Citizen Science Success Stories

Citizen Science in the City

Fran Bosi, Alexander Graham Bell School, PS 205, Queens, New York

New York City may seem like an unlikely location for citizen science, but Fran Bosi has been successfully involving her students in a variety of outdoor projects since 1998. She began doing data collection through GLOBE (Global Learning and Observations to Benefit the Environment) and finds these projects especially teacher-friendly because of the excellent materials and teacher training workshops that GLOBE provides. Fran has also had great success using Tomatosphere, a project in which students perform experiments on tomato seeds that have been subjected to conditions that simulate the process of aerocapture as a space vehicle enters the atmosphere of Mars. Fran says, "Tomatosphere is a great project to start with because it's short-term, about two weeks, and everything that you need is sent to you. Fran also recommends Project BudBurst as another citizen science project. Excellent student and teacher resources are provided online and her students love going outside to observe trees in their area. You can see photos of Fran's students recording data for Project BudBurst on pages 11 and 14 of *How We Know What We Know About Our Changing Climate*.

As a result of participating in citizen science projects, Fran reports that her students are much more aware of their surroundings and notice changes that they would otherwise overlook. They also show greater care and concern for the natural environment. If someone litters the school grounds, they take care of it right away. One of their on-going projects is implementing a school-wide recycling program.

Speaking from experience, Fran suggests that teachers start with a small project, choosing one that fits easily into their schedule. Fran herself began a school gardening program on a small scale, starting with a single 10-foot by 11-foot bed. She patiently grew her garden program along with the plants, and in 2002 Fran was named the New York Agriculture in the Classroom Teacher of the Year. Her enthusiasm has touched others, and now fellow teachers, the school custodian, and parents are all involved in growing vegetables and flowers at the school.

Weather RATS Learn Life Skills

Lori Painter, Monroe School, Enid, Oklahoma

Every Friday one of Lori Painter's 5th-graders gives the weather forecast on the local radio station. Due to their experience as Weather RATS, Lori's students are more than qualified for this task—they're experts at reading and interpreting weather data from MESONET and a variety of other sources. Making the weekly radio forecast connects schoolwork with the real world and helps build students' confidence and self-esteem. Positive changes include improved behavior, greater effort, and better grades.

Lori measures the success of her weather science program student by student, realizing that success means something different for each child. And Weather RATS isn't just about science; it's a way to teach life skills. One skill that Lori feels is important for everyone is "getting along with others." Cooperation and collaboration are a part of every weather project, and Lori tells her students, "You can help anybody, as long as you don't give them the answers." To give her students lots of practice in getting along, weather projects are done in groups, and each student is responsible for a specific job. These jobs rotate and students use a checklist to regularly evaluate themselves and their group members. In this way students learn to rely on one another as peer tutors. Speaking from years of experience, Lori says that it can take up to nine weeks for her students to realize the benefits of getting along, but once they do, they have a skill that will serve them all through their lives.

See photos and read about Lori's students collecting weather data on pages 48-49 of *How We Know What We Know About Our Changing Climate*. Although Lori's students collect weather data, they do not fit the strict definition of "citizen scientists" because they don't send their data to scientists. However, they are certainly citizens using science in meaningful ways.

SUGGESTIONS FOR IMPLEMENTING A CITIZEN SCIENCE PROJECT

Planning and managing a citizen science project requires consideration about a wide range of issues. Use the tips below for a successful start to using citizen science in your classroom.

- **Choose projects that appeal to your students.** Projects are most effective when they are student-centered; therefore, the first step in planning is to determine your students' needs, interests, and motivations. *How We Know What We Know About Our Changing Climate* mentions a variety of citizen science projects that are available for classroom participation, including Classroom FeederWatch, Project BudBurst, and Monarch Watch. (These and other projects are explained in more detail on the pages that follow.)
- **Start small.** Don't feel as though you have to commit to a year-long project the first time you use citizen science in your classroom. Shorter projects with specific beginning and end dates are easier to manage and give you and your students time to adjust to a new way of learning. Stay within your comfort zone and branch out as you gain experience and success.
- **Adjust your role.** In project-based learning, your focus shifts away from delivering information and moves toward organizing learning experiences. A lot of your work will be done before the project begins. Once students are in the field, you become the "guide on the side" monitoring and facilitating their success.
- **Integrate goals and objectives with curriculum standards.** Make sure that the project fits into your science, social studies, and/or language arts curriculum. Many citizen science projects have supplemental teacher information that identifies the national and state standards that correlate with the project. In addition to academic goals, projects are also an excellent avenue for teaching life skills, such as collaboration, cooperation, perseverance, and self-discipline.
- **Establish clear guidelines and expectations for behavior outside.** Discuss your expectations for acceptable behavior with students before the project begins. Working outside has its own unique management challenges, so have a specific goal for each outdoor session. Providing each student or group with a clipboard for recording data helps students stay focused.
- **Use rubrics to assess student performance.** Identify specific criteria for evaluation of each outdoor session or classroom assignment, and give students feedback throughout the project, not just at the end. Rubrics help students stay motivated and do their best work.
- **Tap into all available resources.** Many projects provide free training and materials, and your school district may have grants available specifically for science-related education. Local zoos, museums, clubs, and environmental groups or businesses are also excellent sources of support and may provide supplies or materials for your project.
- **Communicate your plans with administrators and parents.** Use the "Project Summary Sheet" on the following page to succinctly share your project with parents and administrators. Get their support upfront and then share your progress and success with them. Taking photos of your students at work in the field is an excellent way to keep everyone informed. The "Project Summary Sheet" helps you plan each aspect of your project and it also gives students an at-a-glance overview of the project.
- **Take time to review and reflect.** Debriefing may include class discussions, journal entries, and/or written assignments. Address the goals that students accomplished, information and skills that they learned and practiced, and the ways that they contributed to science. Also evaluate what went well and what they would do differently next time.
- **Renew and revitalize yourself.** There's no denying that implementing a citizen science project can be a lot of work. To stay motivated, get support and inspiration from others by attending conferences, networking with other teachers, and involving parents and community members.

Special thanks to Fran Bosi and Lori Painter for contributing their ideas and suggestions to this list.

Citizen Science Project Summary Sheet

Goals and Objectives:

Project Title and Brief Description:

Real World Connections:

Standards Integration:

Summary of Observations/Assignments and Timeframes:

Assessment Rubrics for:

Life Skills:

Date for Review and Reflection:

OUTSTANDING CITIZEN SCIENCE PROJECTS FOR THE CLASSROOM

Journey North www.learner.org/jnorth Journey North is an online global study of wildlife migration and seasonal change. Students K-12 report their own field observations. The process is simple. Once each month, students go outside as a class and record the changes they see. They use Phenology Checklists to record their findings. Journey North has excellent teacher and student materials available online. The web site has migration maps, pictures, standards-based lesson plans, activities and information to help students make local observations and fit them into a global context. Widely considered a best-practices model for education, Journey North is a premiere citizen science project for students.

Year-at-a-Glance Timeline
Tulip Gardens: September–May
Monarch butterflies: September–October and February–June
Symbolic Migration: September–October and March–May
Whooping Cranes: September–December and February–May
Bald Eagles: February–May
Gray Whales: February–May
Hummingbirds: February–May
Mystery Class: February–May
Robins: February–June
Weather and Migration: February–June
Other Signs of Spring: February–June

Cornell Laboratory of Ornithology www.birds.cornell.edu The lab sponsors a variety of citizen science projects.

Citizen Science Project	Web site	Season
Project FeederWatch Count birds at feeders	www.birds.cornell.edu/pfw	November–March
BirdSleuth Observe birds and record data ($79 fee includes curriculum)	www.birdsleuth.org	Year-round
Urban Bird Studies Study doves, crows, gulls, pigeons, and other city birds	www.urbanbirds.org	Year-round
eBird Report bird sightings	www.ebird.org	Year-round
NestWatch Monitor nests and breeding	www.nestwatch.org	Spring/Summer
Birds in Forested Landscapes Study habitat requirements	www.birds.cornell.edu/bfl	Spring/Summer
House Finch Eye Disease Track the spread of the disease	www.birds.cornell.edu/hofi	Year-round
Great Backyard Bird Count A continent-wide snapshot of winter birds	www.birdcount.org	President's Day weekend in February

GLOBE www.globe.gov

Around the world, K-12 students are making scientific observations and reporting their data to GLOBE for use in research. For a school to participate in GLOBE, at least one teacher must be trained in the GLOBE science measurement protocols and education activities by attending a GLOBE Teacher Workshop. Training in the protocols is free. Additionally, NSF and NASA have funded GLOBE projects, collectively called the Earth System Science Projects (ESSPs). They include: Seasons and Biomes Project, Carbon Cycle Project, Watershed Dynamics Project, and From Local to Extreme Environments (FLEXE) — a deep ocean project.

Project BudBurst www.windows.ucar.edu/citizen_science/budburst
Project BudBurst is a national citizen science field campaign that targets native tree and flower species across the country. By recording the timing of the leafing and flowering of native species each year, scientists can learn about the prevailing climatic characteristics in a region over time. They will use student data to compile valuable environmental information that can be compared to historical records to illustrate the effects of climate change. An Activity Guide details the six steps for completing a Project BudBurst phenological investigation. Additional student and teachers resources are available online.

Monarch Watch www.monarchwatch.org
Monarch Watch is a citizen science project that involves volunteers across the United States and Canada who tag individual butterflies to assist scientists in studying and monitoring monarch populations and the fall migration. There are a number of ways that teachers can get their classroom involved with Monarch Watch. In addition to rearing Monarchs, ongoing research projects that rely on student-scientist partnerships include Tagging Monarchs, Larval Monitoring, Monarch Size and Mass, Monarch Flight Vectors, and Hydrogen Isotopes. Students are also encouraged to showcase their research or school projects on the Monarch Watch web site. Curriculum materials are available online.

Tomatosphere www.tomatosphere.org
Tomatosphere has a dual-purpose: to educate and inspire young students and to open the door for extended space exploration, eventually leading to Mars. Teachers receive two packages of tomato seeds, one package to use as the control group; the second package contains the same seeds but they have been subjected to conditions that simulate the process of aerocapture as the space vehicle enters the atmosphere of Mars. The scope of the experiment will depend on the teacher. There are extension ideas that involve many aspects related to plants, space and space travel, and its application to life on Earth. Results are sent electronically to be posted to enable participants to compare their results with those of other classrooms across the country.

Audubon Society Christmas Bird Count www.audubon.org/bird/cbc
The Christmas Bird Count is an early-winter bird census, where volunteers follow specified routes through a designated 15-mile (24-km) diameter circle, counting every bird they see or hear all day. It's not just a species tally—all birds are counted all day, giving an indication of the total number of birds in the circle that day. All individual CBC's are conducted in the period from 14 December to 5 January each season, and each count is conducted in one calendar day.

IN CANADA

NatureWatch www.naturewatch.ca/english
NatureWatch includes a suite of monitoring programs such as FrogWatch, IceWatch, PlantWatch and WormWatch which form the founding components of NatureWatch. These programs encourage schools, community groups, individuals, naturalists, backyard enthusiasts, Scouts and Guides to engage in the monitoring of soil, air, water and other aspects of environmental quality.

Caring For and About the Environment

Research tells us that students will "care for" what they "care about." The Japanese conservationist Tanako Shozo said it this way, "The care of rivers isn't a question of rivers, but of the human heart." In order to cultivate a caring attitude toward the environment, students need to spend time outside. David T. Sobel, professor at Antioch University New England and Director of Place-Based Education, advocates involving students and teachers in on-going tasks that care for the school environment. Many of the tasks listed below give elementary students an opportunity to enjoy being outside in nature while they practice environmentally-friendly behaviors.

Seasonal School Beautification	Teachers and students create indoor displays of natural objects such as flowers, vegetables, and rock gardens. The displays coincide with the natural cycles of the seasons.
Flower Garden Maintenance	Teachers and students weed the gardens, put them to bed for the winter, start seedlings, run a plant sale, bring the garden to life, and install new plantings.
Schoolyard Vegetable Gardens	Teachers and students install raised beds, test and amend the soil, order the seeds, plant the garden, harvest vegetables, arrange for a harvest festival, put the garden to bed, preserve foods by drying, and organize the volunteers for summer maintenance.
Maintaining the Schoolyard	Teachers and students keep the nature area or schoolyard clean, devise graffiti and vandalism prevention programs, help to teach schoolyard games, work with school maintenance staff, create homes for wildlife, keep the bird feeders full, and keep running record of birds that visit the feeders.
Running the Recycling Program	Teachers and students design and run the paper-recycling program. They collect the paper and bring it to the collection site. They develop systems for other materials such as glass, aluminum cans, and inkjet printer cartridges and pick up recyclables on the school grounds.
Tending the Composting Program	Teachers and students work with school lunch staff to first design a composting program and staff the post-lunch separation process. Experienced students educate new students about what's compostable and what isn't.
Climate Change Team	Teachers and students work to minimize the carbon dioxide output of the school through yearly projects that monitor and reduce electricity, building heating fuels, and water consumption. Students suggest changes in student/teacher/staff behavior to reduce consumption. Students and teachers work with building maintenance staff to use the healthiest cleaning products.

Global Climate Change Meets Ecophobia

Prof. David Sobel emphasizes the importance of giving students experiences in nature and focusing on environmental behaviors rather than on simply giving children knowledge about environmental disasters in an article published in Connect magazine entitled "Global Climate Change Meets Ecophobia." A condensation of that article follows.

Ever since Al Gore's An Inconvenient Truth brought global climate change firmly into the public consciousness, worried parents and teachers have asked me, "Is it really appropriate for third graders to watch this movie?" Their deep concern: Is it useful, or counterproductively upsetting, for children to be educated about the world going to hell in a handbasket? People ask me because about ten years ago I wrote a little book called Beyond Ecophobia advocating for honoring developmental appropriateness in environmental education. At that point, I railed against premature rainforest education for young children. I was concerned about the curriculum message: The rainforest is being destroyed and it's your responsibility, first graders, to save it! This would have been like asking us children growing up in the early 1950's to find a cure for polio.

The same thing is happening right now with global warming education. The ice caps are melting, mosquito populations are expanding and spreading serious diseases, hurricanes are getting windier, and we need you, children, to understand that it's your responsibility to fix these problems. But no pressure!

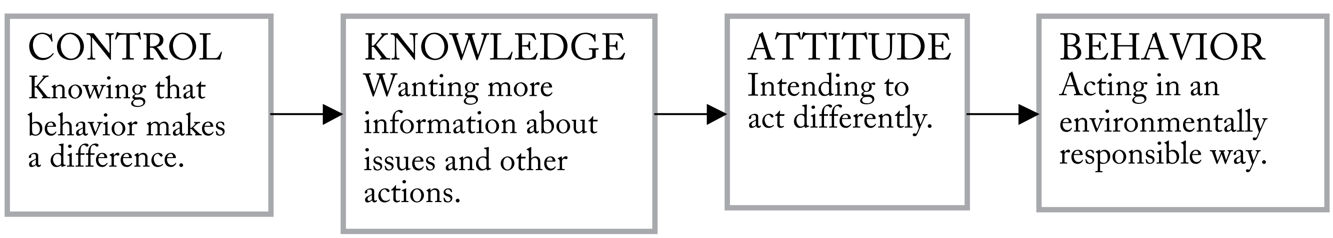
On the one hand I believe that global climate change is caused by human behavior, and we've got to do something about it fast. On the other hand, I'm concerned that prematurely recruiting children to solve this overwhelming problem will just make them feel helpless and hopeless, instead of motivating them to walk to school instead of riding in their parents' cars.

What do we know about effectively cultivating ecological behavior?

The conventional assumption in environmental education starting in the 1960's and 70's was that knowledge led to attitudes, and attitudes led to behavior. If we helped children become knowledgeable, they would become more aware of the environment and its problems, and, thus, be motivated to act toward the environment in responsible ways.

But as researchers Hungerford and Volk discovered, "… behavior, unfortunately, does not bear out the validity of these linear models for changing behavior." Just because children know that burning fuel creates carbon dioxide and that this is bad for the planet, they don't necessarily develop ecologically responsible buying patterns. Increased knowledge and change in attitudes doesn't necessarily translate into different behavior.

The pathway to responsible environmental behavior is more complicated. It's more like: having a sense of control leads to the knowledge of issues and action strategies, which leads to an intention to act, which under the right precipitating conditions, leads to environmental behavior.



If we want kids to adopt responsible environmental behaviors, one of the first things to do is teach children that their behavior makes a difference. *Turning off the lights when you leave the room saves us money and reduces carbon dioxide in the environment.* This sense of personal responsibility leads them to wanting to understand why turning off the lights saves money and reduces carbon dioxide production. This then leads to the intention to make other changes, which ultimately leads to responsible environmental behavior.

At the risk of gross over-simplification, what this suggests is that small behaviors lead to knowledge and attitudes, which lead to medium-sized behaviors, which lead eventually to bigger behaviors. But keep in mind that behaviors are only possible when choices present themselves. If you really believe in recycling, but there's no convenient paper recycling system in your classroom, you're probably going to throw the paper away.

What happens when we give children too much "bad news" about the environment?

A Swiss National Science Foundation study conducted with adults (Finger, 1993) found that too much knowledge about environmental tragedies actually discourages environmental behavior. *If global warming is a done deal, why should I bother to do anything about it?* If this is true for adults, who have well-developed capacities to shield themselves from information overload, think how this must be affecting children.

Finger drew four conclusions that directly affect education programs:

1. "Nature experiences seem to be a necessary condition for any type of environmentally responsible behavior. . . . In particular, nature experiences should be provided for the youngest generation."
2. "It is necessary that social and collective action be an integral part of any continuing education activity."
3. "Fear and anxiety of environmental problems has the potential to turn environmental education into a counterproductive activity." Therefore, education about the problems should be substantially counter-balanced by opportunities to address the problem constructively.
4. "When low fear is involved, environmental knowledge and information do make a difference in terms of environmental behavior."

What does this all mean for global climate change education?

Emphasize behaviors rather than knowledge.

We need to recognize that we've been spending way too much time focusing on conveying environmental knowledge and way too little time on developing environmental behaviors.

Connect children and curriculum to the near-by natural world.

Keep in mind that much of the available research suggests a very strong link behind childhood nature experience and adult environmental behavior. Without that deep abiding sense of comfort in and love for the natural world, no amount of chastising about turning off the lights or biking to school is going to make a bit of difference.

A 2005 Cornell study by Wells and Leckies found that "Childhood participation in 'wild' nature, such as hiking or playing in the woods, camping, and hunting or fishing, is positively associated with environmental behaviors in adulthood." Rather than taking eight-year-olds to a slide show about global warming, it might be more useful to take them fishing or blueberry picking.

Create classrooms and schools that are communities of care for the environment.

Schools are used to a caring mindset in regard to care for people. Now let's extend that care to the environment. Just as teachers develop a set of classroom jobs where all children participate in the daily jobs that keep the classroom functioning, I recommend that schools develop incremental, progressive responsibilities for children at each grade level. These responsibilities would involve every teacher, student, and staff member in shaping a school environment that models environmental sustainability.

One core precept of this approach is to create a developmentally appropriate, school-wide model, which I call a "Ladder of Environmental Responsibility." This Ladder would provide a set of incrementally more challenging tasks for children throughout their school career and would be devised in conjunction with the state-mandated curriculum. Certainly, the science curriculum is one consideration, but all aspects of the language arts, math, and social studies curricula would be considered as well.

As we model and practice responsible environmental behaviors with children, we help them develop the durable commitment to dealing with the more expansive, heavy problems of global warming at the community, regional, and national levels as adults.

Condensed from *Connect*, Vol. 21, Issue 2, November-December 2007, p.14. David T. Sobel is the Director of Teacher Certification Programs in the Education Department, Director of the Center for Place-based Education at Antioch University New England in Keene, Hew Hampshire, and Co-Director of Project COSEED (Community-based School Environmental Education). He is author of *Children's Special Places*; *Beyond Ecophobia: Reclaiming the Heart in Nature Education*; *Mapmaking with Children: Sense of Place Education for the Elementary Years*; and *Place-based Education: Connecting Classrooms and Communities*.

A Teacher's Guide to

How We Know What We Know About Our Changing Climate: Lessons, Resources, and Guidelines about Global Warming

by Carol L. Malnor

Carol L. Malnor has been a classroom teacher for over 20 years teaching elementary, junior high, and high school. She has developed specialty educational programs for high school dropouts, zoos, and even a jail. She was the editor of *The Heart of Teaching*, a nationwide newsletter for K-12 teachers, and has conducted workshops for educators throughout the United States as well as overseas. Carol worked as an instructional designer for a national education company, writing onsite and online courses for college graduate programs. Carol can be found enjoying the natural world near her home in the foothills of the Sierra Nevada Mountains.

Dawn Publications

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Dear Teachers,

As Professor David Sobel writes, "The global climate change wave is cresting, and it's about to crash on public schools." In fact, some people would call this wave a tsunami! How can you teach accurate, scientific information about climate change in a way that empowers your students rather than discourages them?

An excellent resource is the book *How We Know What We Know About Our Changing Climate: Scientists and Kids Explore Global Warming*. Your students will read about modern-day scientists who are using scientific inquiry to find the answers to climate questions. You can count on the quality of the scientific information presented in the book because these scientists are acknowledged and respected worldwide for their work. Many are co-recipients of the 2007 Nobel Peace Prize. We know what we do about climate change because of the questions these scientists have investigated and the results they've found.

The scientific information is written in language students can understand, and the book engages students by featuring the important role citizen scientists—including students just like them—play in contributing scientific data about global warming. It is especially powerful for students to see photos of kids their own age gathering data and recording observations, some of which is used by these scientists.

This teacher's guide is meant as a tool to help you get the most out of using *How We Know What We Know About Our Changing Climate* in your classroom. It provides meaningful, age-appropriate lessons and activities that directly relate to the content of the book and also meet national science standards for students in grades 5-8.

The flexibility of this guide gives you many different entry points into the topic of climate change.

- **Lesson Plans**: Use one or two lesson plans to complement a specific aspect of the book, or combine all of the lessons for a comprehensive study of climate change. You may choose to incorporate the lessons into your existing science curriculum or use them as a basis for an interdisciplinary, thematic unit.
- **Citizen Science Projects**: Involve your students in a citizen science project that lasts one day, two weeks, or several months. You'll find a list of implementation suggestions and recommended projects to help get you started.
- **Choices, Options, and Extensions**: Throughout the guide there are strategy suggestions for using multiple intelligences and for differentiating instruction.

I invite you to use this guide as a springboard for your own creativity and passion as you help your students embrace the challenges of global warming, knowing that they can make a difference in the world.

In support of your teaching,

Carol L. Malnor

About This Guide

The purpose of this teacher's guide is twofold:

- Support you in using *How We Know What We Know About Our Changing Climate* in your classroom as both a student text and resource material.
- Provide age-appropriate, standards-based lessons that you can use tomorrow with your students.

The United Nations Environmental Programme (UNEP) states, "Climate change is one of the most critical global challenges of our time." By the time students are in grades 5-8, most of them are familiar with the term "global warming." However, they probably don't really understand what it means. Additionally, global warming may be alarming for children who feel powerless to control their environment. This guide takes a positive approach, showing you how you can actively engage your students in learning about the challenges of climate change while at the same time helping students discover how they can be part of the solution.

Section One: Exploring Climate Change Clues

Choose from ten lesson plans and numerous extension activities to help your students dig deeper into the evidence behind climate change. All lessons relate directly to the content of the book and also meet national science standards. They may be used on their own or as part of a comprehensive unit.

Section Two: The Web of Life

All life is connected and so are the lessons in this guide. Here you'll find a suggestion for an interdisciplinary unit and also an in-depth lesson on biomes and the impacts of global warming.

Section Three: No Child Left Inside

Citizen science projects motivate and engage your students in learning. This part of the guide explains the hows and whys of successfully implementing citizen science projects into your classroom.

Section Four: Additional Resources

There is an overwhelming amount of information available about climate change, and the sources listed in this section are some of the most reliable, useful, and teacher- and student-friendly.

Best Practices

The essential **brain-compatible** components of variety and choice are evident in the lessons, and students have opportunities to learn and process information using the eight **multiple intelligences**:

verbal-linguistic	visual-spatial
logical-mathematical	intrapersonal
bodily-kinesthetic	interpersonal
musical-rhythmic	naturalist

Strategies for **differentiating instruction** are incorporated directly into many of the lessons, providing students with options in the following areas:

- Content—learning new information
- Process—making sense of the information
- Product—expressing what they've learned

The following **best practices** are used throughout the guide:

- Opportunities for students to make choices and think for themselves.
- Creative and divergent ways for students to access and process information.
- Options for addressing multiple intelligences and learning styles.
- Authentic tasks that connect to the real world.
- Project-based learning activities.

- A variety of student groupings and cooperative learning, including pairs, small groups, and whole class activities.
- Connections to students' prior learning and personal experiences.
- Language development through reading, writing, speaking, and vocabulary.
- Active learning through hands-on activities.

Standards

National Science Education Standards

Each lesson plan correlates to one or more specific Science Content Standards for Grades 5-8.

A: Science as Inquiry
B: Physical Science
C: Life Science
D: Earth Science
E: Science and Technology
F: Science in Personal and Social Perspectives
G: History and Nature of Science

Climate Literacy: Essential Principles and Fundamental Concepts

Climate Literacy Principles are published by the Climate Program Office of the National Oceanic and Atmospheric Administration http://www.climate.noaa.gov/education

1. Life on Earth has been shaped by, depends on, and affects climate.
2. We increase our understanding the climate system through observation and modeling.
3. The Sun is the primary source of energy for the climate system.
4. Earth's weather and climate system are the result of complex interactions.
5. Earth's weather and climate vary over time and space.
6. Recent climate change is very likely due to human activities.
7. Earth's climate system is influenced by complex human decisions involving economic costs and social values.

Climate Literacy: Essential Principles and Fundamental Concepts *was created by members of the scientific and education community, including the Climate Program Office of the National Oceanic and Atmospheric Administration (NOAA) in partnership with the National Science Foundation (NSF), National Aeronautic and Space Agency (NASA), Cooperative Institute for Research in Environmental Sciences (CIRES), American Meteorological Society, TERC, American Association for the Advancement of Science (AAAS), and the University of Atmosphere and Climate Research (UCAR). For the latest updated information go to NOAA's web site,*
www.climate.noaa.gov/index.jsp?pg=/education/edu_index.jsp&edu=climate_literacy.html

Additional Standards

- English Language Arts identified by the National Council of Teachers of English (NCTE) and the International Reading Association (IRA): Standards 1, 3, 4, 5, 6, 7, 8, 11, and 12
- Geography identified by the National Council for Geographic Education Standard (NCGES): All Essential Elements, including Standards 1, 4, 5, 7, 8, 11, 15, 16, 17, and 18
- Math identified by the National Council of Teachers of Mathematics (NCTM): Data and Probability Standards

A word about assessment: Because grade level expectations vary widely between fifth- and eighth-graders, specific assessments are not listed in this guide. However, rubrics to suit the age and abilities of your students are excellent tools not only to assess students, but also to communicate your expectations for each assignment. Just as the standards were used to create the lessons in this guide, they are an excellent basis for creating assessment rubrics.

Section One: *Exploring Clues about Climate Change*

When it comes to learning, one size doesn't fit all, and the following lesson plans provide a wide variety of learning experiences for students, including labs, games, research, and discussions. Students work individually as well as participate in small groups and whole class activities. Lesson plans stand alone, and when used together, in order, they create a comprehensive unit. (See "Section Two: The Web of Life.")

Lesson Plan Elements and How to Use Them

Read these FIRST to help you decide if you want to do the lesson:

Compelling Why	Explains the *compelling* reason why the lesson is important for you and your students.
Lesson Summary	Provides a brief overview of the lesson and explains the types of learning experiences in the lesson—for example, class discussions, lab experiments, small group interactions, and independent research.

Reference this information BEFORE beginning the lesson:

Objective(s)	Identifies what students will *know*, *understand*, and/or *do*. All objectives relate to one of the science standards and Climate Literacy Principles.
Standards	Indicates the National Science Education Content Standards for grades 5-8 (A-G) and Climate Literacy Essential Principles (1-7) that are met by the lesson.
Time	Approximates the amount of time the lesson will take based on a 45-minute class period. Actual timing will vary depending on many factors. Use the time listed as a general guideline to be considered within the context of your unique teaching situation.
Book References	Cites the pages that are referenced from the book *How We Know What We Know About Our Changing Climate*.
Materials	Lists materials that are needed above and beyond the standard classroom supplies and resources such as paper, pencils or pens, white board, blackboard, or overhead projector.
Teacher Preparation	Briefly explains what preparations to make before the lesson is taught. It assumes that you have read the book, especially the pages that are referenced. It's also advisable for you to read additional background information on the topic addressed by the clue.

Follow the step-by-step directions DURING the lesson:

The Lesson Directions separate the lesson into four segments that together make up the Flow Learning™ process. (Flow Learning was developed by Joseph Cornell to motivate students and enhance their learning.)

Awaken Enthusiasm	Begins each lesson in a way that engages students through curiosity, amusement, or personal interest.
Focus Attention	Sharpens students' concentration about the topic. This step often involves reading a selection from *How We Know What We Know About Climate Change*.
Direct Experience	Meets the stated objectives by expanding students' knowledge, increasing students' understanding, or having students to do something with new information.
Share Inspiration	Gives students the opportunity to reflect on what they've learned and share their experience with others, which in turn increases their understanding.

Consider these activities as meaningful follow-ups to do AFTER the lesson:

Extension Activities suggest how to extend the learning and take the lesson further. Although these activities are briefly explained, they are powerful ways to expand the topic and increase learning.

Disappearing Glaciers

Compelling Why: Glaciers grow, move, and retreat in response to changing climate. By studying glaciers and comparing contemporary observations with historical and environmental records, glaciologists get clues about global processes and change. Lonnie Thompson, the glaciologist featured on page 31 of the book, has spent more time above 18,000 feet than any other person on Earth. "No scientist has taken bigger risks to track ancient weather patterns and help us understand the anomaly of current climate trends," says Al Gore.

Lesson Summary: This lesson begins with a kinesthetic activity having student groups pantomime the life of a glacier. Then, either individually or with a partner, students compare photographs of a glacier over a time span of 88 years. They create a Venn diagram of the similarities and differences between the photos.

Objectives **Students will:**	Know the three phases in the life of a glacier. Create a Venn diagram to compare and contrast two photographs of glaciers.
National Standards	Science Content Standards B, D, E Climate Literacy Principles 2, 4, 5
Time	60 minutes (may be done over two class sessions)
Book references	Pages 30-31
Materials	☐ Copies of the book (1 for each group of students is ideal) ☐ Additional photos of glaciers from books and web sites. Excellent sources for photos include: *Earth Under Fire: How Global Warming is Changing the World* by Gary Braasch, Braasch's web site: www.worldviewofglobalwarming.org/index.html and web sites for the USGS www.usgs.gov and NSIDC www.nsidc.org
Teacher Preparation	☐ Make one copy of the Copy Master "Life of a Glacier" and cut it along the dotted lines to make three slips of paper.

Lesson Summary:

Awaken Enthusiasm

Note: You will need a large stage area in the classroom for students to present their pantomimes.

1. Pantomime several actions, such as eating a banana, reading a book, and ice skating on a pond. Ask your students to guess what you're doing.
2. Explain that you demonstrated human actions, and either pantomime or ask for volunteers to pantomime natural events, such as the sun rising, a flower opening, and a tree in autumn dropping its leaves (props are OK).
3. Tell students that they're now ready to pantomime a more complicated natural event—the life of a glacier.
4. Begin by having students brainstorm adjectives that describe a glacier. Create a definition from their adjectives. [Definition: A glacier is a large, slow moving river of ice, formed from compacted layers of snow.]
5. Explain that glacier ice is the largest reservoir of fresh water on Earth and is second only to the oceans as the largest reservoir of total water.
6. Divide the class into three groups and give each group one of the slips of paper you created from the Copy Master. Explain that they are to develop a pantomime that demonstrates the three phases in the life of a glacier: (1) Growing, (2) Moving, and (3) Retreating. To avoid any injuries, you may want to establish some guidelines, such as "No climbing on another student's back." Encourage the use of props.
7. Give groups time to develop and practice their pantomime. It's best if groups can practice out of the view of other groups.

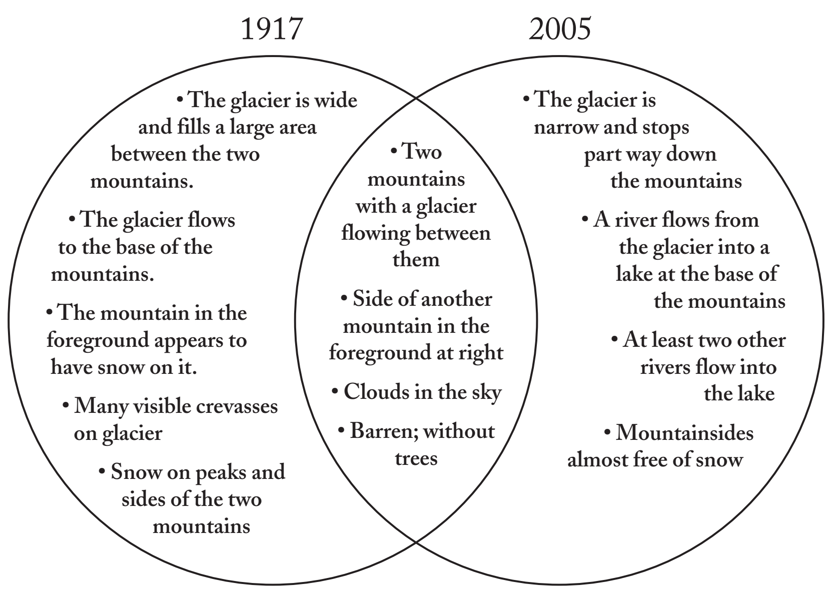
8. When all groups are ready, have them act out their pantomime while you read the information about each of the phases.
9. Have students acknowledge each "performance" with enthusiastic applause!

Focus Attention

1. Explain that most of the world's glaciers are found near the poles, but glaciers exist on all of the world's continents, even Africa. Australia doesn't have any glaciers; however, it is considered part of Oceania, which includes several Pacific island chains and the large islands of Papua New Guinea and New Zealand. Both of these islands have glaciers.
2. Locate glaciers on a world map. Be sure to note the Andes Mountains and Mt. Kilimanjaro in Africa, which have glaciers of special interest to Lonnie Thompson.

Direct Experience

1. Read aloud pages 30–31 from the book.
2. Review the process for creating a Venn diagram. If Venn diagrams are a new concept for your students, demonstrate how to create a Venn diagram by drawing two overlapping circles on the board and comparing two natural objects, such as a bird and a butterfly.
3. Using copies of the book, ask students to carefully observe the two photos of the Athabasca Glacier on page 31.
4. Have students either work individually or with a partner to create a Venn diagram to record the similarities and differences in the landscape of the two photos.



Share Inspiration

1. Compile the groups' observations onto a "master" Venn diagram.
2. View additional photos of glaciers, compare them, and discuss the trends that are occurring.
3. Lead a discussion about why scientists think the shrinking glaciers are a result of climate change.

Extension Activities

Lonnie Anderson: There are several articles about Lonnie Anderson available on the internet. Access some of these articles to share with students and discuss Anderson's extraordinary explorations.

Photo Journal: Have students (or groups of students) choose a location to visit each month during the school year. During each visit, have them record any changes they are aware of and take a photo of the site. At the end of the year, display the photo journal for each site and compare the first photo with the last.

COPY MASTER

Life of a Glacier: Information Slips

The source of information for this activity is the National Snow and Ice Data Center (NSIDC) at www.nsidc.org. You may want to adjust the vocabulary for your students and/or include additional information.

Teacher Directions: Copy this page. Cut apart. Give one part to each group.

Growing Phase

A glacier forms when snow accumulates over time and turns to ice. If the accumulated snow survives one melt season, it is considered to be firn. The snow and firn are compressed by overlying snow, and the buried layers slowly grow together to form a thickened mass of ice. The pressure created from the overlying snow compacts the underlying layers, and the snow grains become larger ice crystals randomly oriented in connected air spaces. These ice crystals can eventually grow to become several centimeters in diameter. As compression continues and the ice crystals grow, the air spaces in the layers decrease, becoming small and isolated. This dense glacial ice usually looks somewhat blue.

Moving Forward Phase

The glacier story continues as the glacier, now grown, begins moving forward. Valley glaciers flow down valleys and continental glaciers (ice sheets) flow outward in all directions from a central point. Glaciers move when the weight and mass of a glacier causes it to spread out due to gravity or when the glacier slides on a thin layer of water at the bottom of the glacier. This water may come from glacial melting due to the pressure of the overlying ice or from water that has worked its way through cracks in the glacier. When a glacier moves rapidly, internal stresses build up in the ice and cracks (called *crevasses*) form at the surface of the glacier. Glaciers erode the rock underneath them. A glacier can "carve" a valley, by wearing away rocks and soil through abrasion and plucking up and moving large pieces of rock and debris. The glacier pushes this earth and rock forward as it advances, almost like a conveyor belt, and dumps it to the side along the way or at the end of the glacier (deposition).

Retreating Phase

The glacier story concludes as the glacier stops growing and begins to retreat. Glacier retreat results from increasing temperature, evaporation, and wind scouring. As large glaciers retreat, the underlying ground surface is typically scoured of most materials, leaving only scars on the underlying surface. When retreating, glaciers leave debris (till) along the way. Mounds of gravel, sand, and rocks that are exposed after a glacier has retreated are called moraines. Some glacial remnants from the last ice age are now vegetated hillsides. Retreating glaciers also leave melt water. In the US, the Great Lakes were created when melt water from the receding glaciers filled the basins that had been dug out when the glacier advanced. The cycle of growing and retreating may be repeated over time.

Life in the Greenhouse

Compelling Why: The amount of CO_2 in the atmosphere provides one of the most significant clues about climate change. The graphs on page 39 of the book show the correlation between an increase of CO_2 in the atmosphere and an increase in the average global temperature. But why does more CO_2 in the air correlate to a higher temperature? To answer that question, it's necessary to understand the carbon cycle and CO_2's role as a greenhouse gas.

Lesson Summary: In this lesson, students create a visual of the greenhouse effect while listening to a brief lecture about it. They then do research on the internet to learn about the carbon cycle. Finally, they participate in a differentiated instruction activity called "Think Dots," which helps them process what they have learned. This lesson is an excellent pre-activity for "Class Climate Change Conference."

Objectives Students will:	Understand the greenhouse effect and how it relates to global warming. Know how carbon naturally cycles through living and non-living parts of the Earth's systems (land, ocean, and atmosphere).
National Standards	National Science Content Standards B, D, F Climate Literacy Principles 3, 4, 6
Time	45 minutes for Awaken Enthusiasm, Focus Attention, and Direct Experience; 30 minutes for Share Inspiration
Book references	Pages 38-39
Materials	☐ Colored pencils or crayons ☐ *How We Know What We Know About Our Changing Climate*, 1 book per group or a book to share among groups ☐ Resource materials about the carbon cycle and greenhouse gases ☐ Computers and internet access ☐ 1 playing die
Teacher Preparation	☐ View the information on the suggested web sites listed below and identify the sites most suitable for your students. Bookmark the sites on your classroom computers. ☐ Collect resource materials on the carbon cycle. ☐ Make copies of the Copy Master: Greenhouse Effect, 1 for each student.

Lesson Directions

Awaken Enthusiasm

Note: The questions in this part of the lesson serve as an informal self-assessment of your students' prior knowledge about the greenhouse effect and greenhouse gases. The questions will be answered when you give the brief lecture in the Focus Attention portion of the lesson.

1. Have students write the word "yes" on one side of a piece of paper and "no" on the other side.
2. Explain that you are going to take a silent poll by having them hold up "yes" or "no" to the following questions. (If you haven't done self-assessments like this before, you may also want to tell students that there isn't a penalty if they answer "no." They should be absolutely honest in their responses.)
   - Have you ever heard the phrase "greenhouse effect"?
   - Do you know what it means?
   - Is the greenhouse effect positive or negative for the Earth?

- Are greenhouse gases poisonous?
- Is carbon dioxide a greenhouse gas?
- Are people influencing the greenhouse effect?

Focus Attention

1. Pass out the handout, "Greenhouse Effect."
2. Tell students that this handout is incomplete and that you will give them directions to finish it. Instruct them to listen carefully and follow your directions as you explain the greenhouse effect.
3. Give the lecture using the chart at the end of this lesson. Complete a larger version of the student handout on the board or overhead as you go along.
4. Check your students' understanding of the greenhouse effect by repeating the silent poll. Review any areas that remain confusing for students.
5. Optional: If you have a projector, show one or more animations of the greenhouse effect that are available on the internet. The following web sites are good sources:
   earthguide.ucsd.edu/earthguide/diagrams/greenhouse
   www.epa.gov/climatechange/kids/global_warming_version2.html
   http://encarta.msn.com/media_701765046_761578504_-1_1/Greenhouse_Effect.html

Direct Experience

1. Explain to students that in order to understand more about CO_2, its role as a greenhouse gas, and the ways we contribute to its increase, they need to know about the carbon cycle. Tell them that what they learn about the carbon cycle they will use to play a game called "Think Dots." (Think Dots is described in Share Information.)
2. Provide students with resources and have them research the carbon cycle. They may work individually or in small groups, depending on the number of computers and other resources you have available.
3. Give students a handout of questions to guide their exploration. (See sample questions at the end of this lesson.)
4. Review the following web sites and bookmark those that are most suitable for your students. The information on these sites is very similar, but it is presented differently. (Please keep in mind that web sites are subject to change.)
   http://www.letus.northwestern.edu/projects/gw/cycles/carbo/index.htm
   http://www.windows.ucar.edu/tour/link=/earth/Water/co2_cycle.html
   http://www.eo.ucar.edu/kids/green/index.htm
   http://www.npr.org/news/specials/climate/video/
   http://epa.gov/climatechange/kids/version2.html
   http://www.epa.gov/climatechange/kids/carbon_cycle_version2.html
   http://www.epa.gov/climatechange/kids/greenhouse.html
   http://earthguide.ucsd.edu/earthguide/diagrams/greenhouse/
   http://www.greenhouse.gov.au/education/factsheets/what.html
   http://encarta.msn.com/encyclopedia_761578504/Greenhouse_Effect.html
   http://www.physicalgeography.net/fundamentals/7h.html

Share Inspiration

1. Think Dots is a differentiated instruction strategy. The name "Think Dots" refers to the number of dots found on a playing die that correspond to questions students need to think about. It has been modified in this lesson to be played as a class game.
2. Divide students into groups. Explain to students that the number of dots on the die corresponds to the level of question they will answer. For example, if they roll a "two," they will answer a Level 2: Comprehension question.
3. Have one group roll the die and ask a corresponding question.

4. Give students time to discuss the answer among themselves. (Be consistent with the amount of "think time" that you will allow for every question.) If the group answers correctly, they earn a point. If they answer incorrectly, the question goes to the next group.
5. Level 5 and Level 6 questions have no right or wrong answer. The group earns a point if they are thorough in their reply. You may want to call on more than one group to get a variety of responses for these types of questions.
6. Play until several questions from each Think Dot (1–6) have been answered.

Sample Questions (Based on Bloom's Taxonomy)

The following questions cover the carbon cycle, the greenhouse effect, and pages 38–39 in *How We Know What We Know About Our Changing Climate*:

One dot—Level 1: Knowledge

- What is (define) the carbon cycle?
- What happens when the amount of carbon dioxide in the atmosphere increases?
- List four greenhouse gases.
- Name five places where carbon is found.

Two dots—Level 2: Comprehension

- What does the Keeling curve show?
- What is the main idea about the greenhouse effect?
- Describe the carbon cycle.
- Explain the enhanced greenhouse effect.

Three dots—Level 3: Application

- How would your life change if you couldn't use any fossil fuels?
- How would you solve the problem of too much carbon dioxide in the air?
- Give four examples of human activities that increase the amount of carbon dioxide in the air.

Four dots—Level 4: Analysis

- Compare the carbon cycle on land and water.
- What steps did Keeling follow in his experiment?
- What are the reasons for the enhanced greenhouse effect?

Five dots—Level 5: Synthesis

- What would happen if the Earth stopped breathing?
- How might life on Earth be different if Earth was surrounded by a glass dome like an actual greenhouse?
- Pretend you are a carbon atom. Name three places you would go and explain why you would go there.

Six dots—Level 6: Evaluation

- Rate the web sites you visited.
- Choose a type of energy the U.S. could use rather than fossil fuels and explain why you think it would be good to use it.
- Choose an action that you can take to reduce the amount of CO_2 you create.

Lecture	Directions for Students
1. The Earth is blanketed by a mixture of gases that make up our atmosphere.	Very lightly shade the atmosphere (between the dotted line and the Earth).
2. The sun radiates energy to the Earth as visible light and ultraviolet light.	Color the Sun and the arrows coming from the Sun to the Earth.
3. As the Sun bathes the Earth in energy, some of the solar radiation is reflected back into space without entering Earth's atmosphere,	Color the small arrow that reflects off the Earth's atmosphere.
4. but most of the radiation passes through the atmosphere and strikes the Earth.	Color the Earth.
5. Some of this radiation is reflected back to the atmosphere and beyond by reflective surfaces such as snow, ice, and sandy deserts. (Albedo is the percentage of the Sun's energy that is reflected back by a surface.)	Color the arrow labeled "albedo."
6. Some of the energy is absorbed by the Earth's surface.	Shade the surface of the Earth.
7. Some of the energy that is absorbed is then released back into the atmosphere as heat (infrared radiation).	Color the three short arrows going from the Earth.
8. Some of this radiation (heat energy) passes through the atmosphere and goes back into space.	Color the long arrow going to the stars and color the stars.
9. And some of the radiation is absorbed by the gases in the atmosphere. These gases then re-radiate the heat back toward the surface of the Earth.	Color the two arrows pointing back to the Earth.
10. The process of the Earth being warmed by this re-radiated heat is called the greenhouse effect, and the gases are called greenhouse gases. (It's interesting to note that the Earth isn't exactly like a greenhouse. In a man-made greenhouse, the glass doesn't absorb and re-radiate the energy; it simply keeps the heat from escaping.)	Circle the words "Greenhouse Effect" at the top of your paper. Write the words "greenhouse gases" under the word "atmosphere."
11. The greenhouse effect is a natural process that keeps the temperature of Earth balanced at an average temperature of about 57 degrees Fahrenheit. Without the greenhouse gases in our atmosphere, all of the sun's energy that wasn't absorbed by the Earth's surface would just go out into space and Earth would be a frozen planet (like Mars) without vegetation and life as we know it.	Draw a tree, flower, animal, or human figure on the Earth to represent life.
12. The amount of greenhouse gases has dramatically increased over the last 300 years, and the Earth's average temperature is also increasing. This is called the enhanced greenhouse effect.	Write the word "Enhanced" in parentheses in front of the words Greenhouse Effect.
13. Over the last 30 years, the average temperature of the Earth has risen by one degree F. This doesn't sound like much, but the observations of events by the scientists in the book (such as rising seas, melting glaciers, changes in ecosystems) illustrate what happens when the Earth warms by just one degree.	Write +1 in the atmosphere just above the Earth's surface.

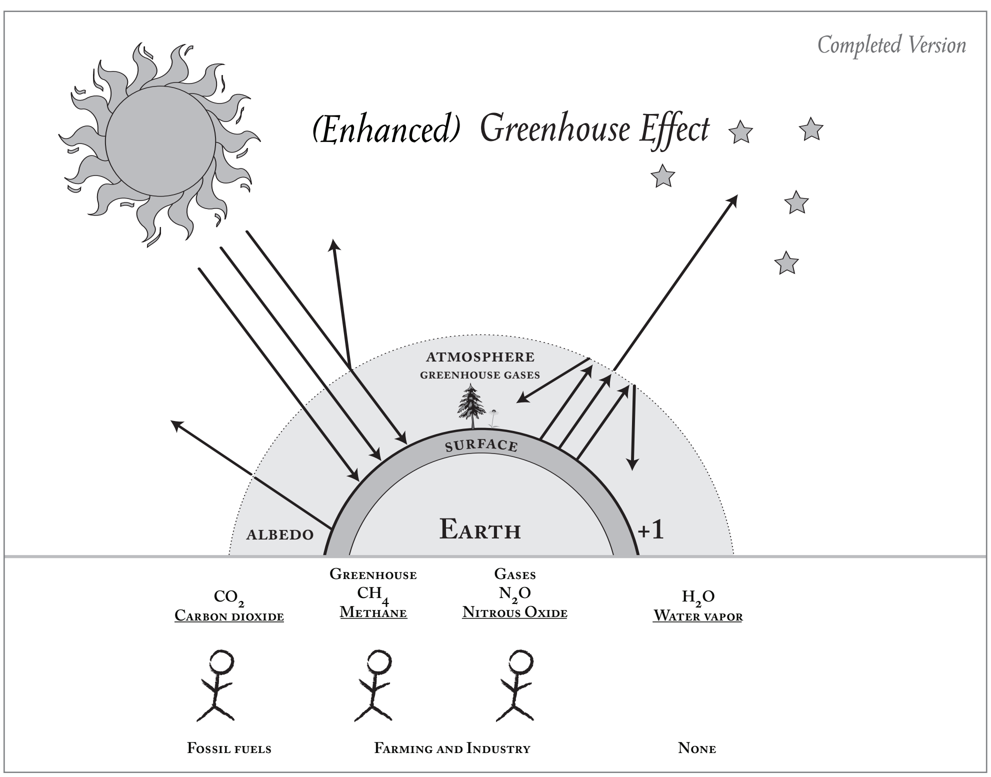
Lecture *(continued)*	Directions for Students
14. The four major greenhouse gases are carbon dioxide (CO_2), methane (CH4), nitrous oxide (N2O), and water vapor (H2O).	Underline these words at the bottom of your handout.
15. Humans have contributed to the enhanced greenhouse effect through increases in the amounts of carbon dioxide, methane, and nitrous oxide our activities have released into the atmosphere.	Draw human stick figures under carbon dioxide, methane, and nitrous oxide.
16. Although water vapor absorbs the most heat, people have very little control over the amount of water vapor in the air.	Under water vapor write "none."
17. Farming and industrial practices put methane and nitrous oxide in the air.	Write the words "farming and industry" under methane and nitrous oxide.
18. Humans have a big impact on the amount of CO_2 emitted into the atmosphere by burning fossil fuels, such as coal, oil, and natural gas. Since 1750, the amount of CO_2 has risen over 30%.	Write the words "fossil fuels" under carbon dioxide.

Your diagram of the Greenhouse Effect is now complete. Turn to a partner and choose who will be "Person A" and who is "B." [pause] Person A will explain the arrows on the diagram to Person B. Person B will explain the role of greenhouse gases in the atmosphere [allow several minutes.]

Sources:

www.esrl.noaa.gov/gmd/infodata/faq_cat-3.html#1
www.ncdc.noaa.gov/oa/climate/globalwarming.html

For additional information about the greenhouse effect go to http://zebu.uoregon.edu/1998/es202/l13.html



COPY MASTER **Students Directions**: Complete the diagram below by following the directions given by your teacher.