Making authentic data accessible: the Sensing the Environment inquiry module

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We report on the development of a middle school life sciences inquiry module, Sensing the Environment. This ‘data-enriched’ inquiry module includes a series of activities exploring the nature of science, photosynthesis, transpiration, and natural selection, which culminates in students’ querying authentic environmental data to support a scientific argument. This inquiry module results from a framework we devised to promote use of authentic data in the classroom. Our framework includes three elements: (a) an online tool, enabling authentic data to be easily searched, visualised, stored, and used to substantiate a scientific argument; (b) an online instructional teacher guide, providing support for teaching through inquiry; and (c) a dynamic data gathering/delivery system, allowing for expansion of the data and enabling students, teachers, scientists, or the public to ‘add value’ to the data. Based on our experience with Sensing the Environment, we suggest our framework can be a means for facilitating integration of rich, dynamic, and authentic data into science instruction.

Key words: Inquiry module; Sensor data; Authentic inquiry; Curriculum development; Educative curricula

Introduction

With the click of a button, the internet provides science teachers with a vast amount of data for use in the classroom. The increasing number of data streams posted on the web by scientific researchers, and freely accessible to the learning community, presents an opportunity for changing the nature of teaching and learning in science classrooms. Online data sources can allow students to learn science through investigations of large, authentic datasets as opposed to the limited and predictable data students often collect in the classroom. For example, The Center for Embedded Networked Sensing, funded by the US National Science Foundation to research and develop environmental sensors, has the potential to post large databases for use by any interested party. In one effort to make these data available to science teachers and students, CENS established a collaboration between research scientists who were collecting sensor data and classroom teachers who wanted to use authentic data to teach the nature of science, scientific argumentation, and specific science content.

Using authentic data during science instruction can, however, present problems for both the novice investigator (student) and the teacher. Domain experts understand data representations differently from students and often the teacher as well (Cook, 2006). Thus, unfiltered authentic data is not readily accessible for students unless teachers are highly skilled at integrating data investigations into their instruction. Furthermore, students have trouble understanding and using conventional methods for representing these data (e.g. graphs, tables, and symbols) unless teachers scaffold the use of these practices in meaningful learning contexts (Tairab and Khalaf Al-Naqbi, 2004; Wu and Krajcik, 2006). Integrating authentic, large-scale, and potentially ‘messy’ datasets into a curriculum is no small feat for teachers. This is even more difficult if the aim is to integrate the data into the inquiry-based instructional practices advocated by the science education community (National Research Council [NRC], 1996).

The ‘data-enriched’ inquiry module, Sensing the Environment (Griffis and Wise, 2005) addresses these issues so that science students, teachers, and independent learners can access, and be supported in the use of, rich sets of archived data for educational purposes. Our inquiry module stems from a framework we developed to describe conditions promoting robust uses of authentic data for science teaching and learning. The framework includes three elements: (a) an online data-mining and analysis tool supporting the use of authentic data; (b) teacher support in the form of an online guide facilitating use of the data for inquiry-based teaching and learning; and (c) a dynamic system allowing for expansion of data sets, annotation of data, and revision of curricular materials. Below, we describe the framework, the module we developed based on this framework, and future applications and expansions of our work.

Framework for online curricula that integrate authentic data

The first element of our framework addressed the way technology could be used to both deliver authentic data and support students’ use of it. An online data-mining tool could be especially potent if, in addition to delivering data, it facilitated students’ investigations of the data by supporting skills ranging from note taking, to graphing, to using graphs and tables for substantiating scientific claims and making scientific arguments (Driver et al, 2000; Osborne et al, 2004). Also, an online data investigation tool could make data analysis available.
to a broader learning audience, including independent learners and citizen scientists.

The second element of our framework focused on teacher support. To be adopted by classroom teachers, data would ideally be embedded in an innovative curriculum that is adequately supported and practical. Our experiences working with science teachers suggest that, although many agree that they would prefer real over ‘contrived’ data, the time required to build lesson plans around authentic data – which may lead to ambiguous or uncertain results – can be a deterrent. This is especially true if it is not explicit how the data are linked to curricular goals or learning standards.

Curricula that integrate such data would therefore be coupled with training materials that suggest to the teacher how to teach content related to the online data and how to explicitly promote students’ understanding of the scientific process. These instructional materials would be ‘educative’, providing – in addition to lesson content – questions that teachers could use to lead students through an exploration of the content, common student responses and misconceptions, etc. (Ball and Cohen, 1996; Schneider and Krajcik, 2002; Davis and Krajcik, 2005).

The third element of our framework recognised that data-enriched inquiry modules should be based in dynamic systems. They should allow for databases to change as scientists collect data, and they should allow lessons to be adapted, depending on the specific skills/knowledge that a teacher wishes to emphasise or the developmental level of his/her students. This aspect of our framework is discussed further at the end of the paper.

**Sensing the Environment**

The Sensing the Environment inquiry module, available at: http://interactive.cens.ucla.edu/education/InquiryModule, is a middle school (age 12-13 years) life science curricular unit of approximately three weeks duration. It is composed of eight lessons or learning activities that are, as a whole, aligned to the framework described above.

The primary content covered by the module relates to the structure and function of plant leaves, with some emphasis being given to the role of natural selection in shaping the former. Students learn about photosynthesis and transpiration and the notion of a ‘photosynthesis-transpiration compromise’ in which a balance is struck between photosynthesis and the amount of water that can be safely lost through transpiration. They also study the role of stomata in regulating both photosynthesis and transpiration and discuss the potential consequences of having small or large leaf surface areas on these functions. Students’ content learning is situated in guided-inquiry-based learning activities.

In line with the first element of our framework, the centre-piece of the inquiry module is an online tool that enables students to not only access authentic data, but easily search the data, present it graphically, and use it to construct arguments about the relationship between environmental variables and leaf traits.

The first activity of the module asks students to make observations about the plants shown in a panoramic photograph (Figure 1a). With teacher guidance, students identify patterns and anomalies and suggest environmental variables that could explain their observations. Using pull-down menus, students search temperature, humidity, and light intensity data in three areas within the photographed region (Figure 1b). A digitised leaf gallery (Figure 1c) displays images of plant leaves that are characteristic for each of the three weather station locations within the photographed panorama. Students use the data to graph relationships between the environmental conditions and calculate the average surface area of leaves across locations.

In a consolidating or ‘capstone’ task, students write a short report on a question posed early in the module, “Why do plants look different?” The online tool scaffolds students’ arguments to this question through smaller guiding questions and a note-taking tool allows them to enter responses to the guiding questions and attach supporting evidence in the form of text, graphs or leaf images. As a final piece to this activity, students learn to review their own reports and those of their peers through a process known as Calibrated Peer Review™ ([CPR] see Robinson, 2001, for a summary of this process; note that the module uses an offline version of CPR, in contrast to...
the original model).

In summary, online technologies provide students with access to data, scaffold their reasoning using the data, and promote the use of evidence for supporting their claims. By the end of the module, teachers have used authentic data and the scientific process to promote content learning, as advocated by the NRC (2005); and students have been guided to make observations, look for patterns and anomalies, propose hypotheses, analyse data, substantiate arguments, and review and evaluate the work of others.

Aligned with the second aspect of our framework, teachers’ use of the sensor data is supported through an online, downloadable Teacher’s Guide. This guide suggests ways of using the weather data to teach content and the nature of scientific investigation. Activities are modular, providing flexibility for the teacher to integrate topics in a manner fitting to their curriculum and grade level. Topics are aligned with science content and investigation and experimentation standards. The guide also provides technical assistance and pedagogical suggestions. For example, teachers are encouraged to create an ‘idea board’ that becomes a public record of observations made, questions asked, key concepts and variables identified, relationships established, and predictions made. The guide also provides questions for leading class discussions, typical student responses, and common student misconceptions. Finally, the guide includes lists of materials needed for the integrated investigations, time frame estimates for each learning activity, and student handouts and keys.

Sensing the Environment is based in a dynamic data-gathering system, which aligns with the third element of our framework. By its nature, our database expands over time as more environmental sensor data is archived, which enables students’ queries and analyses of the data to become more sophisticated or refined as the database changes. For example, students can substantiate their reasoning to the module’s overarching question using data from different seasons or multiple years. Or, they can, across school terms, replicate or test findings from previous classes. Moreover, teachers can add, subtract, or modify activities to customise their curriculum. Finally, as we discuss below, in future versions of educational modules that integrate such data, students, teachers, and other interested individuals can contribute to augmenting and vetting databases.

An efficacy field study of Sensing the Environment (Thadani et al., 2007) at three school sites suggested that it has promise for enhancing students’ content learning. Eight teachers at the three schools were randomly assigned to either the Sensing the Environment or comparison conditions, with the former using the module to meet targeted content standards and the latter covering the same standards as they normally would. Students, pre- and post-tested on content learning (on photosynthesis/transpiration and evolution), demonstrated greater gains when they were in the Sensing the Environment group relative to the comparison group. This effect was observed at two of three schools; at the remaining school, we found neither an advantage nor a disadvantage of the module on students’ content learning.

The module was designed to be used in diverse contexts, and indeed, the two schools in which gains were observed served large proportions of children from racial/ethnic minority and low socio-economic backgrounds. Furthermore, we found that teaching and learning practices differed in module vs. comparison classrooms, with students in the former asking more questions, discussing with their peers, and generating hypotheses and conclusions about and from data during the lesson.

Note that schools participating in the study were not required to have resource- or technology-rich classrooms. Though technology was necessary (one internet-connected computer for every 3–4 students), only the infrastructure already available at the schools (which ranged in the resources they had available) was used.

Data-enriched inquiry modules in the future

Although our database is dynamic, in that it expands as additional data is collected, we envision development of inquiry modules in which the user ‘adds value’ to the data. Our subjective classroom experience suggests that student motivation is improved when students perceive that their actions are adding value to the data.

Experience with the development and deployment of Sensing the Environment leads us to further propose that scientists can utilise a wide ‘work force’ of students, teachers, independent learners, and citizen scientists who investigate and draw conclusions from data, similar to NASA’s clickworkers project (http://clickworkers.arc.nasa.gov). For example, as students group data and develop hypotheses, their groupings and hypotheses provide new ways of looking at the data. With each student’s input, the data becomes more refined and developed, providing an even richer data set from which to extract information and practice argumentation skills. Scientists have their data reviewed, teachers get student buy-in with authentic scientific activities, and students get to participate in a more meaningful learning experience – a win-win situation for students, teachers, and scientists.

The multiple benefits of citizen science projects for both the learning and scientific communities were reviewed by Brossard et al., (2005). Their study, evaluating the effect of a Cornell Laboratory of Ornithology informal science education project, found that factual knowledge increased as a result of participation. We propose that dynamic inquiry projects – particularly if they capitalise on technology as a means for scaffolding the work done by science students and teachers – are a means of promoting meaningful collaboration between...
scientists, teachers and students.

We are currently developing a tool that allows for the dynamic collaborations suggested above. The interactive Data Classification Tool (iDCT) encourages learners to annotate data thereby adding value to the database; they do so by responding to a series of questions of interest provided by field researchers (Figure 2). The initial use of the iDCT is to classify thousands of web cam images of bird activity in nest boxes. By participating in this project, we anticipate that students will gain a better appreciation of what scientists do and what kinds of questions they ask and will be motivated to take a role in the scientific process.

It is clear that more and more authentic data will be available for exploration by the educational community (e.g. from projects at CENS, NEON). In addition, worldwide distribution of the XO laptop to school-aged children (www.laptop.org) could potentially add millions of new users of databases. Pedagogically sound educational tools and curricula can capitalise on these global data collection efforts. Indeed, blending our framework with models of existing collaborative projects (such as the international project, iEARN, at www.iearn.org), could facilitate the exchange of data on a global scale.

The recently developed SensorBase, a data repository managed by CENS (http://sensorbase.org) allows individuals to freely log sensor data – a process referred to as ‘slogging’. Contributions to SensorBase could broaden the learning experience; as students collect and post their own local weather data and leaf images, large scale comparisons of data sets by students at different geographical sites becomes possible.

Conclusion

We feel that development of data-enriched inquiry modules is worthy of the science education community’s attention. Leaders in the science education community have called for science instruction that integrates discussions and readings with opportunities for students to grapple with authentic data (NRC, 2005). Indeed, the benefits of authentic learning opportunities to student achievement have been documented (Newmann et al., 2001). With the increasing availability of rich online data sources, the opportunity is ripe for well-designed educative curricula to provide such learning opportunities for science students.

References


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