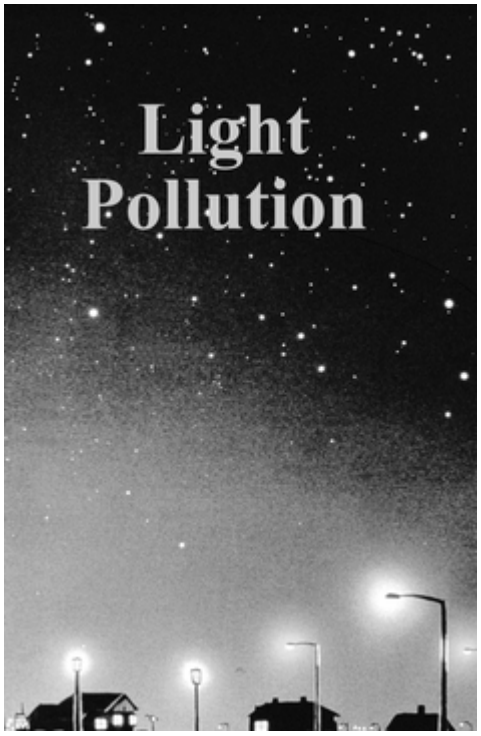
www.astrosociety.org/uitc

No. 44 - Fall 1998

Light Pollution

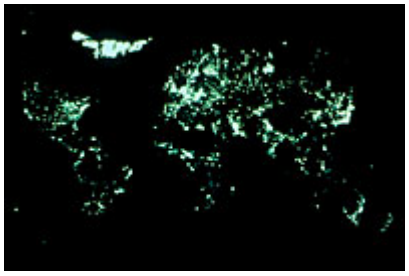


It is an unfortunate fact of today's life that most people are growing up unable to see the stars that our grandparents knew so well. The prime night sky exists only in pictures or at a planetarium. This is true not only in cities but also in suburbs and in rural areas where street lamps and other sources of "light pollution" have obscured our view of constellations, meteor showers, and even the planets.

Indeed, many children and adults say after viewing the night sky for the first time in a really dark area away from a city that "it looks just like this in the planetarium." We have lost our view of the stars, and we have mucked up our nighttime environment as well.

Such a loss might be acceptable if light pollution were the inevitable price of progress, but it is not. Most sky glow is unnecessary. The light that obscures our view of the night sky comes mainly from inefficient lighting sources that do little to increase nighttime safety, security, or utility. They produce only glare and clutter, costing more than one billion dollars annually in the U.S. alone.

For astronomy and science, the impact has been even more dramatic. Astronomers require observations of extremely faint objects that can be made only with large telescopes at sites free of air pollution and urban sky glow. For example, scientists interested in how the universe was formed may study the light of galaxies and quasars at enormous distances from Earth. These images offer information about faraway corners of the universe, helping us understand how our own world was formed. Yet, after traveling countless lightyears, the light from these objects can be lost at the very end of its journey in the glare of our own sky.



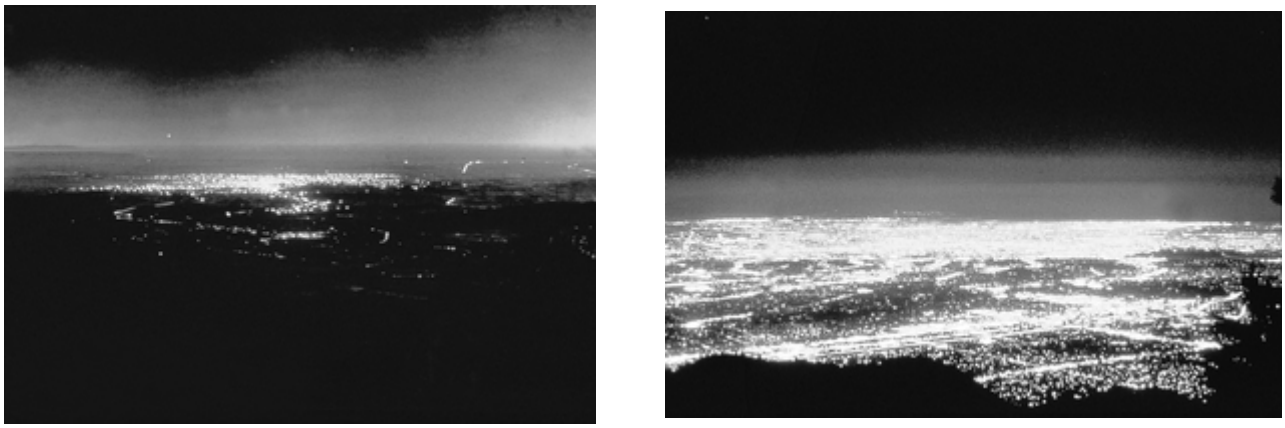
The Earth at night

Space-based telescopes, such as the Hubble Space Telescope, offer one way around the problem. However, large telescopes on the ground will always be used, if only because they are accessible and cost much less to build and operate. Our experience over the past decades has shown that rather than decreasing, our need for ground-based telescopes, even in an age of

telescopes in space, has greatly increased. But only if they can be protected from the encroaching light pollution.

Reducing light pollution is not difficult. It just makes sense, but it does require that we understand the issues and that public officials and citizens be aware of the problem and act to counter it. On an individual level, people can help reduce much sky glow by using lighting only when necessary and by choosing well shielded lighting fixtures.

Curing light pollution saves money while reducing glare and sky glow. Unlike other pollution issues, it presents us with a rare case where we should strive to be kept in the dark. The stars above us are a priceless heritage - not only for astronomers but for all humans. More of our children should be able to look up at night and see that the Milky Way is not just a candy bar.



Tripping the light (not-so) fantastic. View of Los Angeles, CA in 1908 (left) and 1988 (right).

Light Pollution

Villains and Heroes of Lights and Lighting Fixtures

If we are to reduce the effects of light pollution, we must learn about the types, both good and bad, of fixtures used in outdoor lighting. Some of these are heroes: They save energy, direct light to where it is needed, and add to the ambiance of our nighttime environment. Others are villains that waste energy, spill light in all directions, produce glare, and ruin the beauty of the night.

The Villains

Globes and similar fixtures. These usually consist of a transparent or translucent "ball" or cylinder with a lamp bulb inside, sitting atop a pole. They look attractive in the daytime when they are not turned on. In fact, this type of fixture is often chosen for this very reason.

These lights are villains because when turned on at night, they radiate not only in the direction where illumination is needed, but in all directions - more than half the light is directed upward to add to the sky glow and sideways to cause glare. Much of the rest is not doing any useful work in helping us see the things we need.

So many billboards, so much wasted light.

Billboards and signs lit from the bottom. Look at the billboards around town. How are they lit? In most cities, it is from below and not from above. If one sees the boards at night, especially in a fog, one can easily see all the up-going light, a lot of it not hitting the board surface at all, the rest bouncing off the board and going up into the sky. These are villainous lights, making a major adverse impact on urban sky glow. Can we make a "hero" of these kinds of installations? Easy, illuminate them from above so that nearly all the light hits the billboard: The light is reflected once from the board to the ground and then again off the ground before going up. This reduces the amount of up-going light a great deal.

Mercury vapor lamps. Although these lamps are not very energy efficient, and they are often found in older, inefficient fixtures that enhance light pollution, they still exist in great abundance in most locations and are still sold by the millions. Why? They are deceptively cheap. They don't cost much to buy, but they cost a lot to operate, more than any of the more modern energy-efficient lamps; over their lifetimes, they end up costing the owners much more than the efficient lamps. In addition, the style of lighting fixtures used for mercury vapor lamps is usually obtrusive, glary, and inefficient.

How do we recognize these villains? Just look for their harsh blue-white light. Mercury vapor lamps are often the illumination sources in glary "dusk-to-dawn" security lights or the so-called "barn lights" seen in rural locations.

Badly aimed or misdirected lights. Otherwise hero lights can become villains if they are badly aimed or mis-installed. Spot lights often become villains for this reason, putting their light output where it is not wanted or needed - through our bedroom windows or directly into an automobile driver's eyes. One must carefully install and aim lights to get the best performance and least glare out of them. All too often lights are installed in the daytime and never checked or aimed at night for good performance.

Wall-mounted, non-directional lighting fixtures. We have all seen these villains in action. Such a light, whatever kind of lamp it has in it, is usually mounted on a wall, often above a door or simply on the side of a

building. The building's owner wanted to illuminate the entrance or the area around the building to help with visibility and to deter criminals, but he goofed: The glare makes it difficult for visitors to see well and, thus, aids the criminal who lurks in the nearby darkness. And lights of this kind do nothing to add to the ambiance and attractiveness of the facility; they probably repel more customers than they attract. However, such lights can be made into heroes by adding good shielding that eliminates glare and directs the light output to where it is useful.

Dropped refractor fixtures. These fixtures are everywhere. Our common street lights are dropped refractor "cobra heads," so named because of the supporting "neck" and the flaring "head" where the lamp is mounted. They have a glass lens or refractor which is "dropped" (hangs down below the fixture) and from which the light output is spread onto the street surface in both directions. Some fixtures of this type have reasonably good control of the light output, but most do not, and most all are very glary.

Other inexpensive fixtures often have nothing but a sort of cylinder of glass which directs the light out horizontally from the fixture; these are usually great sources of glare. In some cases, the "refractor" is nothing but an ineffective glare shield helping somewhat to diffuse the light output from the bare lamp. Light coming from a street lamp configured like this is almost useless because, by the time it strikes any surface (including the ground), it is too faint to provide much illumination and becomes wasted light.

Righting the problem. Local changes can substantially reduce the problem of light pollution, as these images of the University of Arizona in Tucson demonstrate. Before (left), the University used 400 watt mercury vapor lamps; after the University agreed to replace the glary, energy-inefficient lights with 135 watt, low-pressure sodium lights (right), the light levels in dark areas were increased, less energy was used, and sky brightness waas greatly reduced.

Light Pollution

The Heroes

Full cut-off fixtures. These fixtures contain and direct all their light downward. They control the light output with a reflector inside the fixture rather than by a refractor dropped below the fixture, as noted above. No light reaches above or even near the horizontal, so glare is minimized. The fixtures can contain most any kind of lamp but usually are seen with high-pressure sodium or metal halide lamps, both reasonably energy efficient.

These fixtures are easy to recognize because you can't see any glass hanging below the fixture, and you can't see the lamp unless you are relatively close to the fixture and looking directly up at it. They can look like the cobra head fixtures but without the dropped refractor, or they can look like boxes or small opaque cylinders on top of the lighting pole. These fixtures can also be used as wall mounted "wall packs," and they have little or no glare and an excellent distribution of the light output, just as they do when used for street lighting.

Motion sensor lights. These lights are not on all the time from dusk to dawn, but only when their infrared sensor detects motion of people, large animals, or other objects. They then turn on for a few minutes, and go off later when they do not detect any more motion. They don't waste light or energy nor do they create adverse sky glow when well installed to control the light output. Since they come on when a potential burglar approaches, they tend to scare criminals away. They also serve to light walkways or such for the homeowner. They can contain any kind of light that comes on "instantly," but not all lamps do this. Even an energy inefficient incandescent lamp is OK with this type of lighting, as they are so seldom on that little or no energy is wasted.

Timer-controlled lighting. There are many applications where lighting is not needed all night, and this can save a great deal of energy. Some examples are advertising lighting, parking lot lighting, signs of all sorts, decorative lighting, and many others. In some applications, lighting that is still needed can be dimmed when the need for the lighting decreases. Visibility can still remain excellent.

Glare-free lighting. Glare never helps visibility. The eye can see remarkably well even at very low lighting levels in the absence of glare.

Energy-efficient lamps. Naturally, these can help save energy when used in place of energy-inefficient lamps. Here is a list of lamps in order of decreasing energy efficiency: low-pressure sodium, high-pressure sodium, metal halide, and compact fluorescent. Use them whenever possible. Explore your city and your neighborhood, and make a list of the lighting heroes and the villains. Take photographs if you can. Help publicize the heroes. Help others understand the value of heroes and the villainy of villains. Good nighttime lighting has great value.

Recognizing the heroes. Photo of a low-pressure sodium fixture.

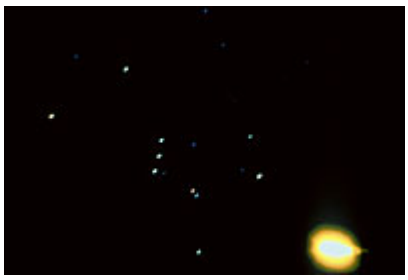
Light Pollution and the U.S. National Science Education Standards

The only good thing about light pollution is that it makes an excellent topic for teaching and learning about science and technology and their relationships to society. And science educators now know that teaching is most effective when an inquiry-based approach is taken. This usually means "hands-on activities," and there are lots of those in the light pollution field. Effective teaching also requires that topics be introduced to students at an age when they can appreciate the concepts and issues involved. As students progress from grades K through 12, the U.S. National Science Education Standards

(NSES) gradually introduce them to the scientific, technological, and societal issues with which light pollution connects so well.

The NSES were developed over many years by thousands of teachers, scientists, and other experts across the country. The Standards address not only content issues but exemplary teaching practices, effective professional development, criteria for assessing and analyzing students' attainments, the nature and design of the school and district science program, and the resources and other supports needed.

The content standards include topics to be addressed in the physical, biological, Earth, and space sciences. They also include unifying processes, science as inquiry, science and technology, personal and social perspectives, and the nature and history of science. The study of light pollution touches on virtually every one of these topics. In particular, activities and projects on light pollution relate to two important themes in the content standards. In "science as inquiry," students ask a question, plan and conduct an investigation, employ tools and equipment to extend their senses, use data to construct an explanation or interpretation, and then communicate their results. In the "nature and history of science" thread, an underlying principle is that science is a human endeavor. What better example than the use and misuse of light!



Returning the heavens. In the photograph to the left, few stars in Orion are visible from Flagstaff, AZ, because of sky glow from low-pressure sodium lamps, but astronomers can easily work around this monochromatic problem by placing a sodium filter in their telescope. In the image to the right, see the return of Orion's stars by the use of such a filter.

At the grade K-4 level in the physical science stream, students are introduced to light. In the biological science stream, they are introduced to the concept of the environment. In the Earth and space science stream, the sky becomes part of the environment. But there may be changes in the environment: "changes... can be natural or influenced by humans. Some changes are good, some are bad, and some are neither... Pollution is a change in the environment that can influence the... activities of... humans." Students learn to recognize that science and technology produce local challenges; the effects may be good or bad.

At the grade 5-8 level, the science and technology stream deals with the development, implementation, and evaluation of technological designs and products (lighting!). The social perspectives include environmental degradation and the concept of risks and benefits; students must think critically about the positive and negative aspects of technological activity. Again, light pollution is an example which can be understood at a very basic level.

At the grade 9-12 level, in the physical science stream, light and spectra are introduced. Astronomy topics center on the origin and evolution of the universe - questions which inspire so many people (including astronomers) to look at the sky and lament the gradual disappearance of its beauty. The topics in the science and technology stream - technological design and the complex nature of science and technology, their motivations and interactions - are tailor-made to be illustrated through a study of light pollution. And the social perspectives include natural resource consumption, environmental quality, and the role of science and technology in local, national, and global challenges.

[Note: All illustrations are from the ASP slide set "Light Pollution: Problems and Solutions."]

David Crawford is a professional astronomer and executive director of the International Dark-Sky Association. He was the 1997 winner of the Van Biesbroeck Award for his leadership in the battle against light pollution. His email address is crawford@noao.edu.

Margarita Metaxa is a physicist and astronomer, and a teacher at the Arsakeio School of Athens, which is associated with the National Observatory of Athens. She is active in astronomy education through projects with the Greek Ministry of Education, Universities, and Schools. Her email address is mmetaxa@compulink.gr.

John Percy is a professor of astronomy at the University of Toronto, and is the current President of the Astronomical Society of the Pacific. His email address is jpercy@erin.utoronto.ca.

Light Pollution

ACTIVITY 1

Objective

In this activity, students will observe that the faintest stars which they can see in the sky are affected by many things: the adaptation of their eyes to the dark, the presence of clouds or haze, the time of year, and the presence of light pollution.

General Information

This activity is for students at the grade 6-12 level. It can be performed by individual students but, for safety and social reasons, it is best completed within a group. If possible, different students, or groups of students, should observe from different kinds of sites — a street corner, backyard, park, rural or wilderness site, etc. It takes about 30 minutes of evening work, plus time to discuss the results in class. The observations lead to discussion of how certain factors or variables affect an observational result. The activity may lead to an interesting investigation of how the eye adapts itself to the dark. Note, however, that this is not a test of vision. Different students will have different visual sensitivity. This is just one more variable to be controlled.

Background Information

Two thousand years ago, astronomers called the brightest stars "first magnitude" and the faintest stars "sixth magnitude." Brighter stars, therefore, have smaller magnitudes. Now the magnitude system is a quantitative way of specifying the apparent brightness of the stars. The faintest star that an observer can see at a location at a given time is called that site's "limiting magnitude," a measure that depends on many factors.

Ursa Minor (The Little Bear), including The Little Dipper asterism, is a constellation which can be seen throughout the year from the northern hemisphere. It has stars ranging from magnitude 2.02 (the brightest) to fainter than 6.00. In some urban and/or light-polluted locations, even the 2nd-magnitude stars may be invisible. A few bright stars (like Capella, magnitude 0.08, in nearby Auriga) will then have to be added.

What the Students Will Do

- locate Ursa Minor in the night sky
- record the conditions under which they observe the constellation
- determine the faintest star which they can see in the constellation and
- note its magnitude (their limiting magnitude)

Materials List

Students will need a seasonal star chart; this can be obtained from most astronomy magazines. They will also need a chart of Ursa Minor, showing the magnitudes of the stars (Figure A1-1). Optionally, you may want to provide your students with a standard form on which to record the information in item (5) below.

Doing the Activity

In this activity, look directly at the stars and constellations, rather than looking out of the side of your eye ("averted vision"). Averted vision may be more sensitive, but it introduces an additional variable into the activity which is difficult to control.

1. Use your seasonal star chart to locate the Big Dipper, Polaris (the Pole Star), and Cassiopeia. Ursa Minor curves back from Polaris towards the end of the handle of the Big Dipper.

2. Use the chart A1-1 to identify as many of the stars in Ursa Minor as possible.

3. Record the magnitudes of the faintest stars in Ursa Minor that you can see. Which star is the faintest (has the most positive magnitude)?

4. Remain outside, in the dark, away from bright lights, for at least 15 minutes more. Repeat the observation, and record the results. When you have finished your observations, you may want to return to a more normal light-polluted location to show the huge loss in limiting magnitude.

5. Record the following information about your observing conditions: (a) place of observation (be as specific as possible); (b) comments on the location, especially with regard to lighting; (c) comments on the sky conditions; (d) number of minutes that you have been in the dark; (e) comments, if any, about your eyesight; (f) comments about your experience as a sky observer — are you a beginner or an expert?

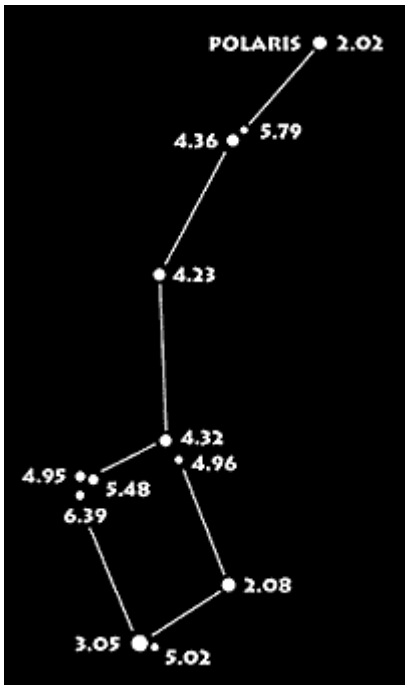


Figure A1-1

Evaluation

The evaluation will be based on the student's report on and discussion of the results. Have they provided clear, complete information about their observation? Do they have an appreciation of the factors (variables) which might affect their limiting magnitude?

Closure

Students will observe that their limiting magnitude depends on the extent to which their eyes have adapted to the dark and on the brightness of the sky. This depends on the presence of natural light (the Moon) and artificial light (light pollution).

ACTIVITY 2

Objective

In this activity, students develop a plan to reduce light pollution by identifying the sources of the problem, the scientific and technological issues involved, the possible solutions, and the technological, economic, and political processes for achieving those solutions.

General Information

This activity can be done at the grade 6-8 level, but it is most suitable for the grade 9-12 level because the societal issues may be complex. Students can work in teams of three to five, with each team member assigned to specific tasks. The activity is open-ended, so it may be done quickly in a brain-storming format, or it may become a term project. This activity can integrate science and technology with social sciences such as business, economics, and politics.

What the Students Will Do

- prepare a clear, concise report on the problem, including the scientific, economic, and societal issues
- list the options available to solving the problem, and the pro's and con's of each
- choose the most promising option, even though it might not be ideal

- identify the methods and channels for implementing this option
- act!

This activity, therefore, provides a "model solution" for dealing with other science-technology-society issues.

Doing the Activity

1. Choose any light pollution problem that you have identified in your neighborhood. It may be light trespass from a security light next door to your house. It may be glare from a high-intensity light in your schoolyard. It may be all-night illumination of a playing field or used-car lot. It may be inappropriate lighting of your local street or highway.

2. Prepare a brief report on the problem, which includes the scientific, technological, economic, and other societal issues. Is the lighting efficient? Effective? Safe? Attractive?

3. Through brain-storming, identify possible solutions to the problem, and list the pro's and con's of each. Discussions with others will be helpful and can lead to understanding.

4. Use discussion and consensus to choose the most promising solution.

5. Determine what is necessary to try to implement that solution. What information do you need? What diplomatic or political channels can you use? Prepare a plan of action.

6. Act!

Evaluation

The students will be evaluated on their project report and their ability to discuss the issues involved.

Closure

After completing this activity, students should have a better understanding of the practical processes for dealing with the light pollution problem and with other environmental and societal issues.

Light Pollution

ACTIVITY 3

[This activity is based on one developed by Jerry Reed and extensively edited and amended by Dave Crawford.]

Objective

In this activity, students observe the design of outdoor lighting and discuss how this affects the efficiency and effectiveness of the job which the lighting is intended to do and the degree of light

pollution which occurs. More advanced students may also observe and describe the spectrum of the outdoor lighting and how that is related to the effectiveness of the lighting and to the degree of light pollution.

General Information

This activity can be done at the grade 6-12 level. Students at the grade 9-12 level may have been introduced to light and spectra in their science courses, and this activity is a good application. It is safer and more interesting and effective if students work in small groups. The activity can be completed in one or two evenings, plus a class period for discussion. It effectively integrates science and technology.

Background Information

Most of us are vaguely aware of lighting in our environment, but how often have we looked closely at lighting fixtures (even those in our own back yard)? We may have noticed deficiencies in lighting, but not investigated their cause.

Research has shown that many students have deep-seated misconceptions about light and lighting. What happens when yellow light shines on a blue car in a dark parking lot? Can you see a mirror or a bicycle reflector in a completely darkened room? Does light from a given source travel further at night than during the daytime? This activity is useful for dealing with such questions.

What the Students Will Do

- make a study of outdoor light fixtures as scientific, technological, and societal devices
- answer the question: How efficiently and effectively do the lights they observe do their job?

Doing the Activity

1. Go outdoors in front of your house during the evening, and look at your block or the area visible from your home. Make a diagram of your block (or area).

2. Observe all the lights — the lights at your house, at your neighbors' houses, on the street, and any others visible to you. Note *every* one of the them by recording each light's approximate location on your diagram, record what kind of light it is (porch light, security light, street light, decorative yard light, flood light illuminating a tree, etc.), and try to identify the type of lamp. Mercury vapor lamps are a coldish white. High-pressure sodium lamps are pinkish or amber. Low-pressure sodium lamps are bright yellow. Incandescent lamps are a yellowish white.

3. *[Optional]* Use a spectroscope or diffraction grating to analyze the spectrum and identify the type of lamps you observe (as in Activity 2).

4. Note the following about the lights you observe:

- what kind of fixture the lamp is in (if easily apparent)
- observe how street lights are mounted (on their own pole or on a utility pole...are they "cobra head" or "full cut-off"?)
- estimate the amount of glare (on a scale of 1 to 5, for instance, where 1 is "no glare at all" and 5 is "very glary")
- estimate qualitatively how well the lights do their job by considering their contributions to glare, energy waste, and light pollution

Evaluation

The evaluation should be based on the reports kept by the students, including their ability to record and fully describe the light sources in their neighborhoods.

Closure

The students will become aware of the different types of lighting in their neighborhoods and how well each type of light does its job.

Koyaanisqatsi — Life Out of Balance

The Hopi Indians have a fine word, one that does not exist in English or any other language. It expresses a concept that is so evident in the modern world. It is *koyaanisqatsi*. One translation is "life out of balance." Others are "crazy life," or "life in turmoil," or "life disintegrating," or "a state of life that calls for another way of living."

Descriptions often make better definitions. One such is "A Los Angeles freeway at 4:00 p.m. on a Friday afternoon." Light pollution is another. The environmental problems we all live with, and which are growing daily, are all excellent examples of *koyaanisqatsi*.

An Example: *The Light Pollution Project in the Schools in Greece*

Margarita Metaxa

Arsakeio School of Athens and National Observatory of Athens

The light pollution project in the schools of Greece has been organized through the Greek Ministry of Education and Religion, with funding and support from the "Action III" initiative of the European Community. It began in 1997 and will culminate with a major symposium in Athens on 7-9 May 1999. The project was proposed by the Astrolaboratory of the Second Lyceum of the Arsakeio School of Athens (one of a family of high schools operated by a non-profit organization in Greece), in partnership with two other schools — one in Ioannina, Greece, and one in Manchester, U.K.

The objectives of the project are: (1) to familiarize students (and teachers!) with the scientific and technical aspects of light pollution through a study of astronomy, physics, computer science, and related topics; (2) to expose the students to the cultural and social dimensions of light pollution; and (3) to encourage students to understand and appreciate the effects of light pollution on their heritage and environment.

For maximum effectiveness, the students work in four groups:

- the "astronomical group" studies the astronomical aspects of the problem of light pollution;
- the "lighting group" investigates the nature and design of different types of lighting fixtures and their impact on the problem;
- the "social group" explores the social dimensions of light pollution— the psychological aspects, the effects on ecosystems, and the legal and political channels which can be used to deal with the problem;

- the "public relations group," a team which includes members of the other three groups and who are directed to inform the local authorities, the media, and society, about the problem by organizing special events. The group's ultimate goal is to inform, educate, and influence planning authorities to produce and install efficient, effective lighting systems.

The students who participate in this project receive valuable experience working and collaborating in groups and in taking initiatives, which will enable them to become active decision-makers in the future.

In addition to the three partner schools, a total of 40 schools — 32 in Greece and 8 from abroad, with 76 teachers and 690 students — have joined the project. In 18 Greek cities, local light pollution centers have been organized. These promote efficient, effective lighting in their local areas. In the city of Tarrega, Spain, a light pollution by-law has been passed as a result of the project. Many other organizations and individuals have contributed to the success of the project: the scientific advisory committee, the International Dark-Sky Association, the lighting companies Siemens and Philips Hellas SA, the municipalities in Greece which co-operated with the project, and the individuals who prepared scientific information for the project's web pages.

Much has been learned from the project already. Obviously, light and air pollution have robbed our towns and cities, both large and small, of the beauty of the night sky. Even so, most students, teachers, and the general public are totally unaware of the important and impressive environmental issue of light pollution. The strategy of having students work in four groups has proven to be very effective, as demonstrated by the excellent presentations and posters which were given at meetings held in Athens, Crete, and Manchester at the end of the project's first year.

In addition to the observatories, universities, lighting companies, schools, municipalities, and scientific and educational organizations who are already co-operating with the project, others are welcome to join. The best way to find out more and to register is through the project's web site at *http://www.uoi.gr/english/EPL/LP/lp.htm*.

Light Pollution

Resources

Organizations

International Dark-Sky Association, 3225 North First Avenue, Tucson, AZ 85719; ida@darksky.org; *http://www.darksky.org*

Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112; *http://www.astrosociety.org*

Books and Articles

Several articles on light pollution in *Sky & Telescope*, Sept. 1998

Crawford, D. and Hunter, T. "The Battle Against Light Pollution," in *Sky & Telescope*, July 1990, p. 23

Hunter, T. and Goff, B. "Shielding the Night Sky," in *Astronomy*, Sept. 1988, p. 47

Sperling, N. "Light Pollution: A Challenge for Astronomers," in *Mercury*, Sept./Oct. 1986, p. 144

Several dozen IDA Information Sheets, on almost every topic related to light pollution, are available from the International Dark-Sky Association (see address above)

Web Sites

International Dark-Sky Association: *http://www.darksky.org*

New England Light Pollution Advisory Group: *http://cfa-www.harvard.edu/cfa/ps/nelpag.html*

Ohio Light Pollution Advisory Committee: *http://www.fpi-protostar.com/olpac/*

British Astronomical Association: *http://www.u-net.com/ph/cfds/*

Slides and Other Audiovisual Materials

Light Pollution (Set of 20 Slides), ASP Catalog AS 294, $26.95

The Earth at Night (Poster) ASP Catalog AP 380, $9.95

Several other slide sets are available through the International Dark-Sky Association (see address above)

Activities Materials

Transmission Diffraction Gratings

The Spectrometer Kit (Set of 10), ASP Catalog KT 102, $79.95