

# DEVELOPING MEANINGFUL STUDENT-TEACHER-SCIENTIST PARTNERSHIPS

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## ABSTRACT

Through the Earth System Scientist Network project we are working with scientists to facilitate the meaningful participation of students in their research projects. In these projects the scientists can take advantage of having an extended research team, and the students and teachers can contribute to a research project while developing skills in inquiry and expanding content knowledge in Earth system science. In order to successfully achieve these partnerships the development of each research project requires the scientist and development team to address a series of issues. These include identifying the scientific research questions, the data that the students will analyze, the requirements for participating schools, the tools and protocols that the students and teachers will use during their research, logistical issues such as assuring that all the instruments and tools are available to the teachers and students, the background information and training they will need, additional research questions that can help spark the interest of students and encourage them to ask their own questions, and meaningful recognition of students and teachers for their contributions to the research projects.

Keywords: Integrating research and education, Education-Earth system science, Inquiry

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## INTRODUCTION

“Students discover gifts in science by trying their hands at it providing they have a chance to do so.  
(Port, 1990)

The National Science Education Standards (NSES) (National Research Council, 1996) emphasize that student learning of science benefits when an inquiry approach is used (Science Content Standard A Science as Inquiry) and that students should understand the concepts and processes that shape our natural world (Science Content Standard D Earth and Space Science). Within the science education community, there is a long history of support for students to engage in authentic scientific investigations (DeBoer, 1991; Lockwood, 1994). As noted by the National Research Council (NRC) in Inquiry and the National Education Standards (National Research Council, 2000), simply conducting hands-on investigations is insufficient:

“At each of the steps involved in inquiry, students and teachers ought to ask What counts? What data do we keep? What data do we discard?

What patterns exist in the data? Are these patterns appropriate for this inquiry? What explanations account for the patterns? Is one explanation better than another?” (p.18)

One method of having students learn science through an inquiry approach is to involve them in a student-teacher-scientist partnership (STSP) that involves students in ongoing research programs (Barstow et al., 1996) Morse and Sabelli (1991) state “When students, scientists, and teachers truly collaborate, they build a powerful environment for learning science, whether in the K-12 classroom or in an informal setting.” Sound STSPs require the students to select an authentic research question, not a recycled or reconfirming question. Then students need to design a research plan to explore the research question, understand how to access or take the data they need to answer that question, then must analyze their data, draw conclusions, and communicate their results to the scientific community (Barstow and Diarra, 1997; Lockwood et al., 1996).

The Earth System Scientist Network (ESSN) project is working with scientists to develop research projects for the participation of 8<sup>th</sup>-12<sup>th</sup> grade students. This development goes beyond identifying a research question that teachers and students are asked to consider. It also requires: addressing logistical issues surrounding the data; identifying spatial and time requirements unique to each project; identifying, testing and making available the instruments and tools (both hardware and software) that the teachers and students will use; developing the background information and training they will need; identifying additional research questions that provoke the curiosity of the students, and identifying incentives for and methods of recognition of the students and teachers participation. Each project is unique and thus needs to be developed independently of the others; however, each research project needs to address all of these issues.

The ESSN project is currently working with three scientists to develop their research projects for the participation of students and teachers (see Table 1). The project staff is also building a web site (essn.terc.edu) that will allow teachers to review the projects, and will contain the information and most of the resources students will need to participate. Here we discuss the issues that need to be addressed by the scientists and educational development team in order to assure successful student-teacher-scientist partnerships.

Table 1 - Earth System Scientist Network Scientists and Projects

Scientist and Affiliation	Student-Teacher-Scientist Partnership Research Project
David Brooks Drexel University Philadelphia, PA	Atmospheric Aerosols: Collecting and Correlating Data
Julia Robinson Johnson Space Center Houston, TX	Urban Growth: Using Images Taken from Orbit to Monitor Change
Josefino Comiso Goddard Space Flight Center Greenbelt, MD	The Arctic: Sensing Change in a Fragile Environment

## DEVELOPING A RESEARCH PROJECT FOR THE PARTICIPATION OF STUDENTS

The primary goal of developing student research projects is to enable students to develop a sense of the sometimes graceful, yet sometimes stumbling, esoteric, and exciting schema that scientists employ to “do science.” As Robert Yager (Yager and Penick, 1989) states, the common lecture-textbook-recitation model of teaching science is akin to teaching all the rules of a sport to a child, like softball; how to bat, catch, throw, slide, learn how to wear the uniform, and then never letting the child actually play in a game! Simply put, “If science is inquiry, and its knowledge is the product of inquiry, then we must allow the students to inquire.” (Samples, 1966)

The main requirement for a successful student-teacher-scientist partnership is that all involved benefit from the partnership. This means that the scientist needs to be able to see the advantage of having students work on his/her project, and that students and teachers need to see that their efforts will contribute to the project. Teachers also need to understand how participation in the project will help their students develop skills in inquiry as well as content knowledge in the geosciences (Barstow et al., 1996). Often scientists find that working with younger students and teachers is difficult and time consuming and does not yield sufficient results. Consequently, it is often challenging to get scientists to partner with students and teachers.

The major issues involved in developing successful STSPs have been identified by our work with national STSP implementation projects. Large-scale programs such Research Corporation in Arizona and the Murdoch Foundation in the northwest have funded hundreds of scientist-teacher col laborations, resulting in authentic research projects for thousands of students. Over the years, these programs have identified common characteristics of successful partnerships (Bacon, 2000). Other programs, such as the NSF funded “The Use of Astronomy in Research-Based Science Education” (RBSE), established 75 scientist mentor-teacher-student research projects, and have also identified characteristics of partnerships that were both meaningful for teachers and their students (Jacoby and Lockwood, 2000).

The ESSN project addresses the concerns of the scientists by reviewing potential projects thoroughly,

and by working with the scientists to address the issues necessary to ensure that their student-teacher-scientist partnership is successful. We discuss the ten major issues that, from our experience with student-teacher-scientist partnerships, need to be addressed in developing successful student-teacher-scientist partnerships.

**What is the Scientific Research Question?** – Scientific research typically involves a large set of interrelated threads, with a combination of broad questions and very specific activities. Teachers and students cannot be expected to have a comprehensive overview of a research field. However, the specific activities often involve smaller, more approachable pieces. One challenge is to identify those pieces within a larger project that would benefit from the efforts of an extended research team. At the same time, these activities must offer interesting and attainable scientific inquiry experiences that will increase students’ inquiry skills and content knowledge in the field.

The ESSN development team works with the scientists to identify specific research questions that are interesting to students and conceptually understandable by students, and can be addressed in some significant way within a school-compatible time frame– typically a school year. The team also seeks the input of teachers to assure that these criteria are met. Although our team identifies a set of pre-designed questions, teachers and students are free to strike out in new directions, and seek the answers to their own research ideas using our data sets or protocols.

One of our projects is “Atmospheric Aerosols: Collecting and Correlating Data” directed by David Brooks (Dept. of Mechanical Engineering and Mechanics, Drexel University). Dr. Brooks has been conducting research to learn more about how the concentration of atmospheric aerosols varies in time and space, and how those variations are related to other changes on the Earth. This research addresses global long-term issues, but building a global understanding of aerosols relies heavily on a high density of local data. Therefore, teachers and students can be active research partners by investigating aerosol concentrations in their own geographical area. Locally, aerosol concentrations are closely related to weather patterns and air quality, thereby increasing the interest and relevance of the project for both students and teachers. We have

identified two research questions that are understandable to students, and that can be addressed within the school year. These questions are: 1. How do atmospheric aerosols relate to the published Air Quality Index and 2. How do atmospheric aerosols relate to relative humidity? These questions relate aerosols an unfamiliar concept to high school students to more familiar quantities. Students have the opportunity to contribute data to Brooks' project while they use his data as the basis for a relevant, community-based project of their own.

In another project, "Urban Growth: Using Images Taken From Orbit to Monitor Change," directed by Julie Robinson at NASA's Johnson Space Center, students analyze a pair of images taken by astronauts that show a metropolitan area at two different points in time. Students calculate the change in area of urbanized land across that time period and compare it with population change. They also investigate what was lost to urbanization during that time. In addition to analyzing images, students may contact historical societies, residents of the study area, and urban planners as they conduct their research. Again students can choose a city that has some relevance for them. Their analysis will help address Robinson's scientific research questions as well, and will support researchers around the world with whom she works.

**What Data Will the Students Work With? -** Once research questions are identified, the scientist and the development team identify the data that the students will need, determine in what format it will be, and how students will acquire the data. In some cases (such as the aerosol project), the students will deal with a combination of data provided by the scientist and their own measurements. In other cases, students will use datasets, such as satellite data, provided by the scientist to conduct their research. This data can be in various forms and obtained in various ways. Some will be ground-based environmental data obtained by people or by automated instrument networks, some will be socioeconomic/health data or other data from other fields, and some will be satellite data taken by manned and unmanned spacecraft. Once identified, these data will be made accessible to students in a usable format on the ESSN Web site or on CD if necessary.

**How Is Data Quality Checked and Controlled? -** A common difficulty with large-scale student research efforts is the quality and variation of data among students (and their teachers) arising from differences in observation techniques, instrumentation, and lack of definitive protocols. David Brooks removes much of the data quality and uniformity problem by supplying teachers with instruments that he has calibrated, ensuring the reliability of data coming from different areas of the country. He also supplies a spreadsheet for students to record their data and send it via e-mail. Robinson and Comiso massage image data to debug it, and trim large files (200 Mb) into manageable processing chunks for students. In each of the projects, the scientists monitor the quality of student data by staging a dry run of sorts, an initial session of data gathering and analysis at the beginning of the project so each scientist can work with students and teachers on data quality issues.

**Are There Requirements for Participating Schools? -** Some projects require that students be in specific

locations, live in or near specific types of environments, or be able to take measurements at specific times. This would limit the schools that can participate. These issues need to be identified early in the development of the research project. In the case of David Brooks' Atmospheric Aerosols project, aerosol measurements are desired over as large an area as possible, so the location of the students is not a limitation. However, Brooks also hopes that students will take aerosol and related measurements every day (weather permitting), even during holidays and vacation periods. Part of facilitating this research project will be working with participating teachers to involve parents and possibly community members to fill in the gaps when school is not in session.

In the cases of Julia Robinson's Urban Growth project and Joey Comiso's project, the data has mainly been taken by satellites. Students will not be collecting their own data, so their location and ability to take continuing measurements is not important. Other types of projects may require students to be in a particular location, region, or type of environment. The scientist and the development team must identify these restrictions before teachers commit themselves and their students to participating in a project. Scientists, teachers, and students will communicate primarily by e-mail, and data analysis requires computers, so a good amount of access to computers, either in-class or a lab is essential.

**What Research Tools are Needed and What Protocols Will Students and Teachers Follow? -** Once the research questions and data have been identified, the tools that the students need to analyze the data and steps they need to follow in the research are identified. The tools and protocols, which are identified and developed by the scientists in collaboration with the ESSN development team and reviewed by teachers, will vary depending on the research questions and the data being analyzed. Tools may include the GLOBE visualization tools that will be used in analyzing the data from David Brooks project, spreadsheet software which can help students manipulate the data mathematically and view it graphically in many ways, and image processing software such as NIH Image, which can help students identify important characteristics of the satellite data they need to analyze. In each case, the scientists and the development team determine what, if any, enhancements unique to the project need to be made to facilitate the analysis by the students. Once appropriate tools are available, protocols are developed to ensure that students and teachers perform the analysis correctly and the scientists' needs are met.

**What are the Logistical Issues That Need to be Addressed? -** The logistical issues that must be addressed can vary greatly from project to project. A typical issue involves ensuring that students have access to the necessary computers, software, and instruments. For most projects, students will need Internet access. Some may require high-speed access if large images need to be transferred, as in Robinson's Urban Growth project, but a dial-up phone line will be sufficient for projects such as Brooks' Atmospheric Aerosols project.

Students and teachers may also need appropriate instruments and be able to take measurements on a continuing basis. This is true of David Brooks' project, where students are requested to take atmospheric optical thickness measurements using a hand held sun photometer every day (weather permitting). In the case



of Julia Robinson's project particular software is needed to conduct the analysis of the satellite photographs of cities. The same is true with Joey Comiso's project, which involves working with satellite derived environmental data from the Arctic. The ESSN development team, the scientist, and the teacher work together to ensure that the instruments and tools needed to participate in the research project are affordable and available to the students and teachers.

**What Background Information Do Students and Teachers Need?** - The scientists and the development team need to work together to determine the background information that students require in order to understand the scientific importance of the research question, the physical processes being studied, and how they will approach answering the research question. Some of this information will be included within the project web site, or will be available via links from the site. Other background information may be in reference material that students can find in a library. This will give the students and teachers a broader understanding of the project they are working on, and will make it possible for students to formulate and answer their own questions.

During the development of the project the scientist's works with the ESSN development team and with the reviewing teachers to understand better how to work with teachers and students. Once the project is implemented, the ESSN development team will monitor the progress of the partnership, and provide guidance to the scientist, teacher, and students to assure success.

**What Training is Needed for Teachers, Students and Scientists?** - Again, each project is unique and therefore each demands different training scenarios. The Atmospheric Aerosols project requires that the students be able to take accurate measurements with a hand held sun photometer and record the time of the measure to the nearest 15 seconds. The Urban Growth project requires that students be able to accurately distinguish urban from vegetative features in a satellite photograph of a city. In the Arctic project students need to be able to look at the data from various perspectives such as change over time and variation in space. For each of these projects the scientist or a colleague who is also working on the projects need to visit each classroom at the start of a project to discuss any issues related to collecting or acquiring the data, analyzing the data, and reporting their findings. The scientist needs to maintain close contact with the teacher and students via e-mail or telephone during the start-up phase of the work to ensure that they are taking the data correctly and that they understand how to do the analysis. Members of the ESSN team are also available to support teachers and students during this time. This training period can last as long as the scientist and teacher feel that the students need the support.

In David Brooks' project during the training students will learn how to use the sun photometer, and take several sets of trial measurements that Brooks will evaluate prior to the time they start collecting data they will use for their research. In Julia Robinson's project students must learn to interpret images taken from Earth orbit as they look for the outer limits of urbanized land. During the training phase they will evaluate practice images and send them to Robinson for her review and feedback.

It is important to inform scientists about the level of classroom and student readiness. Also, scientists and teachers will both need some assistance in learning how to work together effectively to implement a new pedagogy in different district, school, and classroom contexts.

**What Additional Research Questions Can Students Develop?** - One of the goals of the ESSN project is to inspire the students to ask and try to answer their own questions based on the data they are using and/or collecting. This may not always occur without some impetus. In order to help spark students' interest, the ESSN project team and identify some specific research questions and needs to encourage the students to identify additional ones that may capture their interest. The project team and the scientist need to work closely with the students and teachers to ensure they do not launch research projects beyond their reach.

These research questions can use the same data and tools as the research project. As students begin to ask their own questions, however, they may also consult with the scientist about additional data or information they may need to help them answer their own newly formed questions. The results of the students' efforts on these questions could result in a research paper or a science fair project.

**What are the Opportunities for Recognizing the Students and Teachers Contributions?** - Scientists receive recognition for their work through the publication of scientific research papers and the presentation of their results at scientific meetings. Students and teachers will receive recognition through these methods if possible; however, each project should also identify other types of recognition that may be more meaningful to students and teachers. Newspaper articles, visits to the classroom by the scientist at the end of the project, letters to principals and school boards are a few of the methods that scientists can bestow recognition to teachers and their students. Acknowledgement for contributions and success should also be made to school administrators, board members, and parents.

## SUMMARY

Through the Earth System Scientist Network project we are working with scientists to facilitate the meaningful participation of students in their research projects. In these projects the scientists can take advantage of having an extended research team, and the students and teachers can contribute to a research project while developing skills in inquiry and expanding content knowledge in Earth system science. In order for these partnerships to be successful the development of each research project requires the scientist and development team to address a series of issues. These include identifying the scientific research questions, the data that the students will analyze, the requirements for participating schools, the tools and protocols that the students and teachers will use during their research, logistical issues such as assuring that all the instruments and tools are available to the teachers and students, the background information and training they will need, additional research questions that can help spark the interest of students and encourage them to ask their own

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Dr. Tamara Shapiro Ledley, a senior scientist at TERC, conducted research in Earth system science at Rice University for 15 years and has authored over 30 scientific papers on the mechanisms of climate change with an emphasis on the polar regions. Dr. Ledley is leading the Earth System Scientist Network for Student and Scientist Partnerships project, and the GLOBE Exploring the Connections project, which is developing the Earth as a System chapter of the next GLOBE Teacher's Guide.

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Dr. Jeff Lockwood, a project director at TERC, taught high-school physics, astronomy, chemistry, Earth science and biology for 27 years, and planetary and stellar astronomy for 20 years at Pima Community College in Tucson. Lockwood was co-PI of the NSF funded "The Use of Astronomy in Research Based Science Education" program. He is the project director of the "Investigating Life in the Universe: An Integrated Science Approach" curriculum project.

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