About Powers of Inquiry

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Powers of Inquiry: Using Image Analysis to Explore Environmental Health Science is a set of nine lessons created for the National Institute of Environmental Health Sciences (NIEHS) that allows middle and high school students to explore important environmental health science issues using real data and suitable research tools.

A Project of the NIEHS Small Business Innovative Research Program, Powers of Inquiry was developed with funding from NIEHS's Small Business Innovative Research (SBIR) program. It represents a collaborative effort between educators, students, and scientists. Science Approach's goal with this SBIR project is to develop and disseminate high-quality, inquiry-based instructional materials for middle and high school students that:

- introduce students to environmental health science through an engaging visual medium; and

- support achievement of state and national standards for science, mathematics, and technology education.

To achieve this goal, Powers of Inquiry lessons use GIS and/or image processing and analysis technology to provide students with:

- computer-based map layers, images, animations, and virtual simulations derived from current environmental health science research and practice; and

- authentic experiences in scientific research that go beyond simply learning about science, mathematics, and technology.

Philosophy

National concern over the quality of our environment began in the 1970s with the passage of major legislation such as the Clean Water and Clean Air Acts, and continues today. With environmental factors estimated to be responsible for 25–40% of the burden of human ill-health around the world—often most seriously affecting the most vulnerable members of society, such as young children, pregnant women, and the poor—environmental health science will remain an important discipline.

The interaction between humans and their environment has created new and challenging problems and opportunities for this field. With these new opportunities comes the need for scientifically literate and technologically well-trained workers. To effectively assess the human health impacts of physical, chemical, and biological agents in the environment, and find ways to measure and control them, those entering the field of environmental health science must have a strong foundational understanding of the physical and biological sciences, as well as technical expertise in environmental quality assessment techniques and information processing tools. They must also be able to practice the skills of science, think critically, and solve problems.

At Science Approach, we believe that learning environmental health science (as well as other science subjects and mathematics) is facilitated by the use of GIS and image processing and analysis. When students explore data with a GIS, they can represent geographic data on a map in a multitude of ways, enabling them to quickly see certain attributes of the features displayed (e.g., city size, ozone level, vegetation type, elevation, etc.), and observe the spatial relationships between them. With GIS, students can discover patterns they might not discern in tabular data, and delve into and analyze nonspatial data associated with map features (e.g., the number of endangered species present at a particular location, a city's name and population, etc.).

When students explore digital images with image processing and analysis software, they can enhance images to reveal features otherwise difficult or impossible to observe, and measure those features in sophisticated ways. They can also animate images to visualize dynamic scientific processes.

Powers of Inquiry is designed to provide a template that helps learners:

- investigate real data;
- integrate science process and information technology skills;
- understand important concepts in environmental health science through guided discovery and critical thinking; and
- integrate knowledge and research approaches from a variety of disciplines.

Using this approach to environmental health science education, we believe that educators can build confidence among students that they can succeed in science and mathematics, thereby encouraging them to enter into and remain in science and mathematics education tracks. In Powers of Inquiry, students use geographic information systems and image processing and analysis to become actively involved in explorations of real scientific data. They get to experience the excitement of making their own discoveries, and are encouraged to see environmental health science as an intriguing topic of study.

Powers of Inquiry also offers schools an educational tool that puts available computing power to better use. It is designed to help create a bridge between comfortable uses of computers in educational settings (e.g., use of word processing and presentation software) to less comfortable but infinitely more rewarding and educationally beneficial uses.

Teachers and students who wish to go beyond the self-contained structure of a Powers of Inquiry lesson can use the lesson as a template for original research.

Investigating Real Data

Students are often anxious to learn how their knowledge applies to the “real” world and/or a future career. They want to study authentic data and processes, using appropriate research tools. In "Where Did the Ozone Go?," for instance, students work with real ozone data that is being studied around the world by researchers in universities, government agencies, and private corporations. Students analyze the data in the same ways that professional scientists do by using powerful image processing and analysis technology. From the analysis of their collected data, students are able to form conclusions and make decisions.

Integrating Science Process and Information Technology Skills

Powers of Inquiry lessons incorporate science process skills with an emphasis on observing, measuring, organizing, representing, analyzing, synthesizing, communicating, and acting. For instance, in "Where Did the Ozone Go," students use a variety of image processing and analysis techniques to observe and measure the size of the ozone hole over time, organize the data they gather in tables, graph the data, analyze it by observing patterns and trends, and synthesize these observations with other information they have learned. They also communicate their conclusions and decisions about how their actions will change based on their new knowledge. Students acquire these science process skills by using information technology tools including image processing and analysis, spreadsheet, and graphing software.

Platforms for Independent Investigation

The use of computer and imaging technology is increasingly prevalent in the environmental health science world. Computer and image interpretation skills will be invaluable to the environmental health science professionals of the 21st century. However, many teachers and students lack experience and confidence with the use of computer technologies for conducting research. As a result, independent use of image processing and analysis and geographic information systems software as a learning tool becomes a formidable and even frightening prospect to the uninitiated.The software used in Powers of Inquiry are powerful research tools being used by educators and scientists around the world. The programs are simple but powerful, capable of sophisticated analysis operations yet easy to learn and understand. As such, their application in the classroom is natural. Used on their own, the Powers of Inquiry software programs are completely open-ended. Student researchers are free to create and explore data in ways that mirror the processes of research scientists.

Modules

Powers of Inquiry will release ten modules during the fall of 2009:

Warming Seas: What Phytoplankton Can Tell Us About the Effects of Global Warming.

Using ImageJ, students explore and analyze multispectral imaging data from space to understand how the warming surface of the ocean affects phytoplankton populations and the

health of the planet.

Where Did the Ozone Go? Exploring the Public Health Implications of a Hole in the Sky.

Students explore how people’s lives and health are being affected by decreased stratospheric ozone, and use NI2K9 to measure and analyze the Antarctic ozone hole using 28 years of ozone monitoring data. This module includes a role-playing activity in which students are stakeholders deciding who should be exempt from an international ban on the use of a popular and effective ozone-depleting pesticide.

Sprawling Waistlines: Does Suburban Sprawl Make People Fat?

Using an online survey tool, students input their weight, height, and age to calculate their body mass index (BMI). Then, after using a visual guide to classify the kind of community in which they live, they

evaluate whether they see a correlation between development patterns and BMI. The lesson includes an online forum where students post their conclusions and share strategies for addressing the nationwide obesity epidemic.

Who’s Killing Crystal Creek? Exploring a Local Stream’s Effect on Public Health

Student detectives use water chemistry and IPA with ImageJ to investigate a possible river pollution crime. Part of this module is a role-playing activity in which students participate in a public hearing.

Purchase Crystal Creek from Ward's Natural Science

Purchase Crystal Creek from Science Kit

Ozone Here and There: Measuring and Mapping Impacts of Ozone in Communities.

Students use My World GIS to look at how and why ground-level (“bad”) ozone varies around the nation, exploring variables including sources of ozone, air movement, topography, rainfall, temperature, and time of day. They also monitor ozone levels in their own community, map the data, and brainstorm an action plan for reducing their exposure to ozone and other air pollutants.

The Power of You: Understanding Your Role in Preserving Environmental Health.

In this online tutorial that summarizes the main points of the Powers of

Inquiry modules, students explore how global, polar, regional, watershed, community, tissuelevel, cellular, genetic, and nano-sized environmental health issues relate to their daily and future lives. Designed for high school health and environmental science courses, the module concludes with an online forum for students to post a letter to policy makers about how they can address environmental health concerns at all levels of inquiry.

Hormone Imposters: Investigating How Everyday Chemicals Affect Human Health.

Students employ a number of tools to investigate whether everyday chemicals are disrupting the normal functioning of the endocrine system in humans, laboratory animals, and wildlife. The module also includes a primer on the human endocrine system, a short unit on molecular genetics, a section on the interplay between science and policy, and an extensive further exploration section.

Breathing Room: Exploring Ground-level Ozone’s Effect on Nasal Tissue.

Students explore the symptoms and possible causes of asthma and develop hypotheses about the relationship between the inflammation and environmental factors. They then use ImageJ to replicate an experiment conducted by NIEHS scientist, Jack Harkema. Authentic digital histological images are examined and analyzed to quantify the effects of ground-level ozone on cell structure and function in nasal tissue.

Unseen Influences: Sleuthing the Effects of BPA on Gene Expression.

Students develop an understanding of how scientists conduct research on the effects of endocrine disruptors on gene expression by using ImageJ to analyze the results of a microarray study of tissue

exposed to bisphenol A (BPA). After measuring how much the genes in the experiment were up- or down-regulated following exposure to BPA, they investigate the genes’ functions and predict the impact of the changes in gene expression on human health.

Small Worries? Exploring the Environmental Risks of Nanoparticles.

Students develop an understanding of the size and strange properties of nanoparticles by using ImageJ to measure various small particles and explore how aspect ratio affects surface area. Using quantitative

and qualitative measurements of images from toxicology studies, they analyze inflammation and macrophage activity in mice exposed to two types of asbestos, and determine which type is toxic. Next, they examine five types of nanoparticles and predict which ones may be toxic based on what they learned about asbestos, then compare the nanoparticles’ effects to those of asbestos. Lastly, they weigh the promise of nanotechnology and the potential risks of introducing nanoparticles into the environment.

Formats
Depending on the particular module, the Powers of Inquiry modules will be offered to teachers in a variety of formats:

- a downloadable archive containing a PDF-formatted lesson, data files, and software

- a kit available from Wards Natural Science

- online e-Learning modules

The Powers of Inquiry modules will integrate with high school Earth science, environmental science, and advanced placement courses. The modules will also be useful in undergraduate science courses.

Curriculum Integration
The Powers of Inquiry lessons integrate concepts not only from science, mathematics, and technology, but also from language arts and social studies. They also teach image processing and GIS tools and techniques in an applied context. Applied contexts include environmental quality, epidemiology, community planning, forensics, and risk analysis. The lesson materials also lend themselves to further discovery about numerous professional fields that currently utilize image processing and GIS, ranging from the arts to aerospace.

Powers of Inquiry uses a "guided discovery" approach to provide format and structure to the learning process. With this approach, students are able to stay on track and use their time efficiently while still actively practicing the skills of inquiry and analysis. Using digital images and image processing and analysis software or GIS technology, students are guided to make observations and measurements of data gathered in real environmental health science research. They are given background information and raw data, and then asked to collect and analyze data and form conclusions. Many questions are open-ended and designed to promote critical thinking.

Platforms for Independent Investigation
The use of computer and imaging technology is increasingly prevalent in the environmental health science world. Computer and image interpretation skills will be invaluable to the environmental health science professionals of the 21st century. However, many teachers and students lack experience and confidence with the use of computer technologies for conducting research. As a result, independent use of image processing and analysis and geographic information systems software as a learning tool becomes a formidable and even frightening prospect to the uninitiated.The software used in Powers of Inquiry are powerful research tools being used by educators and scientists around the world. The programs are simple but powerful, capable of sophisticated analysis operations yet easy to learn and understand. As such, their application in the classroom is natural. Used on their own, the Powers of Inquiry software programs are completely open-ended. Student researchers are free to create and explore data in ways that mirror the processes of research scientists.

Information Technology for Environmental Health Science
The mission of the NIEHS is to “reduce the burden of environmentally associated disease and dysfunction by defining (1) how environmental exposures affect our health, (2) how individuals differ in their susceptibility to these exposures, and (3) how these susceptibilities change over time.” Understanding the complex interactions among these factors is difficult, requiring powerful information-handling tools and processes.

Powers of Inquiry introduces students to the complexity of the NIEHS’s mission, and contributes to environmental health science education by having students use information processing software tools to enhance and analyze environmental data.

Although Powers of Inquiry lessons are designed primarily to teach environmental health science content, students also learn basic computer skills and geographic information system and image processing concepts along the way. In addition, other basic information-handling tools, such as spreadsheet and slide presentation software, can be used in conjunction with Powers of Inquiry. These valuable learning and workplace skills will serve students well in any career they choose to pursue.

Work Place Competencies
Powers of Inquiry emphasizes many of the workplace competencies and foundational skills recommended by the U.S. Departments of Labor and Education in What Work Requires of Schools: A SCANS Report for America 2000. These include the productive use of resources, information, systems, and technology, as well as teamwork and thinking skills. In particular, using computers to process information and applying technology to tasks. Interpersonal competencies may also be attained by employing the lesson in a collaborative learning environment. Thinking skills—such as problem solving, decision making, reasoning, and creative thinking—are utilized throughout Powers of Inquiry lessons, and are a key component of the guided discovery approach.

In 1990, the Secretary of Labor appointed a commission to study the kinds of competencies and skills our county’s young people need to succeed in today’s changing workplace. The fundamental purpose of the Secretary’s Commission on Achieving Necessary Skills (SCANS) was to encourage a high-performance economy characterized by high-skill, high-wage employment.

For more information about the commission and the reports it has produced, go to http://wdr.doleta.gov/SCANS/
Software
My World
Two Powers of Inquiry modules use the My World GIS software from the GEODE Initiative at Northwestern University in Illinois. My World enables users to construct interactive maps and analyze them using database and geospatial queries. Implemented in Java, My World works on any platform that supports Java, including Windows, Macintosh OS X, and Unix. My World was developed at Northwestern University as part of a research program on the adaptation of expert data visualization and analysis tools to support inquiry-based learning. It was designed specifically for use in middle school through college classrooms.

My World provides a carefully selected subset of the features of a professional GIS environment. These features include multiple geographic projections, table and map views of data, distance-measurement tools, buffering and query operations, and customizable map display. The features are accessed through a supportive interface designed with the needs of students and teachers in mind.

NASA Image2009-
Students use an advanced technology tool—NASA Image2009—to complete two Powers of Inquiry lessons. NASA Image2009 is an image processing and analysis program designed by NASA specifically for use in education, as well as eventual use by Principal Investigators to perform rapid analysis during missions. NASA Image2009 puts substantial computing power in the hands of students, allowing them to develop their own research questions, conduct investigations, and come to their own conclusions about the data contained within digital images.

NASA Image2009 is a public domain image processing and analysis software system developed to meet the needs of educators by NASA Goddard Space Flight Center's Advanced Architectures and Automation Branch (Code 588) and NASA's Scientific and Educational Endeavors (SEE). It is based on Sun's Java Advanced Imaging and is designed to bring high-end scientific image processing capabilities to the standard desktop computer.

NASA Image2009 can acquire, display, edit, enhance, analyze, animate, and print digital images, including geocoded satellite imagery. The program can be used to measure distance, area, brightness, location, and angles on digital images, and measurement results can be printed or exported to other software packages for further analysis. Users can enhance images through false coloring, contrast enhancement, and digital filtering using both built-in and user-defined digital filters. NASA Image2009 provides tools for editing grayscale and color images, and allows users to draw lines, shapes, and text on images. The program can flip, rotate, invert, and scale selections, and it supports multiple windows and ten levels of magnification. All measurement, editing, and filtering functions operate at any level of magnification, and can be undone.

In the Powers of Inquiry lessons that use image processing and analysis to explore data, students can:

- display and manipulate digital images from research being conducted by NIEHS-supported and other scientists;

- filter and enhance images to highlight and identify important features;

- display and animate archived and near-real-time data relayed to Earth from orbiting satellites;

- capture and display images for microscopic and macroscopic explorations;

- apply spatial scales to images and make meaningful measurements of lengths, perimeters, and areas;

- calibrate images that contain temperature, chemical concentration, topographic, and other kinds of data, and use the calibrated images to measure intensities and rates of biological and chemical processes; and

- animate stacks of images and measure changes occurring with the passage of time, including events that occur in milliseconds or those that take days, weeks, and years.

What is a Digital Image?
A digital image is:

- a rectangular array of measurements (usually of light, but they may be measurements of things such as temperature, x-rays, the elevation of points on the surface of a planet, etc.) sampled at regular intervals and rounded off to the nearest whole number; and

- displayed according to a color Lookup Table (LUT), which translates each measurement into a pixel value that is then assigned a specific color or shade of gray.

In other words, a digital image is a long string of numbers representing different levels of brightness for grayscale images, and brightness and color for color images (such as RGB images). When the numbers are placed in the correct order (rows and columns), and a shade of gray or a color is assigned to each number by an LUT, a recognizable picture is formed. Look at the series of magnifications of the Antarctic ozone hole on the right to see how a digital image is really an array of numbers mapped to colors.

Pixels also correspond to distances and areas. For example, a length of twenty pixels in an image may represent one micron in an electron micrograph or one hundred kilometers in a satellite image. The more pixels there are in an image, the greater its resolution; an image with a high number of pixels and a high bit depth therefore more closely represents the actual thing that was measured. Bit depth tells you how much data is being used to define each pixel in an image. A bit is the smallest unit of data, and comes in two possible states: either 1 or 0 (or on/off, or black/white). A black-and-white image is a 1-bit image, since only one bit is needed to define each pixel; 8-bit and higher images give you a lot more information. Unlike graphics, where meaning comes only from the patterns formed by many pixels, each pixel in a digital image may contain meaningful information.

What is Image Processing and Analysis?

Image processing is the manipulation of numeric data contained in a digital image for the purpose of improving or altering its visual appearance, either for aesthetic reasons or to make image features easier to see. This may be done by using image processing functions such as brightness and contrast enhancement or application of filters that reduce noise (irrelevant data) or sharpen edges. LUTs can be used to apply color to a grayscale image or to redefine the values of pixels in a color image so that certain types of image information become more obvious. For example, the pixels representing a particular type of ground cover or weather phenomenon shown in a satellite photo can be displayed as one bright color.

A major purpose of image processing is to alter the appearance of features in an image so that they may be better measured. Image analysis involves collecting data from digital images in the form of measurements (e.g., measuring the size of a tumor in an x-ray of a brain, or determining the amount of sulfur dioxide gas and ash in the plume of a volcano shown in a satellite photo). The accuracy and precision of measurements using digital image analysis is far greater than is possible with rulers and calipers.

Travel Within Data: The Power of Digital Images

Digital images are powerful because they are composed of thousands of pixels representing data that can be displayed in virtually any color or shade using computer software such as NASA Image2009. An image can be manipulated to bring out features not apparent at first glance, complex structures can be accurately selected and measured in many different ways, and time-lapse sequences can be animated.

Image processing and analysis allows learners to examine scientific information in ways that are not possible with textbooks, videos, interactive multimedia, and Internet Web pages. While other tools can show static images of structures, play animations, or display three-dimensional representations of objects, only image processing and analysis permits learners to travel within data and conduct scientific investigations on what they are visualizing.

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