Exploring Student Understanding of Complex Causality in an Ecosystems-Based Multi-User Virtual Environment

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Abstract: Action at a distance, time delays, and non-obvious causes make it difficult to discern the underlying causal patterns in ecosystems (Grotzer, 2009). Multi-user Virtual Environments (MUVEs) support science inquiry (Ketelhut, Nelson, Clarke, Dede, 2010) and offer affordances that may help students realize these underlying causal features and their role in ecosystems dynamics. During a pilot study conducted in the spring of 2010, students showed significant improvement in understanding action at a distance.

Research Goals and Theoretical Framework

Ecosystems are inherently complex and dynamic, but research suggests that students have trouble thinking of them as such (e.g. Grotzer & Basca, 2003; Hmelo-Silver, Pfeffer, Malhotra, 2003). Researchers at the Understandings of Consequence Project at Harvard's Project Zero have studied students' specific difficulties in reasoning about causal patterns in ecosystems, such as non-obvious causes, indirect effects, time delays between causes and visible effects, population versus individual effects, and balance and flux (e.g. Grotzer, 2009; Grotzer & Basca, 2003; Grotzer & Honey, 2008).

To address and further study these issues, we developed EcoMUVE, a Multi-User Virtual Environment (MUVE)-based ecosystems curriculum for middle school science. MUVEs, such as Harvard's River City Project, have been effective at engaging middle school students in authentic science inquiry (Ketelhut et al, 2010). Building upon ten years of research within River City, the EcoMUVE seeks to extend this design-based research approach, which relies on an iterative cycle of implementation and revision based on student and teacher feedback (Dede, 2005), into ecosystems science education.

EcoMUVE is comprised of two one-week modules that both complement and extend the Understandings of Consequence curriculum. The first module represents a pond ecosystem (Figure 1). Students explore the pond and surrounding area and discover realistic organisms in their natural habitats. Students visit the virtual pond over time – observing; exploring; collecting physical, chemical and biological data; and conducting lab experiments. Students then work in teams to collect and analyze information to solve a mystery about a fish-kill event and to understand the complex relationships within the pond ecosystem.

Figure 1. The EcoMUVE Pond Module.

The second module, currently in development, represents a forest ecosystem. Similar to the pond module, students will collect data, make observations in the virtual world, and conduct experiments. Visiting two islands over the course of multiple decades within the game, students will work together to solve a mystery about predator-prey fluctuations in wolf and deer populations that indirectly affect other species.

Data and Results

Data was collected during the pilot testing of the pond module with 3 teachers and 69 seventh and eighth grade students in the spring of 2010. Students were given a pre- and post-survey of cognitive measures to elucidate their understanding of the complex causal mechanisms of action at a distance, time delay, and non-obvious causes. The preliminary results are presented below (Figure 3).

Students demonstrated significant increases in understanding the importance of action at a distance in analyzing ecosystem problems (McNemar test, $\chi 2(1,69) = 14.73$, $p < .0001$). Scores on questions related to changes over time and non obvious causes also increased, though these results were not significant. Responses to open-ended questions about student causal understanding are currently being coded and analyzed for consistency with the binary data and emerging themes. More data will be collected on the pond module in the fall of 2010, and similar data from pilot testing of the forest module will be collected in the spring of 2011.

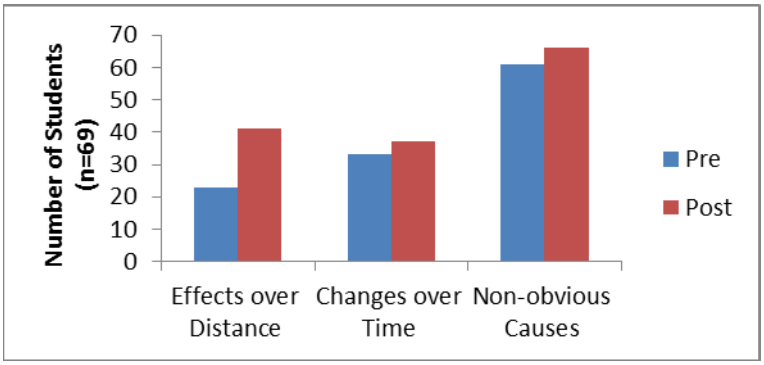

Figure 3. Results of pre-post causal questions.

Significance

Immersive environments support student learning by allowing for multiple perspectives, engaging students in situated learning, and supporting transfer (Dede, 2009). We designed EcoMUVE to test the effectiveness of those affordances – zooming in to the microscopic level and out to a population view, traveling backward and forward in time, viewing emergent effects in a dynamic system, and graphing patterns to see relationships between small behaviors and large outcomes – in order to help students to better understand complex causal patterns in a real-world context.

References

Adeniyi, E. O. (1985). Misconceptions of selected ecological concepts held by some Nigerian students, *Journal of Biological Education,* 19(4), 311-316.

Dede, C. (2005). Why design-based research is both important and difficult. *Educational Technology, 45*(1), 5-8.

Dede, C. (2009). Immersive interfaces for engagement and learning. *Science, 323*(5910), 66-69.

Grotzer, T.A. (1993). Children's Understanding of Complex Causal Relationships in Natural Systems. Unpublished doctoral dissertation. Harvard University, Cambridge.

Grotzer, T.A. (2002) *Causal patterns in ecosystems: Lessons to infuse into ecosystems units.* Cambridge, MA: President and Fellows of Harvard College.

Grotzer, T.A. (2009) Addressing the challenges in understanding ecosystems: Classroom studies. Paper presented at National Association of Research in Science Teaching (NARST) Conference, Orange Grove, CA, April 18, 2009.

Grotzer, T.A., & Basca, B.B. (2003) Helping students to grasp the underlying causal structures when learning about ecosystems: How does it impact understanding? *Journal of Biological Education*, 38,(1)16-29.

Grotzer, T. & Honey, R. (2008) Tacit Assumptions that Limit Understanding of Ecosystems, Ecological Society of America Annual Meeting, Milwaukee, WI. August, 4, 2008.

Hmelo-Silver, C.E., Pfeffer, M.G., & Malhotra, B.A. (2003, April). Fish swim and rocks sit: Understanding structures, behaviors, and functions in a complex system. Paper presented at the American Educational Research Association Annual Meeting, Chicago, IL.

Ketelhut, D. J., Nelson, B. C., Clarke, J. E., & Dede, C. (2010). A multi-user virtual environment for building and assessing higher order inquiry skills in science. *British Journal of Educational Technology* 41(1), 56-68.