Designing Soil Quality Mobile Inquiry For Middle School

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Abstract: LET'S GO aims to develop, implement, research, and scale a new paradigm to foster collaborative student learning in ecological sciences. We integrate geo-positional data sensing, participation frameworks for learner collaboration, mobile inquiry, reflection and information visualization tools to create science learning collaboratories. We describe motivations for our project and related research, discuss our experiences designing a pilot set of Soil Quality Inquiry activities, and the challenges faced.

Introduction

Learning science concepts and inquiry strategies should appropriate new tools from science—sensors for data capture, data visualization, low-cost mobiles for field-based science, and geo-tagged digital photos and videos for documenting field research. Inspired by Design-based Research (Cobb, diSessa, Lehrer, & Schauble, 2003), we have designed classroom interventions aimed at developing theoretical frameworks for domain-specific learning processes. Our first objective is to provide interactive educational activities and tools enabling students to participate in collaborative scientific inquiry as they craft hypotheses, and collect, analyze, compare and discuss local data while studying environmental and ecological sciences.

LET'S GO (Learning Ecology with Technologies from Science for Global Outcomes) convenes partners across disciplinary and geographical boundaries, and academic and commercial interests, sharing a vision of collaboratories (Bos et al. 2007) for mobile science. Guided by these aims, we design activities which integrate geo-positional data sensing, multimedia communication, data visualization and Web 2.0 tools in specific ecology learning scenarios, using co-design methods with teachers, learners, developers, learning and domain scientists on topics such as water quality, soil quality, ecosystems and biodiversity.

Inquiry Learning and Mobile Sensing

Inquiry learning is "an approach to learning that involves a process of exploring the natural or material world, and that leads to asking questions, making discoveries, and rigorously testing those discoveries in the search for new understanding" (National Science Foundation, 2000), In educational settings, inquiry learning in science is commonly embodied in project-enhanced science learning, where students engage in authentic, open-ended and motivating tasks extending over days and mediated by various tools and expertise. These tasks require collaboration and communication within—and sometimes beyond – the classroom, taking advantage of online data resources (Blumenfeld et al., 1991; Pea 1993, Quintana et al. 2004; Scanlon, Jones and Waycott, 2005; Tinker & Kracjik, 2002). These conditions are intended to support the social model of teaching and learning known as "cognitive apprenticeship" (Collins, Brown & Newman 1989) where authentic problem definition and problem-solving processes are guided by mentors, with learners gradually taking on increasingly complex tasks and autonomy as support fades.

More recently, rapid developments in mobile, wireless, and sensor technologies have provided new design possibilities for augmented learning activities that may be orchestrated across diverse environments such as schools, nature and science centers/museums (Rogers & Price, 2006; Roschelle & Pea, 2002; Scanlon et al. 2005; Sharples, Taylor and Vavoula, 2007). Building on this prior work, we are leveraging new mobile multimedia technologies, sensors, digital maps and interactive data visualization tools. Opportunities with open platforms and less costly component technologies make integral use of mobile science learning more broadly adoptable (Giemza, Bollen & Hoppe 2010, Vogel et al. 2010).

Co-designing for Mobile Science Inquiry Learning

The activities and tools we are designing explicitly support inquiry, integrating sensor data collection from school sites with a collaborative learning system using locally networked mobile devices. Our approach to designing the mobile science collaboratory is guided by use of Design-based Research (Cobb, diSessa, Lehrer, & Schauble, 2003) and co-design methodologies (Penuel, Roschelle & Schechtman 2007). Our design process involved co-design workshops teaming teachers, experts, science educators, learning researchers, software developers and learners. We conducted co-design workshops in Sweden and the US (Spikol et al., 2009; Maldonado & Pea, 2010), and piloted activities in both countries to yield feedback for revisions toward a more flexible curriculum adaptable to the local culture and educational system.

Inquiry activities and assessments were created that matched the standards for a 7th grade level science class using field inquiry practices and mobile technologies. The school offered additional constraints and possibilities: activities had to fit within the school periods, within the academic curriculum and each teacher's yearly lesson plan. Equipment, procedures, materials and assessments had to be standardized so as to be able to be deployed and evaluated several times throughout the day.

Our co-design team chose five devices for the present trials, based on their usefulness to the students' outdoor inquiry activities, and the feasibility of incorporating them quickly into the educational flow.

(1) A *smartphone* with built-in sensors (camera, GPS), and a mobile client application developed by the Linnaeus University Celekt team for students' data collection and related observations, using 3G networking for communication purposes (Vogel et al, 2010).

(2) *PASCO scientific's SPARK Science Learning System* with built-in sensor interface and additional sensors. Its handheld touchscreen science appliance enables data collection and visualization, and connects to different sensors to measure phenomena such as pH, temperature, humidity, and dissolved oxygen.

(3) *Livescribe*'s Pulse pen digitizes the users' notes, recording audio in sync with pen strokes. Student groups use this digital pen for data collection and recording discussions during field investigations. These conversations are later replayed by the team when reflecting on inquiry processes and report writing. Researchers can also study how students incorporate their classroom knowledge into the inquiry process.

(4) A *laptop computer* to visualize geolocated data by the groups for comparison and discussion across groups, and to prepare each group's presentation.

(5) A *digital video camera* for the teams to document their discussions and observations.

Mobile Inquiry Learning Activities in Schools

Following the success of our Water Quality Modules (Pea, Milrad, Maldonado, Vogel, Kurti, Spikol, 2012; Maldonado & Pea, 2010), the LET'S GO co-design team chose Soil Quality as the next focal science topic to address the critical unmet need for Soil Quality lesson plans and activities in classrooms, particularly at the middle- and high-school level (Collins, 2008). Understanding basic aspects of Soil Quality is necessary for making decisions on sustainable land uses, at a personal and civic level. Today's students will soon be voting on issues like soil depletion, food security, soil erosion, sustainability, biofuel, and climate change.

Our team narrowed the activities' goals to four key concepts about Soil Quality: (1) importance of Soil Quality to plant and human life; (2) Soil Quality is a scale, not a binary judgment, composed of many micro- and macro-properties of soil; (3) existence of macro- and micro-organisms in soil such as groundworms (nematodes), which reflect and contribute to Soil Quality; and (4) the interaction of these macro- and micro-characteristics of the soil have a clear effect on the (plant) life supported by soil, impacting its ability to grow and propagate, as well as other features such as color.

We developed formal student roles in terms of group-worthy activities (Lotan, 2003): 'documentary filmmaker,' 'lab technician,' 'reporter,' 'data scientist.' Each role contributes a different, significant part of the inquiry activity. Groups decided on their own rotation pattern for the roles, so that each student in a group would have the opportunity to fulfill each of the roles and responsibilities on different days. By empowering the students to record their own video, we hoped to gain an insight into their attention process, as it quickly became apparent that the students' video focus differed from that of researchers.

The LET'S GO Soil Quality Inquiry Modules

Our final design called for four activities, implemented across three to four classes lasting 90 to 120-minutes. The first two inquiry activities were conducted inside class, with the third and fourth outdoors on school grounds. Students' inquiry processes would be scaffolded heavily during the first module, and gradually these scaffolds would fade throughout the sessions (Collins et al.,1989). Activities were designed to appeal to the intended audience in presentation and level of pre-existing knowledge, and to introduce gradually the concepts and inquiry processes.

Figure 1: (A) *'Is Soil Alive?'* Students evaluating the composition of a soil sample in the classroom. (B) '*PlantSmart Mystery*': Students measuring Soil Respiration. (C) Hydrangea plants' color-pH correlation.

Figure 2: 24-hours of PlantSmart sensor readings: (A) Soil Moisture, (B) Sunlight Data, (C) Temperature.

The four LET'S GO Soil Quality activities are:

(1) *Is Soil Alive?* Students learn to use sensors to measure soil respiration rates of different types of soil. They then contrast these results with data obtained through guided observation and evaluation of soil samples (see Figure 1A) to answer questions such as: What does the soil sample smell like? What color is it? What is its texture? What is it made of? The goal is to have students link properties of the soil that they can observe, such as the prevalence of organic matter, with the invisible characteristics of Soil Quality – in this case, soil respiration, and, through this link, to discover the invisible layer of the soil ecosystem.

(2) *Understanding the Effects of pH*. the second activity, examines the link between invisible properties of the soil and the impact on the life sustained by that soil. It addresses two key student misconceptions: first, how despite the fact that soil pH cannot be directly observed, it has visible effects on the life that grows upon that soil. Secondly, students are keen to assign the labels of 'good' and 'bad' to pH values that deviate from the center of the scale. Yet even pH levels that may not be ideal for sustaining *human* life can sustain beautiful life forms.

We focused our activity around soil samples from differently colored Hydrangea plants (known as Hortensia). These small flowering bushes are common and inexpensive, and more importantly, several of the varieties (most notably Hydrangea Macrophylla and Hydrangea Serrata) have the property that the color of their flowers is affected by the soil pH . An acidic soil (pH< 6) will usually produce flowers with blue coloration, whereas a more alkaline soil (pH > 6) will produce pink flowers (see Figure 1C). Students were presented with a wide-range of hydrangea plants from which to choose several soil samples to evaluate their pH. This exercise offers an immediate view into how a single invisible property of soil directly impacts the life supported by the soil.

(3) *PlantSmart Mystery.* PlantSmart sensors are inexpensive and measure sunlight exposure, temperature and soil moisture over time. In this activity, we placed eight of these sensors for 24 hours in different locations around the school campus. The data was then downloaded to the computer, and each student group received the information for all eight sensors, labeled with letters (Sensor A, Sensor B, etc). A typical example of these readings is visible in Figure 2. The students also received a list of GPS coordinates for all eight sensors labeled numerically (Sensor 1, Sensor 2, etc). From the latter list, each group was 'assigned' a sensor. The groups' task was to design an inquiry that would allow them to decide which of the sensor readings matched their assigned sensor site. To design their inquiry experiment, the students could choose which measures to collect from their assigned location, including collecting measurements with the PASCO sensors with which they had prior experience (see Figure 1B) for an example of a group working on their '*PlantSmart Mystery*' activity).

One of the intentional challenges student groups faced in this activity was that the PlantSmart sensor readings are given qualitatively (see Figure 2): for example, temperature is reported on a six-point scale: Cold, Cool, Moderate, Warm, Hot, Very Hot. Within their group, students had to make their own judgments to transition between the data collected by the PlantSmart sensors qualitatively and the quantitative data they collected through the PASCO sensors.

(4) *'Can My Site Support Life?'*, the fourth activity was originally linked with the prior activity during our pilot deployment, although we have since separated them. The students groups are asked to answer how their site may support life through an inquiry they design among themselves. We kept the same GPS coordinate site as for the prior activity, but the focus shifts from gathering data about soil characteristics in the '*PlantSmart Mystery'* activity. For this last Soil Quality activity, we want students to move upwards in the level of abstraction, and make conclusions about Soil Quality of their site based on the soil characteristics. At the end, each group prepared a presentation for the class, following a template that scaffolded their inquiry.

Next Steps

The four Soil Quality modules we have outlined were experienced by twenty-four students at a local middle school. We are currently evaluating the results from this intervention through video analysis, as well as qualitative and quantitative assessments.

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