**Research Essay**

**Ecosystem Science Learning via Multi-User Virtual Environments**

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EcoMUVE is designed as a collaborative, inquiry-based, simulated ecosystem experience to support learners developing an understanding of complex causality in ecosystems. (http://ecomuve.org/) Students typically use simple linear causal forms in their science learning – reasoning that one thing directly makes another thing happen. They also tend to focus on obvious variables – ones they can perceive directly (Grotzer, 2004). Even after instruction, students often retain inaccurate interpretations about ecosystems’ structural patterns and systemic causality (Grotzer & Basca, 2003).

Ecosystems are complex systems which are impacted by non-obvious as well as obvious causes, distributed causality, effects at a distance and over long periods of time. An understanding of complex causality is necessary to understand the dynamics involved in concepts such as energy transfer, matter recycling, decomposition, and interaction between biotic and abiotic factors (Grotzer et al., 2009).

The EcoMUVE project, supported by the Institute of Education Sciences in the U.S. Department of Education, builds on our previous research with multi-user virtual environments (MUVEs) (Ketelhut et al., 2010). Immersion in virtual environments can transform the learning experience by superimposing perceptual overlays on phenomena to support student understanding. EcoMUVE aims to harness the affordances of virtual worlds – e.g., zooming in to the microscopic level, traveling to different points in time, and seeing effects emerge across time and distance – to accomplish ecosystem understanding goals that are otherwise difficult to achieve. MUVEs are vehicles for authentic, situated learning - learning by being embedded in a rich simulated context (Dede, 2009).

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EcoMUVE includes two one-week virtual-world modules. The first is a pond ecosystem (Figure 1). Students explore the pond and the surrounding area, see realistic organisms in their natural habitats, and collect water, weather, and population data. Students visit the pond over a number of virtual “days” and eventually make the surprising discovery that many fish in the pond have died. Students are challenged to figure out what happened – they work in teams to collect and analyze data, solve the mystery and learn about the complex causality of the pond ecosystem.

EcoMUVE doesn’t replace students’ experiences in nature, but provides new ways of accessing the causal structures inherent in ecosystem relationships via immersive simulation. Students gather information by taking measurements, talking to residents, and attending to tacit clues within the environment.

Moving through the immersive virtual world can help students understand spatially distributed ecological phenomena. The EcoMUVE world models the pond and its surroundings, including a nearby golf course and a housing development. Students walk their avatars uphill to the housing development, and down along a drainage ditch to see how water flows into the pond. Through exploration, students discover that fertilizer runoff from the development is the distant cause of an algae bloom at the local pond (Figure 2).

Linked visual representations reinforce student learning of abstract ecosystem concepts. For example, students see the surface of the pond become noticeably greener during the algae bloom. Students measure pond turbidity and can link the measurements to their experiences walking under the water of the pond and seeing how murky it looks on different days. EcoMUVE’s submarine tool allows students to explore the microscopic organisms in the pond, helping them understand that organisms that they cannot see, such as algae and bacteria, play critical roles in the pond ecosystem (Figure 3).

A pilot study evaluated the effectiveness of EcoMUVE to facilitate student learning of ecosystem concepts difficult to attain in the real world. After using EcoMUVE, students gained in their understanding of particular ecosystem concepts. Specifically, scores improved on learning goals related to the interactions between biotic and abiotic factors, on the processes of photosynthesis and respiration, and on the role

Figure 1. Screenshot of EcoMUVE pond ecosystem
Figure 2. Rain causing runoff from a virtual housing development

Figure 3. Submarine tool

of decomposition in gas exchange. Initial findings on learning of complex causality in ecosystems showed significant increases in understanding the importance of effects over distance (McNemar test, $\chi^2(1, 69) = 14.73$, $p < .0001$). Scores on questions related to changes over time and ability to recognize non-obvious causes were non-significant (McNemar test, $\chi^2(1, 69) = 1.14$, $p > .05$; and $\chi^2(1, 69) = 2.77$, $p > .05$, respectively). Students’ high pre-survey scores indicate that they already had an appreciation for non-obvious causes before working with EcoMUVE.

It is challenging to enact pedagogies in the classroom that encourage students to attend to and reason about certain challenging ecosystems concepts. Teachers have expressed difficulty coming up with demonstrations and simulations that invite deep and authentic reasoning (Grotzer et al., 2009). EcoMUVE offers a medium that works well in the classroom to provide new ways of accessing the causal structures inherent in ecosystem relationships via immersive simulation, leading to a more expert understanding of ecosystems. Upcoming
research will assess students’ learning on the first module as well as test a second module—a forest ecosystem that models a predator/prey causal system—as part of a full four-week curriculum that includes both MUVE-based modules. Our research will include classroom observation, student and teacher interviews and surveys, log-files and student artifacts, in order to further explore whether interaction with EcoMUVE components had a differential effect on student motivation and learning.

REFERENCES


Shari Metcalf is Project Director of the EcoMUVE project at the Harvard Graduate School of Education. Previously she worked as a research scientist at the Concord Consortium on a number of educational technology projects in science, math, and sustainability education, including research on computer-based data collection and analysis tools for middle school science students. She holds a BS and MS from MIT, and a PhD in computer science from the University of Michigan. Her PhD research involved the design and development of Model-It, a software tool for students building models of dynamic systems. Her professional focus is the design of educational software tools, and in particular the use of modeling, simulation, and virtual immersive environments to support inquiry-based science learning.

Amy Kamarainen is a postdoctoral fellow with the EcoMUVE project. Amy holds a BS in Zoology from Michigan State University and a Ph.D. in Zoology from the University of Wisconsin in Madison along with a Certificate in Research, Teaching and Learning (through the NSF-funded CIRTL). Amy uses ecosystem models to study how nutrients and pollutants are processed by aquatic ecosystems embedded in urban and agricultural watersheds. She is also interested in how technology may be used to enhance learning of complex concepts related to ecology, evolution and ecosystems science. In particular, she is interested in examining whether combining technology with field experiences can build student efficacy in 21st-century modes of scientific inquiry. Amy aims to contribute to teaching materials and curricula that place science learning in the context of real-world issues and appeal to students who may otherwise not like science.
M. Shane Tutwiler is a Doctoral candidate at the Harvard Graduate School of Education. He served as a radiation health physicist and nuclear water chemist aboard fast-attack submarines before transitioning into science education, earning his B.S. in Science Education, summa cum laude, from Temple University. He subsequently earned a Master of Education from the Harvard Graduate School of Education, where he was the recipient of the Intellectual Contribution and Faculty Tribute Award. He taught various science classes at the Avon Old Farms School before returning to Harvard to pursue his doctorate in Human Development & Education, focusing his research on studying human causal understanding of complex systems within multi-user virtual environments.

Tina Grozert is an Associate Professor of Education at Harvard’s Graduate School of Education and a Principal Investigator at Harvard Project Zero. She directs the Understandings of Consequence Project, funded by the National Science Foundation (NSF). Her current research includes a follow-up NSF grant, “Learning to RECASP Students’ Causal Assumptions in Science through Interactive, Multimedia Professional Development Tools” and an NSF Career Award, “Causal Learning in the Classroom” in addition to her work as Co-PI on the EcoMUVE Project. She studies how causal reasoning impacts K-12 science learning and how to frame research results for public understanding given the human causal reasoning assumptions.

Chris Dede is the Timothy E. Wirth Professor in Learning Technologies at Harvard’s Graduate School of Education. His fields of scholarship include emerging technologies, policy, and leadership. His funded research includes four grants from NSF and the US Department of Education Institute of Education Sciences to explore immersive simulations and transformed social interactions as means of student engagement, learning, and assessment. In 2007, he was honored by Harvard University as an outstanding teacher. Chris served as a member of the 2010 National Educational Technology Plan Technical Working Group.