A Kit for Exploring Light Pollution Issues and Solutions

Connie Walker

National Optical Astronomy Observatory
Imagine Everyone Enjoying This Sky
London – 1880 first street lights
Light pollution is a global issue with local solutions...
Light Pollution affects...

Astronomical Research

Energy, Safety & Cost

Human Health

Wildlife

January 8, 2016

AAS Meeting, NSF Pavilion
I often think that the night is more alive and more richly colored than the day.

Vincent Van Gogh
Quality Lighting Teaching Kit

• One of 5 International Year of Light “Cosmic Light” projects funded by the International Astronomical Union.

• Produced by the National Optical Astronomy Observatory’s Education and Public Outreach group for IYL2015
  – Dark Skies Rangers, Dark Skies Africa, Dark Skies Yuma

• Launched in December. To be used in schools, afterschool programs, museums and national parks.

• Designed around problem-based learning scenarios.

• Adaptable to age group, venue, time allotment, etc.
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Quality Lighting Teaching Kit

Glare (Aging Eyes)

- Energy
- Wildlife
- Safety
- Sky Glow

January 8, 2016

AAS Meeting, NSF Pavilion
Overall Approach

- Teacher = Mayor of the city.
- Citizens have complaints about lighting.
- Students get into task groups to solve six issues.
- Context with respect to the City of the Future.
<table>
<thead>
<tr>
<th>Energy</th>
<th>Glare</th>
<th>Animals</th>
</tr>
</thead>
</table>
| **Dear Mayor,**  
I am a small business owner, and I rent a space in a shopping center. Our electricity bill is astronomical! We do everything we can to conserve energy at our store. Can’t you make a rule to turn off the lights after a certain time or something?  
Sincerely,  
Bill Payne |
| **Dear Mayor,**  
I have lived in this city for my entire life, but not with all your new-fangled lights on the streets. It is very hard to see while driving at night. They shine right in my eyes, which is very painful! The city should do something about this!  
Sincerely,  
Iris Auld |
| **Dear Mayor,**  
I am a representative with the city’s Audubon Society, and I love birds. Our city is on a migration path, and every year hundreds of birds are killed due to collisions with brightly lit buildings. What can we do about this?  
Sincerely,  
Birdy Knight |

<table>
<thead>
<tr>
<th>Safety</th>
<th>Light Trespass</th>
<th>Night Sky</th>
</tr>
</thead>
</table>
| **DEAR MAYOR,**  
WHY ARE OUR STREETS AND SIDEWALKS SO BRIGHT AT NIGHT? I’M WORRIED WHEN I’M OUT WALKING MY DOG THAT SOMEONE MIGHT JUMP OUT FROM THE SHADOWS AT ME AND I FEEL UNSAFE.  
SINCERELY,  
TERRI FIDE |
| **Dear Mayor,**  
Every night my neighbor’s porch light and a streetlight on our street shine right into my children’s bedroom windows. We have curtains, but the light still comes in. It is hard for them to fall asleep with the light shining in their faces. I’m sick and tired of this light trespassing onto my property! What can the city do?  
Sincerely,  
Kurt Tan |
| **Dear Mayor,**  
My daughter and I love looking at planets with our telescope at home. When I was growing up here, you could see an infinite number of stars, but now I see only a few of the brightest ones. The inspiration that was once there is now gone! There must be some way to keep the skies dark for future generations.  
Sincerely,  
Sara and Skye, Noir |

<p>| | | |</p>
<table>
<thead>
<tr>
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</tr>
</thead>
</table>
| **Dear Mayor,**  
I like to walk the bike n’ bike trail along the river at night, but the lights are really bright and make shadows near the river bank. I’m afraid that if I step out of the way of people on bikes that I could fall.  
Sincerely,  
Beau Coup-deLumiere |
| **Dear Mayor,**  
I live behind a major shopping center in town. The parking lot & building lights stay on all night. The bright lights shine into mine and my neighbors’ homes at all hours of the night. Why can’t the light be turned off after hours?  
Sincerely,  
N. Som Nie |
| **Dear Mayor,**  
I’m a member of the city’s amateur astronomy club. We hold weekly star parties in the park, as has been the tradition for many decades. But now we can’t see the stars in the Milky Way Galaxy anymore! We’re going to lose this tradition! Help!  
Sincerely,  
Luna Crater |
First, background is provided through 6 posters.

Students read the poster, search with key words, and do an activity with the kit supplies.

Then students address the issues using “PBL”

Presentations made to the Mayor.

**Problem Based Learning approach**

1. What are the issues?

2. What do we know?

3. What is the problem?

4. What are some possible solutions?

5. What do we still need to know?
Light Pollution and Safety

Safety
- Does more light mean more safety? Not necessarily!
- While we need light to see at night, bad lighting can be just as unsafe as no lighting at all!
- Glare from lights makes it harder to see, especially while driving.
- Look at the two sets of images to the right. Can you see the person in the left pictures? What about in the right pictures? What’s different about the lights in each scene?

Crime
- Lights which are glaring or overly bright can be easy hiding spots for burglars.
- Lights which are poorly shielded or glaring can create shadows where people can hide.
- People feel more safe in the light. But criminals can hide in the excessive light or shadow.
- Roughly half of all crimes are committed during the day time. Outdoor lighting by itself does not keep you or your property safer than little or no light.

Public Lighting Standards
- The table below lists minimum recommended lux or brightness levels for outdoor lights in different areas. The bigger the number, the brighter the area. Intersections of streets are lit about 2X the rest of the street.
- The Mayor will have a more detailed table of brightness levels for indoor lighting as well as for the outdoors.

<table>
<thead>
<tr>
<th>Area</th>
<th>Brightness Level (lux)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suburban Street</td>
<td>6</td>
</tr>
<tr>
<td>Highway</td>
<td>8</td>
</tr>
<tr>
<td>Major Street</td>
<td>11</td>
</tr>
<tr>
<td>Parks, Schools, Buildings</td>
<td>11</td>
</tr>
<tr>
<td>Parking Lot</td>
<td>22</td>
</tr>
<tr>
<td>Sports Stadium</td>
<td>500</td>
</tr>
</tbody>
</table>

Lighting Responsibly
- Responsible, safe lights should light up the ground without being glaring.
- Glare is caused by an overly bright, exposed bulb.
- Lights should be task-oriented, meaning that they have a specific purpose.
- How much light is actually needed? What is the minimum amount of light needed to see? Does the light cause shadows?

Now Try This!
- Take out the lux meter and read the instructions on how to use this brightness measuring device.
- To calibrate the lux meter, keep the cap on the sensor and turn the lux meter on. What should the reading be? Calibrate before each set of measurements. Always make multiple measurements per location. Record readings after each measurement, noting all pertinent details.
- You will be exploring ranges of lighting levels for different locations and deciding what minimum light levels are needed to accomplish tasks in those areas and still stay safe.
- Take the lux meter cap off to measure the brightness of a regularly lit classroom. Then make the classroom as dark as you can and repeat the measurement. Then measure the book light turned on in the dark room. Always put the meter at the point of interest. For example, in a dark classroom, the lux meter may be on the desk next to the book light where a student is reading.
- Take measurements in the school’s restroom, library and main office to see how they compare with standard light levels of 200, 300 and 500 lux, respectively. Take measurements outside in sunlight (1000 lux).
- If you can visit a home, a restaurant, a supermarket, a hospital or places in the list on the left with the lux meter, take a few measurements per area.
- If not, perhaps the Mayor can gather extra light and with a dark classroom, simulate the lighting levels corresponding to one or more areas listed in a table the Mayor will provide. For example, an operating room at a hospital is between 750 and 1500 lux.
- Compare your measurements with the Mayor’s provided list of light levels and the list to the left. Determine what numbers or range of numbers a lux meter should read to have enough light to see and stay safe, but not to over-light each area.
- How might you design a light to do this? Do all parts of the city need to be lit the same amount?
- Create a powerpoint, a video, or a poster in which the issues, problem(s), and your resulting recommendations are presented to the Mayor.

Key Ideas
- Light pollution and safety
- Public lighting and crime
- Public lighting lux levels
Light Pollution and Safety

Safety

- Does more light mean more safety?
- While we need light to see at night, it can be unsafe as no lighting also serves as a hiding spot for burglars.
- Glare from lights makes it hard to see for drivers.
- Look at the two sets of images. Which makes the person in the left picture more visible than the right? What’s different about the images?

Criminology

- Lights which are glaring or poorly shielded may serve as hiding spots for burglars.
- Lights which are poorly shielded or shining at people’s faces create shadows where people can hide.
- People feel more safe in the dark and respond better in the excessive light or shadow.
- Roughly half of all crimes are committed during the day. Outdoor lighting by itself may make property safer than little or none.

Public Lighting

- The table below lists minimum brightness levels for outdoor lighting.
- The bigger the number, the brighter the lighting level.
- The Mayor will have a more specific list of brightness levels for indoor lighting.

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</tr>
</tbody>
</table>

| Parks, Schools, Buildings  | 11               |
| Parking Lot                | 22               |

Key Ideas

- Light pollution and safety
- Public lighting crime
- Public lighting lux levels

Now Try This!

Read and the instructions in the brightness measuring device manual. Keep the cap on the meter on. What should you do before each set of readings? Make multiple measurements to record readings after each round.

Ranges of lighting levels and deciding what are needed to accomplish the task safely:

- Off to measure the bright classroom. Then make the room as bright as you can and repeat the reading to see if the light is sufficient.
- The school’s gymnasium may be on the list next.
- The school’s restrooms, to see how they compare to the measurements outside in the parking lot, in a restaurant, a supermarket, and in the list on the left with other measurements per area.
- Color can be gathered by using a light meter.
- Simulate the lighting in one or more areas listed next.
- For example, in a dark bedroom, turn on the lamp to light one area.
- Light pollution may differ from place to place.
- The city needs to have enough light to see what needs to be seen.

- Create a powerpoint, a video, or a poster in which the issues, problems, and your resulting recommendations are presented to the Mayor.
Light Pollution and Glare

Glare

- Glare is a visual sensation caused by an overly bright, exposed bulb, meaning that you can see the light bulb itself.
- Glare can be disabling or simply uncomfortable. (See section on Disability vs Discomfort Glare.)
- Older people are usually more sensitive to glare due to the aging characteristics of the eye. (See section on Aging Eyes.)
- Because glare causes pain or discomfort, it can be very unsafe. When a light is glaring to the eye, it makes it very hard to see, especially while driving.
- Have you ever been blinded by car headlights? That’s glare!
- Glare affects everyone in some way.

Aging Eyes

- Glare can severely affect people with aging eyes.
- Many people of all ages wear glasses. Glare from lights can scatter off dust, dirt, scratches, or smudges on the lenses making the effects of glare worse.
- As some people age, they lose some control of the muscle that changes the size of the pupil when light levels change. This means that if a light is very bright, the pupil will stay open wider in older people and more light will enter the eye. This can be very painful.
- Cataracts cloud the lens inside the eye. Symptoms include blurriness, lights appearing brighter, poor color perception, and difficulty seeing at nighttime. Advanced cataracts can be corrected with surgery. The clouding causes more light to scatter inside the eye. Glaring lights can cause pain and more blurring!
- Nearly everyone over the age of 60 has pre-cataracts, which can cause yellowed or blurry vision.

Disability vs Discomfort Glare

- Disability glare is the reduction in vision caused by intense light sources in the field of view, while discomfort glare is the sensation of annoyance or even pain induced by overly bright sources.
- Disability glare degrades your vision by decreasing your ability to see contrasts and color perception. The loss of vision is caused by stray light being scattered within the eye.
- With discomfort glare, the light can be so painfully bright, that is causes you to have to look away from the light.

Shielding and Dimming

- Glare is reduced when the light bulb is not exposed.
- Lights should be task-oriented, meaning they light what they were designed to light.
- When a shielded fixture or light is not exposed, often bright light is no longer needed and the wattage can be lowered.

The images show two examples of glaring lights.

Key Ideas

- Glare
- Aging eyes
- Cataracts
- Glare and safety
- Discomfort glare
- Disability glare

Now Try This!

- Post the eye chart at eye level on a wall. We’re going to use this to explore how glare affects people with and without aging eyes.
- Read the smallest line you can at a distance of 6 meters (20 feet) from the chart. Record the line number you read. For students with glasses, try to read the smallest line you can with and without your glasses. For perfect vision, you should be able to read line 8.
- Then try again with 1 layer of the fuzzy transparency immediately in front of your eyes; repeat with 2 layers, 3 layers, and then 4 layers. Each time, record the line numbers you read. The layers of transparency will simulate different severities of cataracts.
- Now make the room as dark as you can. Using the large flashlight in your box, fully illuminate the eye chart (so you can still see it). Repeat the second and third steps.
- Keeping the room lights off, have one person in the group stand near the eye chart pointing the Maglite in your eyes. Repeat the second and third steps under these conditions.
- What are the problems? Using your experience here and some background research online, formulate recommendations to solve the problems and to address the complaints from the Issues Poster for this case scenario.
- Create a powerpoint, a video, or a poster in which the issues, problem(s), and your resulting recommendations are presented to the Mayor.
Light Pollution and Glare

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Shielding and Dimming
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- When a shielded fixture orients all the light downward, often bright light is no longer needed and the wattage can be lowered.

Key Ideas
- Glare
- Aging eyes

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Light Pollution and Light Trespass

Light Trespass

• Light trespass is when light goes somewhere it is unwanted and unneeded, such as into a bedroom window at night.
• As you may have experienced, it can be hard to fall asleep or stay asleep with light shining into your room.

Blue Light at Night

• Most white lights contain all the colors of the rainbow and a lot of blue.
• Blue light at night can have negative effects on people who are frequently exposed to it.
• Because blue light waves are the right size to bounce off particles in our atmosphere, it easily scatters in our atmosphere and thereby contributes to a lot of light pollution.
• While you sleep, a chemical called melatonin is produced. Melatonin helps regulate many functions in our body. Any light at night will decrease melatonin production, but blue light suppresses production more than other colors of light.

Sleep Cycles

• Humans have a biological clock that follows the 24 hour cycle of day and night called the circadian rhythm.
• Exposure to light at night can disrupt this cycle, such as light from a streetlight coming in the window or looking at computer, tablet, or phone screens before bed.
• This can cause fatigue and insomnia (the inability to sleep at night) as well as other sleep disorders and health issues.

Lighting Responsibly

• Making sure lights are task-oriented is key to reducing light trespass. Task-oriented means the light has a specific job. How can the light be directed only where it needs to be?
• How might the height of the pole or the spacing between poles affect light trespass?

Now Try This!

• You will have a scene that includes a street, a house, a streetlight (represented by a Maglite or book light), and one figurine of a person. The person should be in the house, laying by the window as if they are sleeping.
• Place the house near the street but in the grass. Remove the cap on the Maglite, and place it on the bottom of the Maglite to be used as its base. Carefully put the ping pong ball over the bulb. Place the Maglite across the street from the house. What are your observations? Where is the light going? Where is the light not going? Where should the light be going? Try moving the Maglite to different locations. Record your observations. To log your observations, you may want to make a table. Repeat this step using the black cap provided in your box.
• Repeat the above step with the book light. Also try changing the angle of the top of the book light from 45 degrees to horizontal.
• Try to recreate the problems presented in the Issues Poster using each of the lights. What are the problems? Can you make the light go into the window?
• Think of ways to solve the issues and problems you came up with. What might your solutions look like? Can you draw a picture of it? You should also make a case for why this is an important issue. Generalize this beyond the Issues Poster. What is the purpose of the streetlight? What are the consequences (both positive and negative) of your solution(s)?
• Create a powerpoint, a video, or a poster in which the issues, problem(s), and your resulting recommendations are presented to the Mayor.

Key Ideas

• Light trespass
• Circadian rhythm
• Blue light at night
• Light shielding

• Light pollution and health
• Task-oriented lights

The photos above show two examples of light trespassing into a window. The picture below shows how a streetlight can trespass.

The National Optical Astronomy Observatory (NOAO) is the U.S. national observatory operated by the Association of Universities for Research in Astronomy, Inc. (AURA) under cooperative agreement with the National Science Foundation (NSF).
Light Pollution and Light Trespass

Light Trespass

- Light trespass is when light goes somewhere it is not wanted or needed, such as into a bedroom or a bright light shinning into a room.
- As you may have experienced, it can be a very distracting and annoying problem.

Blue Light at Night

- Most white lights contain a lot of blue.
- Blue light at night can have negative effects on your body.
- Because blue light waves are the shorter waves in our atmosphere, it easily penetrates the atmosphere and thereby contributes to skyglow and light pollution.
- While you sleep, a chemical called melatonin helps regulate many functions of your body. Shorter waves of light at night will decrease melatonin and increase the amount of light needed to wake up.

Sleep Cycle

- Humans have a biological clock that controls the cycle of day and night called the circadian rhythm.
- Exposure to light at night can disrupt your body’s natural cycle, from the blue light coming in the window to the orange light from your computer, tablet, or phone screens.
- This can cause fatigue and insomnia (the inability to sleep at night) as well as other sleep disorders and health issues.

Key Ideas

- Light pollution and health
- Task-oriented lights
- Light trespass

Lighting Responsibly

- For a given task-oriented application, the light should be directed only where it needs to be, so that the glare does not create problems, such as the light of the pole or the spacing between the lights.

How Try This!

- Create a scene that includes a street, a house, a parking lot, and a streetlight (represented by a Maglite or book light), and place it on the floor.
- The person should be in the house.
- Place the streetlight near the street but in the grass. Remove the streetlight and place it on the bottom of the house, the house, and above the house. Carefully put the ping pong ball under the streetlight.
- Place the Maglite across the street from where your observations are being made. Where is the light being lighted? Where should the light be placed? Where should the light be directed? To log your observations, you can use a table. Repeat this step using the black light box.
- Step with the book light. Also try turning off the top of the book light from 45 degrees. What are the problems presented in the Issues Poster?

Tips on ways to solve the issues:

- Turn off ways to solve the issues and problems you came up with. What might your solutions look like? Can you draw a picture of it? You should also make a case for why this is an important issue. Generalize this beyond the Issues Poster. What is the purpose of the streetlight? What are the consequences (both positive and negative) of your solution(s)?
- Create a powerpoint, a video, or a poster in which the issues, problem(s), and your resulting recommendations are presented to the Mayor.
Light Pollution and the Night Sky

Sky Glow

- Sky glow is when lights from a city shine up into the night sky. This light scatters off particles in the air causing a glowing haze over the city and washing out the stars.
- Millions of people have never seen the Milky Way in the night sky due to sky glow.
- Sky glow affects astronomers trying to study objects in outer space.
- Sky glow is evidence of wasted light, energy & resources.

The night sky inspires science and art.

Heritage

- A clear view of the night sky has been crucial for navigation for centuries.
- It has inspired art, music, literature, science, philosophy, and human curiosity in general.
- How can we preserve this piece of our cultural heritage for future generations?
- International Dark Sky Places are places dedicated to preserving a dark night sky. (See darksky.org/isp).}

An observatory with a lot of sky glow.

Now Try This!

- Keep the star projector in its box with the lid open and place a piece of black construction paper under the box. Make the room as dark as you can, and turn the star projector on by pressing the “LED” button.
- Hold a piece of white paper above the star projector to see the entire circle. Try count the number of stars you see on the paper. Record this number along with setting conditions. You may want to make a table to record this information.
- Next, take the cap off the Maglite to be used as its base, put on the ping pong ball, and place it next to the star projector. Estimate what percent of the stars are left (10%? 50%? 75%?). Record this number along with setting conditions and your observations. Repeat this step using the cap in your box to cover the light.
- Repeat the above step using the book light rather than the Maglite, both with and without the black cap on top. Also try adjusting the angle of the book light.
- Write down recommendations you have for how to maximize the number of stars while having enough light for people to still see. How can the lights be changed? Is there a better option than the lights presented? What might your solution look like? Using materials provided by the Mayor, construct a new shield to go on the lights. Be sure to test it using the star projector. What percent of stars are left with your new shield? Generalize this beyond the issues in the Issues Poster. What are the consequences (both positive and negative) of your solution(s)?
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Wasted Light

- Light going up into the night sky that creates sky glow is light that is wasted and not used where needed on the ground.
- Roughly 30% of the light used outside is wasted in this way.

Observatories & Astronomers

- Most astronomers need a dark sky to be able to study all of the faint objects in outer space.
- If a city produces too much sky glow, astronomers can no longer see faint objects, and the observatory can become unusable.
- Different types of light can affect the data astronomers collect at observatories. Lights which only emit a single color (like low pressure sodium lights) are better because astronomers can remove that one color from their data. However, white light contains all the colors of the rainbow; removing all colors would leave no data for the astronomers to use.

Key Ideas

- Sky glow
- Night sky heritage
- Globe at Night
- Light pollution and astronomy

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Light Pollution and the Night Sky

Sky Glow
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- Millions of people have never seen the Milky Way in all its glory or the night sky due to sky glow.
- Sky glow affects astronomers trying to study objects in the universe and outer space.
- Sky glow is evidence of wasted light, energy & resources.

Wasted Light
- Light going up into the night sky that creates sky glow is a type of light that is wasted and not used where needed on the ground.
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Light Pollution and Animals

**Sea Turtles**
- After sea turtles hatch, they make their way to the ocean, as shown in the picture to the right.
- Normally, sea turtles hatch at night when most predators are asleep.
- They use the light of the moon and stars reflecting off the ocean to find their way.
- If there are bright lights near the beach, the sea turtles go the wrong direction and never make it to the ocean.

**Birds**
- Migrating birds can become confused by bright lights.
- Birds will circle around the light, become exhausted, and collapse or die.
- The photograph on the bottom left shows birds circling around a very bright column of light.
- Birds can also crash into bright buildings, causing injury or death.
- It is estimated that between 100 million - 1 billion birds die from striking buildings every year in North America alone.

**Insects**
- Insects see primarily blue and purple light. Bright white lights usually have a lot of blue light.
- Insects will circle around lights, making them easy prey for predators.
- The bottom right photo shows insects flying around an outdoor light.

**Other Animals**
- Light pollution affects the habitats and habits of other animals including bats, amphibians, and marine animals.
- Some animals affected by light pollution, like sea turtles, are already endangered species.

**Sleep Cycles**
- Animals have an intrinsic biological clock that allows them to tell time.
- When animals are exposed to lights at night, this biological clock is disrupted and they become fatigued and disoriented.
- This can also disrupt migration and mating patterns.

**Now Try This!**
- You have a game board, game pieces (buttons), game cards, a die, and game instructions. In this game, you are a Kirtland’s Warbler, a type of bird, migrating north from the Bahamas to the breeding grounds in the Great Lakes region of the United States and back again. These birds mostly fly at nighttime.
- Read the game instructions for information on how to play the game.
- After you’ve played the game, discuss what happened. What are the problems? How do these related to the issues raised in the Issues Poster?
- How can you solve the problems you came up with? What are the consequences (both positive and negative) of your solutions?
- Create a powerpoint, a video, or a poster in which the issues, problem(s), and your resulting recommendations are presented to the Mayor.

Key Ideas
- Sea turtles and light
- Animal navigation
- Wildlife and light pollution

Newly hatched sea turtles (top) and insects (bottom right) are attracted to light. Birds and bats are attracted to light from the Luxor in Las Vegas, Nevada, USA (bottom left).
Light Pollution and Animals

Sea Turtles
- After sea turtles hatch, they make their way to the ocean, as shown in the picture to the right.
- Normally, sea turtles hatch at night when most predators are asleep.
- They use the light of the moon and stars reflecting off the ocean to find their way.
- If there are bright lights near the beach, the sea turtles may be led to the wrong direction and never make it to the ocean.

Birds
- Migrating birds can become confused by bright lights.
- Birds will circle around the light, become exhausted, and either crash into buildings or die.
- The photograph on the bottom left shows birds circling around a very bright light column.
- Birds can also crash into buildings, causing injuries or death.
- It is estimated that between 100 million - 1 billion birds are killed every year in North America alone.

Insects
- Insects see primarily blue and ultraviolet light. Bright white lights usually have a lot of blue light.
- Insects will circle around lights, making them easy prey for predators.
- The bottom right photo shows insects flying around an outdoor light.

Key Ideas
- Sea turtles and light
- Bird strike lights
- Animal navigation
- Wildlife and light pollution

Other Animals
- Light pollution affects the habitats and habits of other animals including bats, amphibians, marine birds, and marine animals.
- Some animals affected by light pollution, like sea turtles, are already endangered species.

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Light Pollution and Energy

Energy Waste
- All the light you see in the images is wasted. About 30% of all outdoor light is being wasted by shining upward.
- Energy is a precious resource. Most electricity is produced by burning fossil fuels, which are non-renewable and are quickly being depleted.
- How can we keep the light from going up, and instead, keep it down where we need it?

Cost
- Lighting accounts for 11% of the total energy usage in the United States by all sectors (residential, commercial, industrial, and transportation).
- In 2012, each person in the United States spent over $3,000 on energy usage.
- The United States accounts for 18% of the world’s energy consumption.
- An estimated $3.3 billion is spent on wasted energy in the United States.
- How can individuals and families reduce their energy costs? How can cities and countries reduce costs?

Carbon Footprint
- A carbon footprint is the amount of greenhouse gases emitted due to burning fossil fuels. Greenhouse gases (like carbon dioxide) contribute to climate change by trapping heat that would otherwise escape into space.
- Most electricity in the United States is produced by burning fossil fuels (39% by coal, 27% by natural gas, and 13% by petroleum). Fossil fuels are the fossilized remains of plants that lived hundreds of millions of years ago.
- For each kilowatt-hour of energy produced, 0.84 kg (1.85 lbs) of greenhouse gases are released into the atmosphere.
- An estimated 875 million trees would have to be planted every year to offset all the carbon dioxide released.

Efficient Bulbs
- One way to reduce energy waste, cost, and carbon footprint is to use energy efficient light bulbs.
- Efficiency is an output over an input, or how much light you get out for the amount of energy you put in.
- See the "Types of Lights" handout for more information.

Shielding
- Another way to help reduce energy cost is to cover the light bulb, so that the light does not go up (where it is wasted).
- Concentrating all light downward (where needed) allows for the bulb’s wattage to be reduced.
- Lights should be task-oriented, designed for a specific purpose while seeing the light on the ground, but not the bulb.

Now Try This!
- Examine the International Space Station (ISS) aerial photograph of Houston, Texas, United States found in your group’s folder. Notice the grid of squares superimposed on the city; there are 1,344 squares total. Each square of the grid is 3 km (1.8 miles) on a side.
- There are three different colors of lights on the map: white, yellow, and brown. The white lights are usually in lines following the roads, the yellow lights are blobs of densely packed lights, and the brown lights are spread all over.
- Count the number of squares of each color, marking the squares with a different colored marker or pencil. You’ll probably want to make a key. When counting squares, count any square that is more than half lit. If there is more than one type of light in one square, pick whichever light takes up more of the square. Do not double count squares!
- The white lights are 250 Watt (W) Metal Halide lights, the yellow are 150 W High Pressure Sodium lights, and the brown are 250 W High Pressure Sodium lights.
- Refer to the "Energy Calculation Mat – First Side" to see how to calculate energy, cost, and carbon footprint from these lights for one night, as well as the light being wasted in one night. Discuss your results with your group.
- Using the "Types of Lights" handout, reduce the energy, cost, and carbon footprint by changing the types of lights, number of lights, length of time the lights are on, etc. Then calculate the energy, cost and carbon footprint for the improved situation using the "Energy Calculation Mat – Second Side".
- Based on your results, make some general recommendations about the changes you made. You should also consider whether there are some places or cases in the city where their general recommendations may not work. What would work better in those cases?
- Create a powerpoint, a video, or a poster in which the case study and your resulting recommendations are presented to the Mayor.

Key Ideas
- Energy efficient light bulbs
- Energy for lighting
- Energy waste
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Key Ideas

- Carbon footprint
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The National Optical Astronomy Observatory (NOAO) is the U.S. national observatory operated by the Association of Universities for Research in Astronomy, Inc. (AURA) under cooperative agreement with the National Science Foundation (NSF).
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Quality Lighting Teaching Kit Inventory

Kit contents are color coded mainly by activity as follows:

- **General**
  - Energy
  - Glare
  - Animals
  - Safety
  - Night Sky
  - Light Trespass

- **Animals Envelopes**
  - Game Instruction
  - Kirkland’s
  - Game Card
  - Dice (1)
  - Buttons (6)

- **Light Trespass Envelopes**
  - City Mats – Street
  - City Mat – Grass
  - House – to Assemble

- **General Supplies**
  - The City Dark DVD
  - Flashdrive
  - Globe at Night postcards (30)
  - QLT Kit postcard

### Loose in Main Container

- Aluminum Foil
- Lux Meter
- Star Master Projector
- “The Migration Game” Board
- Eye Chart

### Poster Tube

- Our Globe at Night Poster
- Issues Poster
- Problem Solving Poster
- Energy Poster
- Glare Poster
5 teacher workshops, a focus group and 15 classroom visits in 2015
Summary

• Through this program, students are presented with real-life issues on light pollution’s effects on energy, wildlife, safety, light trespass, glare and the night sky.

• Posters provide background for each issue.

• Activities provide understanding of the issues through experimentation.

• “The City of the Future” poster provides inspiration for students to solve the lighting issue through the Problem-Based Learning.

• Instructional support is provided by the instructor’s guide, the video tutorial, the Google+ Hangout, the kit supplies for the activities and other documents.
A hope for the future that…

Many hands will make light work!
Interested in this kit?

• We would like to go for further funding. (Ideas?)
• Interested in future collaborations?
• Interested in receiving (or buying) a kit, email Connie Walker at cwalker@noao.edu using “QLT Kit” in the subject line.
• Websites with our light pollution activities:
  o Quality Lighting Teaching Kit  kit (11-14 yrs): www.noao.edu/education/qltkit.php
  o Initial version of the Quality Lighting Teaching Kit (14-18 yrs): www.noao.edu/education/iyl-focus/
  o Dark Skies Rangers activities (8-11 yrs): www.globeatnight.org/dsr/
  o The International Dark-Sky Association: www.darksky.org
Questions?
Globe at Night Citizen-Science

GLOBE AT NIGHT 2016

Get Out and Observe the Night Sky!

Engage people worldwide in observing the nighttime sky.
Encourage students and families to participate in citizen-science with a hands-on learning activity.
Gather light pollution data from an international perspective to monitor sky brightness and its effects.

Can you see the stars?

January 1 – 10
February 1 – 10
March 1 – 10
March 30 – April 8
April 29 – May 8
May 29 – June 7

June 27 – July 6
July 28 – August 6
August 25 – Sept 3
October 21 – 31
November 20 – 30
December 20 – 30

WWW.GLOBEATNIGHT.ORG
• With a lux meter, measure lighting levels in different situations with different lights.

• Determine the lowest level needed to function.

• Compare results with Public Lighting Standards.

• Determine what number a lux meter should read to have enough light to see, but not to over-light an area. How might you design a light to do this? Do all parts of the city need to be lit the same amount?