An Opportunity for Innovation in STEM Education: GeoSTEM

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Abstract

"An Opportunity for Innovation in STEM Education: GeoSTEM" is the second in a series of articles that explore the role of the Geosciences in the national Science-Technology-Engineering-Mathematics (STEM) Education discussion. With a robust history of innovation in the fields of Remote Sensing and Earth Observations, the Geosciences continue to develop and improve the technologies that allow scientists to conduct research and view the Earth as a System. This article examines the role of teachers and students in creating a diverse Geoscience pathway for our next generation of Scientists, Technologists, Engineers, and Mathematicians and how GeoSTEM content can change the course of the discussions surrounding STEM Education Policy.

Observing the Earth System: A History of Innovation

One of the pedagogical changes that has been incorporated into the discussion of Science-Technology-Engineering-Mathematics (STEM) Education is for students to conduct investigations or engage in problem solving that requires both interdisciplinary thought and skill-sets and which encourages innovation. An Earth Systems Science approach to better understanding our planet has been embraced and used by the National Science Foundation (NSF) Directorate for Geosciences, NASA, NOAA, and the US Global Change Research Program, among others. According to NASA, “We now realize that the key to gaining a better understanding of the global environment is exploring how the Earth’s systems of air, land, water, and life interact with each other. This approach, called Earth System Science, blends together fields like meteorology, oceanography, biology, and atmospheric science.”

For Geoscientists, a fundamental principle of Earth Systems Science is how the study of the individual components of the earth system is required to understand the totality of the system, which is comprised of a multitude of interactions among and between systems. The world’s first weather satellite (Figure 1),

Figure 1. The era of Satellite Remote Sensing begins with TIROS I – First Satellite Image from Space - April 1, 1960.
Source: NASA
TIROS-1, was launched on April 1, 1960. From orbit, it provided more than 22,000 pictures of the Earth. This new way to look at Earth revolutionized the science of storm prediction. Today the number of earth observation variables and their interactions is staggering, resulting in our nation’s “supercomputers” becoming engaged with weather and climate modeling. For instance, the National Center for Atmospheric Research (NCAR) has supercomputing resources that serve a wide variety of disciplines including climatology, meteorology, oceanography, astrophysics, fluid dynamics, and turbulence that allow today’s Earth System models to simulate atmosphere, ocean, sea ice, and land surface processes with increasing fidelity. Both NASA and NOAA have made significant investments in earth observing satellites whose data have been infused in much of our country’s daily routine and our lives. During the 1990’s NASA’s Earth Observing System was designed and put into orbit... known as “Mission to Planet Earth”. A current fleet of NASA and international satellites are known as the Afternoon Constellation (“A-Train”), consisting of a constellation of satellites that travel along the same track as they orbit Earth, greatly helping to better understand how the earth system functions (see Figure 3).

**Applications of Satellite Imagery, Remote Sensing, and Computer Visualizations**

The use of remote sensing and real time data to gain a robust understanding of our planet is not a new concept in the Geosciences, yet there is not much evidence that these STEM related practices,
achievements, technologies, and resources have been incorporated into the K-12 education community. At one time, these Geosciences data came from expensive observing platforms, accessible only to the scientific community. Times have changed! These data are now available to anyone with Internet access (see Figure 4).

High school laboratory-based courses such as physics, chemistry, and biology have traditionally been the only science courses available in preparing students for college acceptance, college-level work, and workforce training programs. Currently, the acceptance of Earth Science as a laboratory-based course varies among colleges (American Geological Institute, 2011). Historically, this has led many school districts not to view or even design an Earth Science curriculum as rigorous as a traditional laboratory science. Even though the geosciences, such as geology and meteorology require a fundamental understanding of physics, chemistry, and biology, investigating these sciences in K-12 education requires extensive field data.

In 2011, in an effort to address this inequity, the New Jersey Department of Education designed a comprehensive Earth System Science framework that is “focused on the application of fundamental concepts and principles as powerful tools in understanding the interconnectedness of the Earth’s Systems, including the exosphere, geosphere, atmosphere, hydrosphere, and biosphere” (see Figure 5). The framework was developed to have “students engage in empirical investigations that require the application of their understandings of the interconnectedness of Earth Systems in decision making and problem solving”. In addition, the scientific community collaborates with K-12 education, in the sharing and interpretation of data.

The NSF Directorate for Geosciences (GEO) supports engaging scientists in Workforce Development; “GEO-funded scientists support programs and activities for students, educators, and policymakers that encourage participation in Geoscience research and use of Geoscience data ... the scientific community holds an important responsibility for cultivating the next generation of geoscientists that directly builds on its research infrastructure.” The NSF Directorate for Geosciences has stated an objective that “the activities of geoscientists to understand Earth Systems have been fundamental to developing the natural resources and mitigating the natural hazards that have allowed mankind to progress and prosper. Yet, in spite of the significant relevance of the geosciences, the geosciences suffer something of an identity crisis. The general public, in most cases, does not
understand the contributions that geoscientists make to society. There is a lack of appreciation for the fact that an understanding of Earth systems requires more than just integration of physics, chemistry, and biology concepts.”

**GeoSTEM: Innovative and Student Oriented Research**

In 1987, a small group of innovative teachers and students began to build satellite receiving stations capable of receiving imagery from Polar Orbiting Satellites and developing investigations centered on these images. This presented numerous authentic learning experiences for students and teachers.

Since 1995, The Global Learning and Observations to Benefit the Environment (GLOBE) program (see Figure 6), has been working with K-12 students to learn, practice, contribute, and apply data to global earth system investigations such as water quality, soils, land cover and most recently climate, while collaborating with Global Change Scientists and Principal Investigators. Students from around the world are encouraged to conduct investigations that range from local environments, to issues that have international impact.

More recently, observing platforms, such as High Altitude Balloons (HAB), and CubeSats are being developed by students. CubeSats are a class of research satellites called “nanosatellites” and are equipped with onboard sensors. These innovative practices are now being collaboratively utilized in the K-12 school, college and university communities. One example, the Build, Launch, Utilize and Educate using CubeSats (BLUECUBE) Project (Moore and Simmons), is expanding diversity in the Geoscience Pipeline through working with students and teachers from the K-12 through graduate school communities (see Figure 7).

According to the NSF, “new technologies are enabling automated collection of vast amounts of data and opening new frontiers for exploration of the ocean, the Earth’s surface, the atmosphere and the geospace environment”. Students, teachers, undergraduate students, graduate students, professors, and industry are compelled to work together on design, construction, testing, launching, and data analysis. Furthermore, the NSF states that “a new generation of researchers is needed to develop new equipment, collect, manage and interpret this new data. Earth System Science requires the development of a new generation of interdisciplinary, integrative scientists, capable of working as part of a team, to address questions at the interface of science and society.”
The Teachable Moment

The integration of a Remote Sensing Laboratory into an existing Earth Science program or a new Earth Systems Science course allows students to acquire the necessary rigorous laboratory skills as required by colleges or universities, while developing and becoming proficient in technological skills using industry standard analysis tools. With the accessibility of real-time or near real time data, students in a GeoSTEM driven course can engage in inquiry-based laboratory experiences focusing on real life applications, both local and global. In addition, students are now gathering data directly from student designed BalloonSat or CubeSat, and along with the availability of image analysis and Geographic Information System tools, students can monitor weather, water quality, sea surface temperature, coral reefs, marine wildlife, earthquakes, tsunamis, wildfires, air quality, land cover and much more through remote sensing information and datasets. Students can then create visualizations, many in real time, using Google Earth, data visualization products such as GIS, as well as other geospatial technologies. The Remote Sensing Laboratory opens up possibilities to capitalize on the “teachable moment”. A very recent example is “Superstorm Sandy” (see Figure 8). While the storm was devastating to many northeast coastal communities, it also gave students everywhere the opportunity to track, interpret and analyze data and imagery, in real time. Afterwards, those students were able to observe the impact, thus demonstrating the importance of information and data in real time decision making, and in rescue and clean-up efforts which are still underway.

Innovation: The United States’ National Resource

While countries continue to outperform US students according to studies, these educational systems still seek advice from the American educational system when it comes to innovation. The pedagogical question is how do you teach innovation? Critical Thinking, Systems Thinking, Problem-Based Learning, and Authentic Learning Experiences, come to mind. GeoSTEM can engage students with these strategies through projects described earlier. In addition, learning through competitions has been identified as fostering motivation, promoting diversity, and having students focus on career decisions. The success of programs such as “First Robotics” and “Project Lead the Way” in the engineering fields also has a body of research and evidence to support its success. Do opportunities that support GeoSTEM exist? Consider the Institute for Global Environmental Strategies’ (IGES) competition for high school students. This competition, the Thacher Environmental Research Contest, emphasizes the use of geospatial and remote sensing tools, products, and data sets. IGES states that “everyday geospatial tools are used to make new discoveries and better understand the changing planet.” The scoring rubric includes scientific/technical accuracy, creativity/originality, quality of the presentation, thoroughness of research/methods/procedure, and quality of conclusions. These are skill sets that we need all STEM students to acquire! Other

Figure 8: Beaches and protective dunes are in the process of being rebuilt in southern NJ in the aftermath of “Superstorm Sandy”. Note the height of the deck footings as an indication of the extent of dune loss. Source: Robert P. Wanton
project-based opportunities include NASA’s flight opportunities for high school students on Zero-G aircraft and competitions for student experiments to fly on the International Space Station (ISS) (see Figure 9).

Perhaps what will require more thought is how to have the flexibility to transition into these new educational paradigms from established traditional practices. One model to examine is the Career Technical Education (CTE) Model. CTE schools are driven by a workforce readiness model that is based on proficiencies that include skill sets as identified by industry. The value of this model is that time is available for students to conduct research, practice skills, and apply their knowledge. It is not unusual for CTE schools to partner with local 2-year colleges granting certifications and/or Associate Degrees. This is truly creating a Geoscience pipeline. The flexibility of the CTE Model allows quick revisions in programs because they are tied to industry-based standards, and therefore have to react to changes in the workforce environment.

Creating the GeoSTEM Master Teacher

Studies link the success of students to the preparation and experience of the teacher. It is the teacher that will “prepare and inspire” the next generation of STEM related degree graduates. There has been no shortage of opportunities for the K-12 teaching community to develop content and/or participate in research. These experiences when brought back to the classroom, inspire students and give them the opportunity to know that their studies have meaning and application. These teacher experiences often inspire students to pursue similar opportunities that are available for them. NSF’s Research Experiences for Teachers (RETs), include: Polar Trek, NOAA’s Teacher at Sea Program, Joides Resolution, AMS DataStreme Program, just to name a few. What’s still needed is a “place” where these Master Teachers can gather, strategize, collaborate, share information and resources, and where ideas can be turned into action -- a “Clubhouse” approach. A program here, and a conference there, is currently the best we have to offer teachers. Developing “Teacher Leadership” and the “Teacher’s Voice” in policy and practice is a goal worthy of being embraced by this nation.

While the nation begins to deliberate over how to create a “STEM Master Teacher Corp”, the Geosciences Community needs to bring together the vast resources it has at its disposal, such as satellites, ships, airplanes, remote sensors and other emerging innovative technologies and the datasets derived from them. The goal is the development of teacher leaders who will then implement and/or integrate these innovative technologies and educational opportunities into classrooms throughout the USA. When achieved, this goal will surely change the lives and futures of students.

References

American Meteorological Society (AMS), www.ametsoc.org/amstedu
Earth Systems Science Education Alliance (ESSEA), http://esseacourses.strategies.org
Executive Office of the President, President’s Council of Advisors on Science and Technology (2010), Prepare and Inspire: K-12 Education in Science, Technology, Engineering, and Math (STEM) for America’s Future.
National Aeronautics and Space Administration (NASA), www.nasa.gov
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