Organized Oral Session 14
Ecology Education in 2020: Integrating New Technologies with Mother Nature

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Technology is often on the minds of ecologists; they covet new instruments to advance their measurements or new software tools to accelerate data analysis. The geeks among us have rapidly adopted new technologies such as i-Clickers and Facebook, but how do the spectrum of new approaches and tools of the digital revolution impact teaching (see National Academy reports of the last decade and most recently, the U.S. Department of Education, Office of Educational Technology [2010]), and how can they enhance ecological education? For the upcoming generation of digital natives (Palfrey and Gasser 2008), can we expect incremental steps, or are there revolutions on the horizon? Our oral session in Pittsburgh was planned to address these questions and to prime members' interest in the Environmental Education Summit (‹http://www.esa.org/eesummit/home›) sponsored by ESA and NEA that was to be held 14–15 October.

Prassede Calabi's talk started the session by reminding the audience of the importance of assessment. It is surprising how few of us as teachers have transferred the ideas that are essential in any ecological experiment (pre- and postmanipulation measurements) to the realm of teaching. We tend to test our students after lecturing but not before, so there are no data to support or refute the goal of a successful teaching intervention. Calabi and her coauthor, psychologist Andrew Shtulman, developed an online test to assess conceptual change in understanding evolution, which is a more difficult challenge than simply measuring if there is an increase in content knowledge. The presentation described both a preexisting conception of evolution that students are known to hold and a teaching method designed to facilitate conceptual change. Their data showed that their techniques worked. Calabi recommended Khodor et al. (2004) and the Bioliteracy network (‹http://bioliteracy.net/›) as starting points for those interested in conceptual change. She also recommended broader use of standardize tests to document conceptual change in ecology and evolution courses across the country.

The remainder of the presentations featured practitioners incorporating new technologies with modern ideas about how people learn, or educators developing new technologies that hold significant promise for revolutionary changes.

When working with general education students in an introductory environmental education course at Penn State titled "Geographic Explorations of Earth's Ecosystems," Andrei Israel and Erica Smithwick have reduced the lecture portion of the course and increased the interactive portion, with an emphasis on developing skills of observation and investigation. Initial comparisons suggest that students have greater enjoyment and learning from tactile experiences in the classroom and during field trips when compared with Internet- or textbook-based activities. They acknowledge that engaging nonmajors and diverse students is a challenge, but their observations and preliminary data suggest that experiential learning makes a difference.

What do we remember most easily? Stories! That led David Bowne of Elizabethtown College to write his own short stories, fictional in concept but scientific in content, as a way to engage his nonmajor environmental science students. For example, one titled "Henry Ford Hated Glaciers" chronicles students debating the causes and solutions to climate change. As a follow-up to the reading assignment, students are asked to create a company that offers new products to sequester carbon. In another example, the story "Talking Turkey" draws students into online discussions about the ecological principles behind the main character's choice to be a vegetarian. Online discussions about the story "Breeding Discussion" were also used to get students' opinions about individual choices regarding the number of children and lifestyle they thought appropriate in the face of global shortages of resources. The online discussion technique proved an ideal forum to get students talking about their choices and defending their decisions. This provided expanded opportunities to identify misconceptions and clarify confusions when compared to normal classroom discussions. Making the stories relate to the students' personal lives and providing a forum where they would express their views were the essential features of Bowne's approach.

Molly Steinwald and collaborators at Miami University related their experiences using modern and novel digital imaging techniques to engage and communicate environmental science. In Minnesota's "Digital Bridge to Nature" project, teachers and students are reconnecting to the small schoolyard worlds of bugs and spiders and leaves and flowers by "hunting" nature with their digital cameras. As part of Discover Life in America's All Taxa Biodiversity Inventory project of the Great Smoky Mountains (‹http://www.dlia.org/atbi/›), citizens are documenting species occurrence that will be shared through the National Biological Information Infrastructure and become part of the records of the Earth's heritage at the Global Biodiversity Information Facility. In a third project, scientists from Steinwald's lab, working in the Antarctic, are using blogging with still images to share their work and working conditions with colleagues at their home institution and with students in nearby public schools (‹http://frozenfly.edublogs.org/›). A novel component of the Antarctic project is the use of interactive, online Gigapan images (‹http://www.gigapan.org›), that let others explore a physical space or object documented with a zoomable Gigapan image (stitched together from 10−500 overlapping images) and comment on what they saw. Steinwald described a final project that used digital photography in professional development courses with Project Dragonfly (‹http://www.projectdragonfly.org/›) at the Cincinnati Zoo and Botanical Garden to facilitate schoolyard inquiry teaching methods and place-based education.

Her examples documented how images can connect people to distant places, invoke empathy for nature, capture events at different scales, and teach people how to see. The revolution in digital imagery offers a multitude of advantages, letting a much wider range of people capture and share images at lower costs and faster rates. Steinwald suggested that taking digital images helps bridge the gaps among scientists, teachers, parents, students, and professional photographers and allows environmental education to flourish in both formal and informal learning environments.

Lou Gross from the National Center for Mathematical and Biological Synthesis at the University of Tennessee spoke to the ever-present need for college students to master overarching concepts (i.e., evolution dynamics, energy and matter, information flow, exchange, and storage) and develop competencies (process and nature of science, communication and collaboration, quantitative methods). He gave three examples of quantitative methods (analysis of citizen science data, mapping, statistical analysis) that emphasized the importance of making the material relevant to and fun for the students. As part of an undergraduate general biology course, his team created approaches and examples to weave in quantitative methods throughout the semester. Compared to a control group (see Fig. 1), their intervention improved students' ability to successfully do quantitative problems.

Three of the talks showcased new technologies for use in environmental education. Eric Graham from the Center for Embedded Networked Sensors (CENS), an NSF Science and Technology Center located at UCLA, described some of their work with environmental learning and mobile computing. The Center is developing cell phone applications in a variety of ways to help people and their communities monitor their environment in what has been termed the citizen science approach (Lepczyk et al. 2009). Using smart phones it is possible to easily collect text, images, and geolocation in the field and then quickly upload the data to a server where it can be shared. The CENS project provided 10 Nokia phones to NPS staff, who work in the Santa Monica Mountains National Recreation Area. Each phone was loaded with What's Invasive software (‹www.whatsinvasive.com›, ‹bit.ly/whatsinvasive›) customized with data about the local invasive plants. In two weeks the staff recorded 975 observations of invasive plants, which was more than nine times the rate of observations collected with traditional methods during the previous two years. Graham also demonstrated software that is intended to help automate data collection and data sharing for Project Budburst, a continentwide project devoted to recording the phenology of plants (see BudBurst Mobile: bit.ly/mobileBB or bit.ly/mobileBBapp). Many showed interest in the mobile phone approach in Pittsburgh and at the Ecological Summit because it is clear that smart phones have great powers for communication.

A second talk about novel educational approaches was the first of a two presentations describing the EcoMUVE (Multi-User Virtual Environment) gaming project (‹http://www.EcoMUVE.org›; Fig 2; video clip here: ‹http://www.ecomuve.org/video.html›). In the last 10 years there has been a broad effort across subject domains to understand the potential of games for learning. Initial studies suggest they can be very effective (Gee 2007). Amy Kamarainen discussed the basic philosophy and functionality of the EcoMUVE game to teach ecosystem functions and causality concepts. MUVEs are powerful tools. They allow users to slow down or speed up time, move across space, move across spatial scales, and record data with virtual instruments (‹http://www.ecomuve.org/background.html›). For instance, in the Pond simulation, EcoMUVE employs a submarine tool and atom tracker (‹http://www.ecomuve.org/module1.html›) to understand the ecological concepts of the conservation of matter and decomposition. EcoMUVE allows students to discover and interact with components of complex patterns of a pond ecosystem. When challenged with the problem of an algae bloom in the pond, they actively explored the system with realistic graphics and measurement tools. EcoMUVE provided another example in which personalized approaches and active learning can engage students.

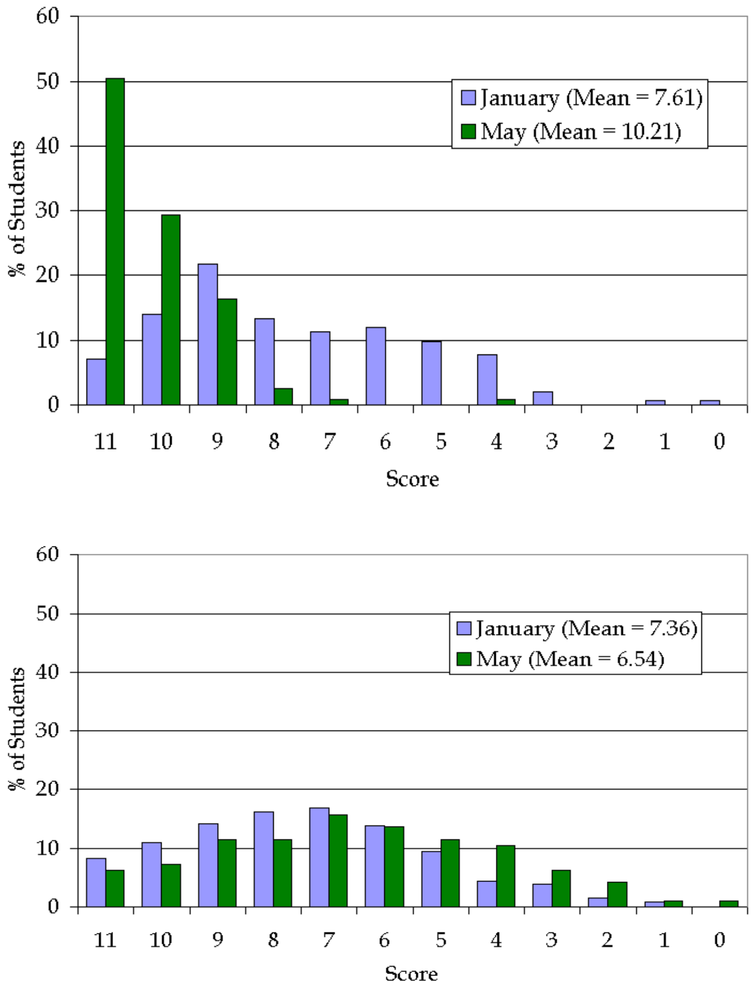

Fig. 1. Pre- (January) and post-testing (May) done in Gen Bio sections taught by University of Tennessee faculty in a standard manner. Panel A shows data with a pedagogy emphasizing quantitative skills and Panel B with pedagogy not emphasizing quantitative skills, as a control. The score is the number of correct answers.

Fig. 2. Screen shot for the EcoMUVE game showing the atom tracker tool that follows carbon atoms as they move in the environment.

Chris Dede gave a second talk on gaming with EcoMUVE as the prime example. He emphasized the advantages virtual environments and augmented realities have for teaching. When students adopt a digital avatar, learning styles based on student motivations and social patterns (rather than those based on personality or intelligence factors) emerge. Of particular note was Dede's discussion about new methods of assessment. It is possible to record every move that students make while playing a MUVE game. Old assessment tools based on multiple-choice tests seem incredibly limited when compared with the variety of challenges and real-world problems that can be presented in virtual realities games. Dede and his colleagues are already starting to use this approach in the Virtual Performance Assessment project (‹http://virtualassessment.org›) that is the measuring the ability of middle-school students to understand complex causality in pond and forest ecosystems (Clarke and Dede, *in press*).

Without question, technological changes are remaking both the science and teaching of ecology. Richard Louv's *Last Child in the Woods* documents ways that technology has removed our youth from nature, but the presenters in the session offered many exciting examples of changes in technology that could supersede those isolating impacts and help reconnect the coming generation of digital natives to their environment. The balance is unclear, but no one will argue that dramatic changes are underway. The consensus among the attendees of the ESA annual meeting and the Environmental Education

Summit was that cell phones and games are two technological developments that have the potential to greatly impact ecological education. Ecologists are among our citizens most attuned to the rates of environmental change and the challenges we face as a society. Perhaps the novel tools described here as well as some of the other approaches can also help educate the coming generation at home in the USA and around the world.

Given the challenges we face with global change and rapid and exciting technological advances that are occurring in education, what support can ESA members seek to advance ecological education? Sonia Ortega of NSF's Education Division added to the program by giving an overview of the variety of undergraduate, graduate, and informal education programs that welcome innovative ideas for education. She noted that programs such as NSF's CCLI (now TUES) and ATE programs at four-year and two-year higher-education institutions include technological innovations that would be used to improve STEM education. The GK-12, the IGERT for graduate education, and the Informal Science Education (ISE) program can incorporate aspects of technology for teaching, too. Dr. Ortega reminded us of NSF's continued effort to develop programs and approaches that support underrepresented minors in STEM education.

Acknowledgments

We thank the organizers of the 2010 ESA conference and the enthusiastic presenters in Session OOS-14.

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