Using Observing System Data in STEM Education

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Abstract- The STEM (science, technology, engineering, and mathematics) community is implementing several new observation systems that rely on sensor technology. With this revolution, the need to educate more science and engineering technicians to work (design, assemble, deploy, troubleshoot and communicate) with sensor networks and meet workforce demands will rise quickly in the near future. The incorporation of technology-enabled systems, tools and services into curricula is critical to addressing these training needs and improving STEM skills. This paper discusses a list of key factors that must be considered by scientists, in order to make their data suitable for public and educational consumption, and also by educators when considering the needs of teachers and classrooms in making use of this information.

I. INTRODUCTION

The STEM (science, technology, engineering, and mathematics) community is implementing several new observation systems that rely on sensor technology. These new and visionary projects will enable longer-term sensing of the environment.

Developing and maintaining a workforce to support these observatories will rely on innovative educational programs that prepare future workforce professionals at a variety of levels and in a variety of environmental and technical fields (U.S. Commission on Ocean Policy, 2004). At minimal levels, the members of non-expert audiences should be aware of the data available and how to access and interpret the data when applicable.

This paper will focus on steps the STEM community should take to make the data more accessible to non-expert audiences, and will provide examples of technology enhanced curricula which are the first step on the path of preparing students with 21st century workforce skills.

II. THE SENSOR REVOLUTION

“In the 1980s, the PC revolution put computing at our fingertips. In the 1990s, the internet revolution connected us to an information web that spans the planet. And now the next revolution is connecting the internet back to the physical world we live in-in effect, giving that world its first electronic nervous system. The Sensor Revolution is here” (NSF, The Sensor Revolution, 2005).

In recent years, the science, technology, engineering and mathematical modeling communities, with the support of the National Science Foundation (NSF) and other funding sources (e.g., National Oceanographic Partnership Program), have successfully conceived, designed, and begun implementing several new observing systems, including the Oceans Observatory Initiative (OOI), the National Ecological Observatory Network (NEON), the Collaborative Large-scale Engineering Analysis Network for Environmental Research (CLEANER), the Hydrologic Observatory Initiative (HOI), and Earthscope. In addition, seventeen Federal agencies are currently planning an integrated, comprehensive, and sustained Earth observation system to address the nation’s critical societal and economic needs. The Integrated Earth Observation System (IEOS) will integrate the data from satellites, ocean buoys, weather stations and in-situ Earth observing instruments into advanced scientific numerical models and decision support tools that will provide new data products benefiting societies and economies worldwide. These new and visionary projects will enable longer-term sensing of the environment.

Real time (or real world) data produced by sensor networks can significantly impact decision making in research, military, business and government. For example, scientists can select optimum locations to deploy instrumentation, ships can steer clear of storms, offshore oil and gas companies can determine production schedules and governments can issue evacuations from a threatened area.

With this revolution, the need to educate more science and engineering technicians to work (design, assemble, deploy, troubleshoot and communicate) with sensor networks and meet workforce demands will rise quickly in the near future.

III. BRINGING THE REVOLUTION TO THE PEOPLE

The incorporation of technology-enabled systems, tools and services into curricula is critical to addressing these training needs and improving STEM skills. These types of learning opportunities are especially critical since trends reported by the National Science Board show that there are not enough students in the pipeline today to support the STEM workforce of tomorrow (NSB 2003, 2004, 2006). In addition, the graying trend in the marine workforce adds to the urgency of training new ocean professionals (Piktialis & Morgan, 2003). This potential workforce deficit poses a significant limiting factor to the development and deployment of sensor networks, not to mention other sectors of the economy.

A. First step – accessibility

To broaden and strengthen the pipeline of STEM students, it is essential to provide data and services that are accessible by
non-expert audiences. Following a traditional definition of the accessible, data produced by observing systems should be available to the public (capable of being reached), data should be easy to communicate, capable of being used and understood (understanding at-a-glance) by non-expert audiences.

1) 24/7 – data should be available to potential users 24 hours a day, 7 days a week. If data is reliable and accurate, users will return. Classrooms are in session 24 hours a day so there is a steady stream of potential users. If a data source is “down” frequently, repeat visits will diminish and classroom teachers will all but disappear as users. Classroom teachers as well as other data harvesters need reliable data sets to do their jobs well. A data provider may consider a mirror site to ensure availability.

It is also important to maintain urls or use redirects if a web site undergoes major reconstruction. Users become frustrated and click out of a site if the information sought is not readily available.

2) Can the data be seen? To reach a large number of users, especially those with lower bandwidth (as is the case in many schools), it is important that data sharing does not hinge on downloads. Many school networked computers do not allow users to download materials from the internet or add new programs. Lower bandwidths also make it frustrating to view high resolution graphics, especially when 30 students are clicking on the same object at the same time as part of a lesson. It should also be noted that several schools do not allow flash players to dissuade students from gaming, etc when in school.

3) Data display – can anyone understand the data? It is important to take a critical look at the data produced by observing systems to determine if it is usable or meaningful to non-expert audiences. How can the STEM community expect to engage and excite students if data is essentially meaningless to inexperienced users? The answer is not to “train” the masses to understand the data; the STEM community must work with the audiences in order to create data displays that are meaningful to non-experts.

4) Organization is a key to communication. A site may have data available 24/7, low bandwidth friendly and meaningful material, but can a user find the information? “Conventions are your friends” (Krug, 2006). Conventions are conventions because they work. “Well-applied conventions make it easier for users to go from site to site without expending a lot of effort figuring out how a site works.” (Krug, 2006). If information is organized in a familiar format, new users will be apt to spend a bit more time trying to figure out what the site and data is all about.

B. Second step – usability

Start with K-12 education. Technology-based and data-enhanced educational experiences are important tools for student learning. In particular, these types of learning experiences prepare and empower students to address real-world complex problems; develop students’ ability to use scientific methods; teach students how to critically evaluate the integrity and robustness of data or evidence and of their consequent interpretations or conclusions; and provide training in scientific, technical, quantitative, and communication skills (Hotaling, et al, 2006).

However, for technology-based and data-enhanced educational experiences to become incorporated into classrooms, the experiences must be meaningful, engaging, dovetail into standard STEM curricula and address educational standards.

For example, the Gulf Stream Voyage, http://www.k12science.org/curriculum/gulfstream/index.shtml is an internet-based multidisciplinary project which utilizes both real time data and primary source materials to enable students to discover the science and history of the Gulf Stream. Students investigate the Gulf Stream current, its influence on the Atlantic Ocean and some of humankind’s experiences dealing with the effects of the current. The Gulf Stream Voyage includes activities for marine science, earth science, chemistry, physics, biology, math, history and language arts classrooms. All of the activities can be easily integrated into today’s technology-enhanced classroom.

The real time data and databases utilized in the project include NOAA buoy data, ship observation reports, sea surface temperature data, current velocities of the Gulf Stream, meteorological data, SeaWiFS, and Global Drifter Program drifter data.

The Gulf Stream Voyage project has been used in grades 6 – 14 classrooms across the country and has been used successfully in Adult Literacy classrooms, teaching users how to access and interpret real time oceanographic and satellite data, and how to use the information to solve real world problems.

Evaluation of projects such as the Gulf Stream Voyage can not only improve the educational content and lesson plans, but also begin to provide information as to how effectively or ineffectively the students are using the data. Potentially, scientists and educators could share this information to improve both products (Hotaling, 2005).

C. Third step – integration

Too often, computers and technology-based curricula are provided for teachers with little or no associated training. Consequently, efforts to use or integrate computers in classrooms have been focused on simplistic uses such as drill and practice programs, a traditional use of computers, but not effective or inquiry-based integration.

In an effort to improve educator understanding of the data, lessons and classroom implementation, more effective professional development opportunities, either face to face, online or a hybrid of the two must be provided to teachers and other school officials.

When providing professional development for educators on Internet-based classroom materials, it is important that:

- teachers experience the material just as the students would experience the material;
• the professional development session should provide
  time for the teachers to become comfortable with the
  lessons and the data source;
• teachers should be offered information for successful
  implementation of projects in classrooms, including:
  o classroom management strategies (one-
    computer classroom, cooperative group
    learning, back-up plans or off-line lessons in
    case of technology failure issues;
  o incorporating the role of facilitator versus
    teacher directed instruction; and
  o plenty of developed examples to use, augment
    and bring back to the classroom.

Teachers effectively educated in the use of real world data
in the classroom tend to:
• feel better prepared to teach problem-solving skills;
  spend less time lecturing;
• report an improved ability to teach complex concepts;
  are better able to conduct small group learning
  activities;
• can more easily implement cooperative learning
  approaches; and
• are more effective in managing diverse learning styles
  [Yepes-Baraya, 2003].

D. Fourth step – preparation

Raising the comfort level of K-12 students (and their
teachers) with the use and application of real time data from
observatories is a very large step in the preparation of the
future STEM workforce. At a minimum, a large portion of the
population (non-expert audiences) will be able to access,
understand and apply observatory data to real life situations. If
a large portion of the population enters college with this
resident knowledge, preparation of the students to use sensors
and sensory data will potentially occur at a much quicker pace,
potentially creating a qualified workforce of sensor network
technicians and observatory scientists and engineers to more
quickly satisfy the employment needs.

IV. CONCLUSION

Making informed decisions based on available data is
dependent on the clarity with which technical information is
represented on a web site. It is important that this data be
accessible and understandable by users with a wide range of
abilities, backgrounds and prior knowledge. It would be
extremely beneficial to investigate and evolve a best practice
methodology for the computerized display of scientific real
time and archived data for consumption by the general public.

It is critical for the scientific community, that non-expert
members of the general public, including legislators, should be
able understand and engage with scientific research. Helping
scientists to understand and address the ways in which the
public access, assimilate and utilize the products of their
research, will increase the awareness of, support for and
numbers of users of that research data.

The sensor revolution is playing a large part in the current
evolution of the field as well as having far-reaching effects on
other sectors of the economy. The continued development,
operation and maintenance of sensors and use of sensor
information depends on a workforce with the ability to apply
STEM and effectively communicate sensor data to a variety of
stakeholders.

Proper leverage of information technology (IT)-enabled
systems, tools, and services will be critical for addressing these
workforce training needs, having a profound impact on the
practice of science and assessment, engineering research,
industry, and global citizenry.

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