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).

DOI: 10.4018/jgcms.2011010107
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
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