EcoXPT: Learning about Ecosystems Science and Complex Causality through Experimentation in a Virtual World

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Observation and experimentation are important modes of inquiry in ecosystems science. However, educators are unfamiliar with epistemologically authentic forms of experimentation in ecosystems, particularly those that attend to the contextualized, systems aspects of ecosystems. EcoXPT introduces students to experiment-based inquiry within a virtual ecosystem. It builds upon EcoMUVE, an existing middle school curriculum that uses immersive virtual worlds to support learning about the causal dynamics of ecosystems. Design-Based Research pilots with newly designed simulated, EcoXPT experimentation tools demonstrates students' ability to learn to use these tools to test causal relationships, address misconceptions, and draw conclusions through experimentation.

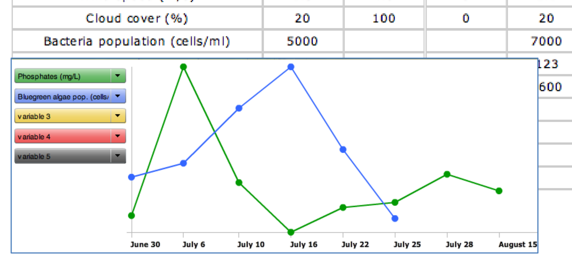
Background: EcoMUVE

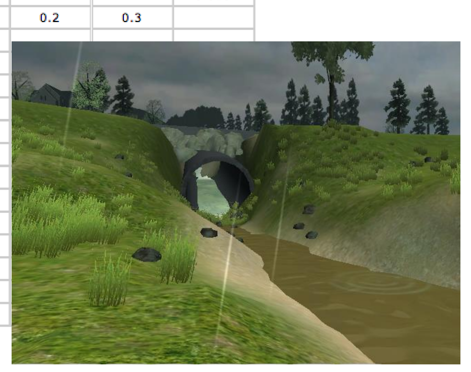
EcoMUVE Pond is an existing two week, inquiry-based curriculum unit centered on a virtual pond and the surrounding watershed. Students explore the pond and its biodiversity, and travel in time to see changes over the course of a virtual summer. They discover on one day that all of the large fish have died, and try to figure out why it happened.

Types of evidence students can collect include *perceptual* information, *data* viewed in tables and graphs, *reference* tools such as the online field guide or atom tracker, and *testimony* from characters in the world.

Students collaborate in teams to develop and present to the class an evidence-based concept map that represents their hypotheses of the ecosystem relationships.

Measurement	June 30	July 6	July 10	July 16	July 22	July 25	July 28	Aug 15
Water temperature (ºC)	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)		10	50	100				
Air temperature (ºC)	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				
				123	114			
				600	1000			
					4000			
					2			
					40			
					250			





EcoXPT Pilot Studies: Methods

Pilot studies of the EcoXPT experimental tools are being conducted to inform our Design-Based Research. Seventh graders who were about halfway through the EcoMUVE curriculum tested out the EcoXPT tools and were interviewed using the PARI technique (Hall et al., 1995). (Precursor - What idea do you want to try out? Action - How do you think you will try it? Result - Tell me what happened. Interpretation – What did you learn?) Students were randomly selected (Pilot 1: (N=13); Pilot 2 (N=16, in 8 pairs) Pilot 3, focused on the tracers, is currently underway.)

Interviews were transcribed and analyzed to evaluate usability of the tool, patterns of experimentation by users, and evidence that using the tool supported student hypothesis-building activities. These studies will inform the new EcoXPT virtual world.

Understanding Experimentation in Ecosystems: EcoXPT

With EcoXPT, students go beyond observational inquiry to authentically test their own hypotheses through epistemologically authentic experimentation and investigation, extending their comprehension of underlying causal relationships.

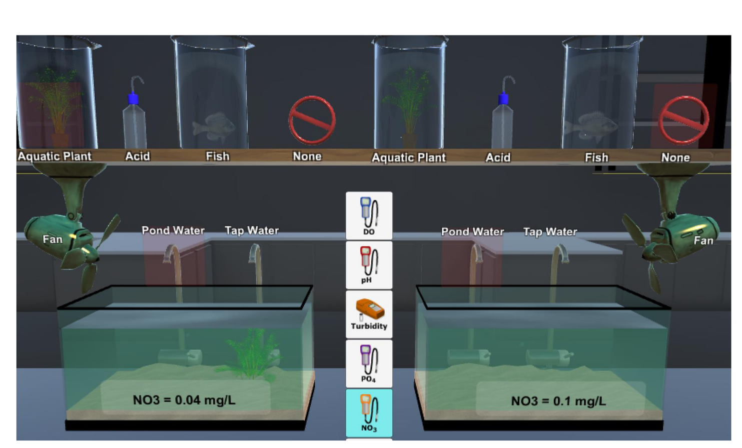
Causal reasoning in purely observational environments tends to be inferential, based on visual information, measurements and correlations observed over time.

Experiment-based learning can support students' understanding of difficult science concepts, and development of mental models (Duit & Treagust, 1998; McElhaney & Linn, 2011; Rea-Ramirez, 2008) and experimentation is promoted in the Next Generation Science Standards (NGSS) middle grades life science standards for ecosystem science (Achieve, 2013).

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.

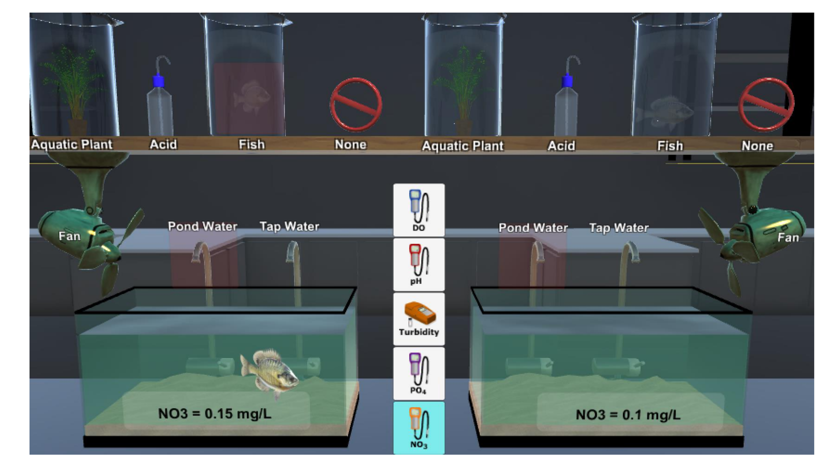
Pilot Studies of EcoXPT Experimental Approaches

Pilot 1: The Fish Tank Tool displays 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.



Just prior to this, the student expressed his misconception that fish need phosphates and nitrates to grow.
R: So now what idea do you want to try out?
S: Maybe if you put a plant in it, compared to if you put nothing in it?
R: So what'd you find?
S: With plants it might take up the phosphates and nitrates, so there's less phosphates and nitrates for the fish maybe to use to grow, because the plants are taking it up?

Then the student decided to try adding a fish:



S: So there's more [phosphates], it's more with the fish, but only slightly, and then it's significantly more [nitrates] with the fish than the pond with nothing in it. So that's interesting. More nitrates and phosphates.
R: So what do you think about that? That surprises you?
S: Yeah, a little, cause I think how the fish might grow, they need the - they have to use the nitrates and phosphates to help them. But that might just be plants that do that, because it seems like I put the plant in and they took in nitrates and phosphates, but the fish like breathed out the nitrates and phosphates…

Here, the student directly tested his misconception, and disproved it. He stated a new, more correct hypothesis, that plants need nitrates and phosphates, and fish produce them.

Pilot 2: The Mesocosm Tool allows students to 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.

In this example, the student states an idea about how fertilizer might affect the nitrates and phosphates in the water, and confirms her idea through running the experiment. In doing so they also realize that is the cause of the algae increase.

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.
[Students put bacteria and fertilizer in the pool. They run the experiment and take measurements.]
S2: So the bacteria levels are high.
S1: Yeah and the algae went up a lot. See? I told you!
Students read phosphate levels.
S1: Oh my gosh! That's so high!
[Students look through their EcoMUVE data, and reflect.]
S2: It could be that the fertilizer was dragged in by the rain and the algae population went up.

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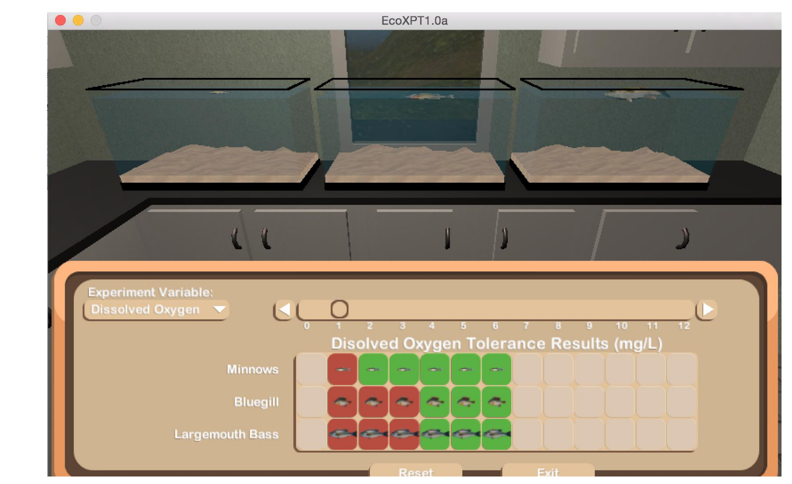
Pilot 2: The Tolerance Tanks allows students to test any of seven factors to see if different levels of those factors would directly kill any of the three types of fish.



S1 & S2: Ohhhhhhh!!!
R: What was that "Oh!" about?
S1: The minnows survived.
S2: When there's almost no dissolved oxygen, then minnows still survive when it's 2-3 mg/L. That's cool.

Pilot 3: 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. We are currently piloting the use of tracers with the students. They can choose to place tracers of different colors in different places.

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.