Teaching the Systems Aspects of Epistemologically Authentic Experimentation in Ecosystems through Immersive Virtual Worlds

Tina A. Grotzer , Shari J. Metcalf,
M. Shane Tutwiler, Amy M. Kamarainen,
Meredith Thompson, and Chris Dede
Harvard Graduate School of Education

Introduction

Experimentation in ecosystems is challenging, and yet ecosystem scientists have developed forms of experimentation that offer insight into the behavior of systems dynamics and that honor the systems nature of the concepts (e.g. Weathers, Strayer & Likens, 2012). These forms of experimentation and the broader epistemological assumptions that surround them are important for recognizing aspects of systems that may be lost in more limited forms of experimentation. For instance, ecosystems thinking requires considering perturbations over time in a prolonged sense in addition to single events and includes interactions between fast and slow variables, the legacy of what happened in past disturbances, delays, and extended time scales (e.g. Carpenter & Turner, 2001). It also involves realizing the broad spatial scale in which ecosystems dynamics often occur and that there can be action at an attentional distance (Grotzer & Solis, 2015) from the point of eventual impact.

Helping students to learn epistemologically authentic forms of experimentation should be an important goal for ecosystems science education and for helping the next generation to understand the dynamics of Earth's environmental systems. However, teaching these forms of experimentation in the classroom in ways that do not reduce their systematic aspects is difficult, particularly in that these systems dynamics play out over expansive spatial scales and extended temporal scales.

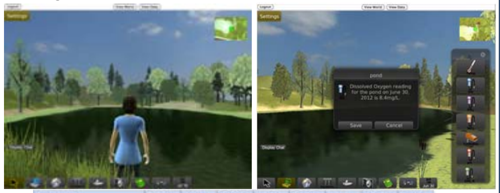
Moving from Correlational to Causal Patterns in Ecosystems without Reducing the Systems Aspects

Reasoning in purely observational environments tends to be inferential, based on visual information, measurements and correlations observed over time. These patterns provide important information about what might be happening. However, without a means to test the covariation relationships, it is not possible to make a causal assessment of what is going on. In EcoXPT, students go beyond observational inquiry to test their hypotheses through epistemologically authentic experimentation and investigation, enabling them to make generate causal explanations and to elaborate the underlying mechanisms. In addition to more traditional, isolation and control of variables forms of experimentation, EcoXPT aims to help students learn forms of experimentation that are contextualized in the complexity of the environment and that offer systems perspectives on the underlying causal dynamics. These include epistemologically authentic forms of "whole ecosystem" exploration, such as the placement of tracers.

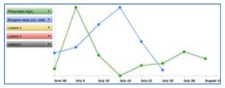
Background: EcoXPT

EcoXPT is a virtual world (developed from an earlier curriculum called EcoMUVE) that is centered on a virtual pond and the surrounding watershed. Students explore the pond and its biodiversity, and travel in time to see changes over the course of a virtual summer. They discover on one day that all of the large fish have died, and try to figure out why it happened.

Students collect evidence based upon: 1) *perceptual* information, *data* viewed in tables and graphs; 2) correlational patterns in the form of graphs and numerical charts; 3) *testimony* from characters in the world; and 4) experimental evidence that is the result of epistemologically authentic forms of investigation as they construct an explanation of what happened to the fish.

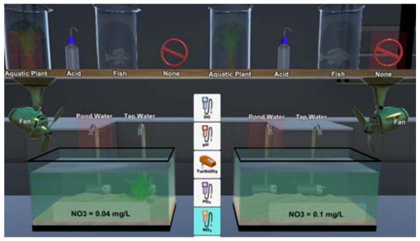


Measurement	June 30	July 6	July 10	July 16	July 22	July 25	July 28	Aug 15
Water temperature (°C)	22	19	21.5	24.5	26.5		25.5	25
Dissolved oxygen (mg/L)	8.4	9.5	9.4	10.2	5.4	4.1		
Phosphates (mg/L)	0.01	0.1	0.03	0	0.015			0.025
Nitrates (mg/L)	0.15	0.56	0.33	0.2	0.11	0.2	0.3	
Turbidity (NTU)	5	25	35	65				
pH		6.7	8	8.4				
Chlorophyll A (ug/L)		19	50	100				
Air temperature (°C)	25.5	20	24.5	27.8	31.1			
Wind speed (m/s)	1.5	4.6	3	2.1	1.5			
Cloud cover (%)	20	100	0	20	100			
Bacteria population (cells/ml)	5000			7000			33000	
Bluegill population	189	163	152	123	114		0	
Bluegreen algae population (cells/ml)	800		1300	1600	1000			
Green algae population (cells/ml)	1000				4000			
Heron population	2							
Largemouth bass population	38							
Minnow population	356							



Lab-Based Forms of Experimentation in EcoXPT

The Comparison Tanks display two virtual fish tanks within a 3D lab environment. Each tank has an associated shelf of objects: a fan, a fish, a plant, or acid. Students choose to fill each tank with either pond or tap water, and select up to one (or "none") object to place in each tank. Once the tanks are set up, students can "run" the experiment and use the water measurement tools to see the results.



The Tolerance Tanks allow students to test any of seven factors to see if different levels of those factors would directly kill any of the three types of fish.

Ecosystems-Based Forms of Experimentation in EcoXPT

Developing Awareness of Interactions and Contextualization Outside

The Mesocosm Tool allows students to investigate how real world contextualization interacts with the behavior of the variables that they combine in the pool. They consider how changing temperature, levels of Nitrates, etc. interact over time. They configure up to four pools with up to two factors each. Once the pools are set up, student can "run" the experiment and use the water measurement tools to see the results.

After students used the Mescosm Tool, they started to ask different questions:

S1: I was wondering if we put fertilizer in it, if that would change the phosphate and the nitrate levels because that's used to enrich the soil and help plants grow.

S2:Why does its do its biggest spike ever right after there is cloud cover?

S3: If we could go back 50 years then we would really know what to think about and whether we should be worried about something….

S4: What is the typical pH in a pond? We could experiment with different variables in the Mesocosms to see how it behaves with different variables.

Developing Awareness of Action at an Attentional Distance and Change over Time

Tracers Placed in the Ecosystem allow students to understand the movement of matter in the environment. They are able to test how the spatial lay-out and topography play a role in the process. They can choose to place tracers of different colors in different places. This allows then to understand how the spatial terrain interacts with the movement of materials.

Then they can observe its behavior over time and space to inform their hypotheses about the causal dynamics in the ecosystem.

The outcomes can reveal surprising information about the terrain and proximal and distal causes.

After the students used Tracer Tool, they made changes to their hypothesis and thought differently about what ecosystems scientists do.

S1: I was surprised that the tracer didn't end up where I thought it would. I changed my mind about where the problem is and had to look for other possibilities.

S2: I was surprised that an ecosystem scientist would really put something into the environment.

This work is supported by the National Science Foundation Grant No. 1416781 to Tina Grotzer and Chris Dede. All opinions, findings, conclusions or recommendations expressed here are those of the authors and do not necessarily reflect the views of the National Science Foundation.

For more information, visit:
http://ecolearn.gse.harvard.edu