org/about-ida/faqs - 8
- www.darksky.org/assets/documents/PG2-wildlife-bw.pdf

Night Sky

- www.darksky.org/light-pollution-topics/night-sky-heritage
- www.mthamilton.ucolick.org/public/lighting/Pollution2.html
- www.darksky.org/about-ida/faqs - 7

Light Trespass

- www.darksky.org/assets/documents/ida_human-health_brochure.pdf
- www.darksky.org/about-ida/faqs - 9
- www.lighttrespass.com/index.html