Patterns of Cognitive Engagement that Complicate Understanding of Complexity and Scientific Research

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Overview

- Backstory: T-800: Research and Evidence: Framing Scientific Research for Public Understanding…
- Course/Literature review highlights
- Connections to NOS and human perception of causal complexity
- Studying middle students’ assumptions within a virtual world: EcoMUVE

Quote from the back of a truck in a New Yorker Cartoon:

"The scientific community is divided. Some say this stuff is dangerous, some say it isn't."

Where does the general public gain their ideas about the nature of science and research?

- “Scientist agree on finding.” (Nothing surprising about that, since they are supposed to agree.)
- “Scientists still search for cancer cure.” (Science must have trouble finding some answers.)
- “Scientists disagree about the smallest particle.” (Scientific truth does not always come clearly labeled—what is true or not true is not agreed upon, even by scientists.)

-Agnew and Pyke (The Science Game)

Headlines in the News

- “Botanist sues to stop CERN hurling Earth into parallel universe:Hawaiian in lawsuit against particle billiards rig” (Physics, 28th March 2008).

- “Big Bang' experiment starts well (BBC News September, 10, 2008) Scientists have hailed a successful switch-on for an enormous experiment which will recreate the conditions a few moments after the Big Bang.”

The Big Questions:

- How do patterns of perception, attention, and cognition influence people's tacit assumptions about the nature of scientific research and research results, including educational research?

- How do these patterns interact with the nature of science and ultimately, public understanding of scientific research?

- Why should any of this matter to educators, scientists, public health officials?

What is known about people’s patterns of attention, perception, and reasoning and how do these impact their understanding and actions?

“The facts speak for themselves.”

"For the mind of man is far from the nature of a clear and equal glass, wherein the beams of things should reflect according to their true incidence; nay, it is rather like an enchanted glass, full of superstition and imposture, if it not be delivered and reduced."

-Sir Francis Bacon

How does the nature of perception influence the information that we take in?

- What is the nature of perception?
- Do people see what they think they see?
- What is the relationship between perception and attention?
- What are the implications for understanding research evidence?

Literature Reviewed

- Microsaccades/saccades
- Change blindness/inattentional blindness
- Attentional capture and the relationship between perception and attention
- The relationship of belief/expectation to perception
- Cognitive science research on how we reason about evidence

Micro-saccades

- Our eyes make involuntary movements that prevent habituation on the image you are looking at.
- This “refreshes” the image allowing you to continue to perceive it.
- These movements are unconscious and essential for seeing.

Saccades

- Saccades are quick, simultaneous movements of both eyes in the same direction.
- We do not look at a scene in a steady way. Instead, the eyes move around, locating interesting parts of the scene and building up a mental 'map' corresponding to the scene.
- Saccades last from about 20 to 200 milliseconds.
- By moving the eye so that small parts of a scene can be sensed with greater resolution, body resources can be used more efficiently. If an entire scene were viewed in high resolution, the diameter of the optic nerve would need to be larger than the diameter of the eyeball itself.

Daniel Simon's Movie Perception Test

Full movie available at:

https://www.youtube.com/watch?v=6JONMYxaZ_s&list=PLB228A1652CD49370

What happens when you are cognitively busy?

Inattentional Blindness

- The tendency to miss information when not attending to a stimulus.
- An “inability” to perceive when not attending to a stimulus.
- Also referred to as “functional blindness” or “sighted blindness.”

Daniel Simon and Daniel Levin's 1998 Study of the Rude Door Changers

Full video available at:

https://www.youtube.com/watch?v=FWSxSQsspiQ&list=PLC0A3CAC7B3A0E288

Summary Points:

- We do not encode information perfectly.
- Even when attending, we miss information during saccades/attentional blink.
- Our attention is spotlight-like—we stitch together broader images from the pieces that we focus on.
- We are selective in what information we take in.
- We privilege certain kinds of information over others.

Some variables are better at “grabbing” our attention…

- size, loudness, movement (“pure” perception)
- location of information (how we focus and construct broader images)
- competition/distractions (load and structural interference)
- meaningfulness/emotional salience
- relevance
- availability/familiarity
- faces

How does science and scientific knowledge “progress”?

Knowledge based on authority (Aristotle and the Bible)

↓

Knowledge based on facts (the Empiricists and the Positivists)

Science as Derived from Facts

- Facts are directly given to careful unprejudiced observers via the senses.
- Facts are prior and independent of theory.
- Facts constitute a firm and reliable foundation for scientific knowledge.

“Science is derived from facts”

“One difficulty concerns the extent to which perceptions are influenced by the background and expectations of the observer, so that what appears to be an observable fact for one need not be for another.”

-Chalmers, pg. 17

One Has to Learn to Be a Competent Observer.

Novice to Expert Shift Research

- Experts structure and construe meaning from information differently than novices.
- Experts notice and attach importance to deeper, more meaningful patterns (e.g. Chase & Simon, 1973; Chi, Feltovich, & Glaser, 1981; Larkin, McDermott, Simon, & Simon, 1980; Simon & Chase, 1973)
- Experts process patterns more efficiently and effectively.
- Expert forms of pattern recognition come with the development of deep understanding of a domain, its rules, exceptions, and nuances (Bereiter & Scardamalia, 1993).

Henry Bauer…

- Science is mistakenly taken to connote fact or certainty. Facts are theory-laden—not uncolored by preexisting belief about the world.
- Since many people think science deals in fact, people criticize science and scientists for being uncertain or changing their minds.
- Scientific knowledge can be conceived of as a map—not reality itself, neither pure fact nor theory, but a representation that helps us understand and navigate/make predictions about the world. (-1992)

How does the nature of science complicate things?: Juxtaposing an accumulation notion of science to a paradigm shift notion

In 1962, Thomas Kuhn wrote "*The Structure of Scientific Revolutions.*"

- It challenged an accumulation model for advancing scientific knowledge and set forth a paradigm shift model.
- Revolutionary character of scientific progress, where one theoretical structure is abandoned and replaced by another incompatible one.
- Scientific communities play an important sociological role.

Some implications…

- The advance of science is largely non-cumulative.
- Progress occurs through revolutions.
- Observation is theory dependent.
- If all scientists remained “normal scientists” science would become trapped in its paradigm.
- Today’s scientifically accepted knowledge may well be tomorrow’s misconceptions.

Trading Up for Increasingly Explanatory Models and (In an Information Age)…

…Taking the
Public Along for the Ride

Autism Then…

- Early theories- “Refrigerator Parents.”
- Particularly focused on mothers.
- The child’s response to cold, unloving environments, viewed as a retreat into autism.
- May have been an artifact of the populations (upper middle class) that they studied that gave the appearance of being formal and cold.
- Given the genetic link, one can question whether there were subtle signs of autism in parents that Kanner and Asperger were noticing.

Autism Now…

- Refrigerator parent theory debunked in the 1970s.
- Focus on genetic components and the interaction of genetic and environmental factors.
- Continuing uncertainty…

How has this work shifted the focus of the research that I am doing in K-12 science?

Looking at how students' default perceptual, attentional, and cognitive patterns interact with learning and helping them to reflect upon those patterns.

In our everyday causal reasoning…

- We notice co-variation and we sum across our experiences to seek out patterns or correlations between events.
- We seek out plausible mechanisms and use our knowledge of particular mechanisms. We may intervene to isolate a mechanism.
- Agency plays a powerful role in causal cognition.
- We tend towards efficiency—impacting what we notice and where we draw boundaries.
- Meaningful or familiar patterns are more salient to us and more likely to be noticed.
- We default towards familiar, “well traveled” patterns.

A Causal Repertoire…

- These tendencies operate at the level of perception, attention, and cognition which contributes to a reinforcing quality to our perceptions and understandings.

- This prioritizes tendencies from early causal induction, that while powerful in many ways, can limit how we engage with a complex world.


DONT DUMP
DRAINS TO
CHARLES RIVER

Reductive Biases

The tendency to reduce complexity to simpler models; to fit simpler structures to complex information thus distorting the information to fit.

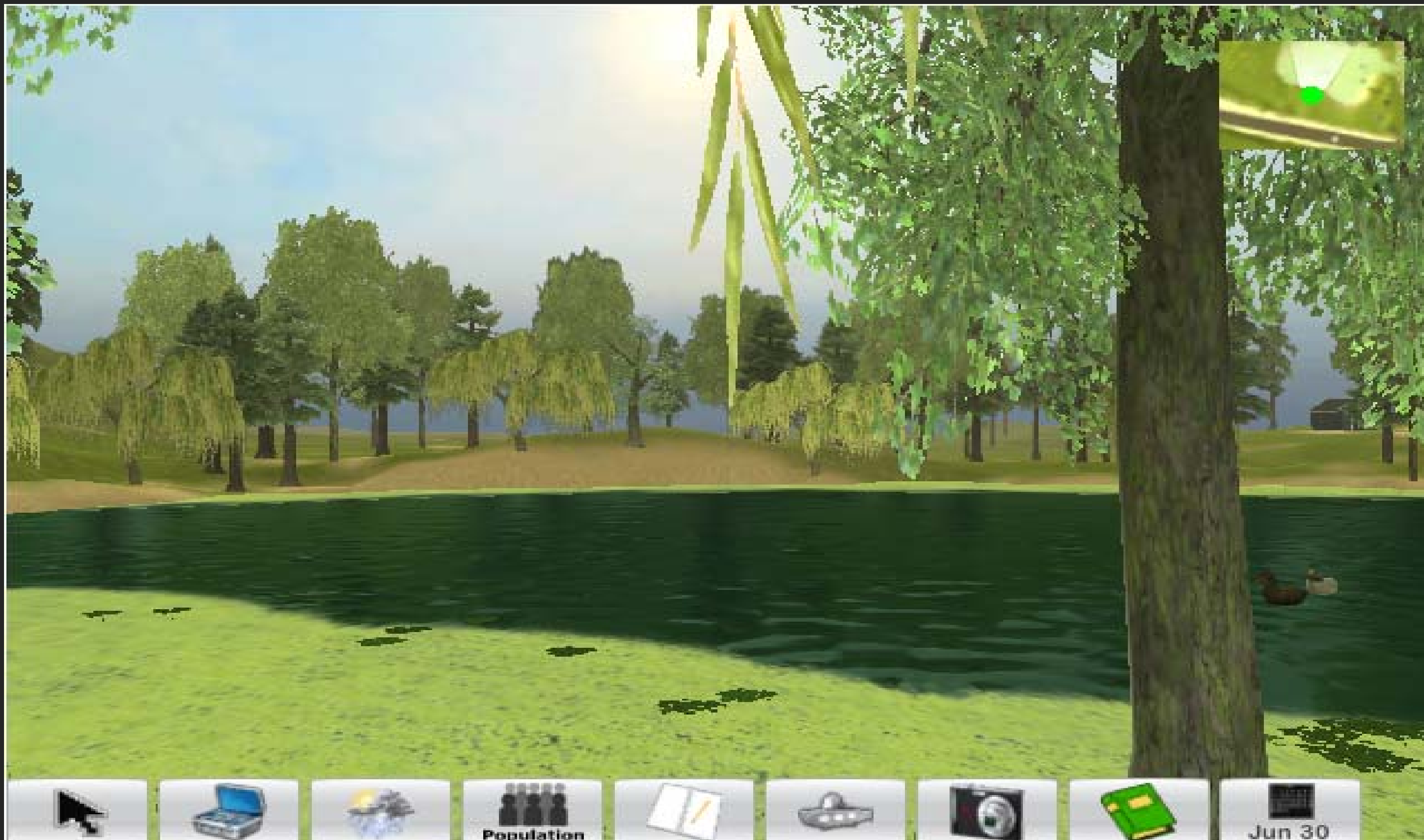
-Feltovich, Spiro, & Coulson, 1993

Causal Default Assumptions

1. linear (vs. non-linear)
2. direct (vs. indirect)
3. unidirectional (vs. bi-directional)
4. sequential (vs. simultaneous)
5. obvious (vs. non-obvious)
6. active or intentional agents (vs. non-agentive)
7. event-based (vs. processes or steady states)
8. deterministic (vs. probabilistic)
9. local (vs. spatially distant)
10. immediate (vs. delayed)
11. centralized (vs. decentralized)

Event-Based vs. Steady States

EcoMUVE



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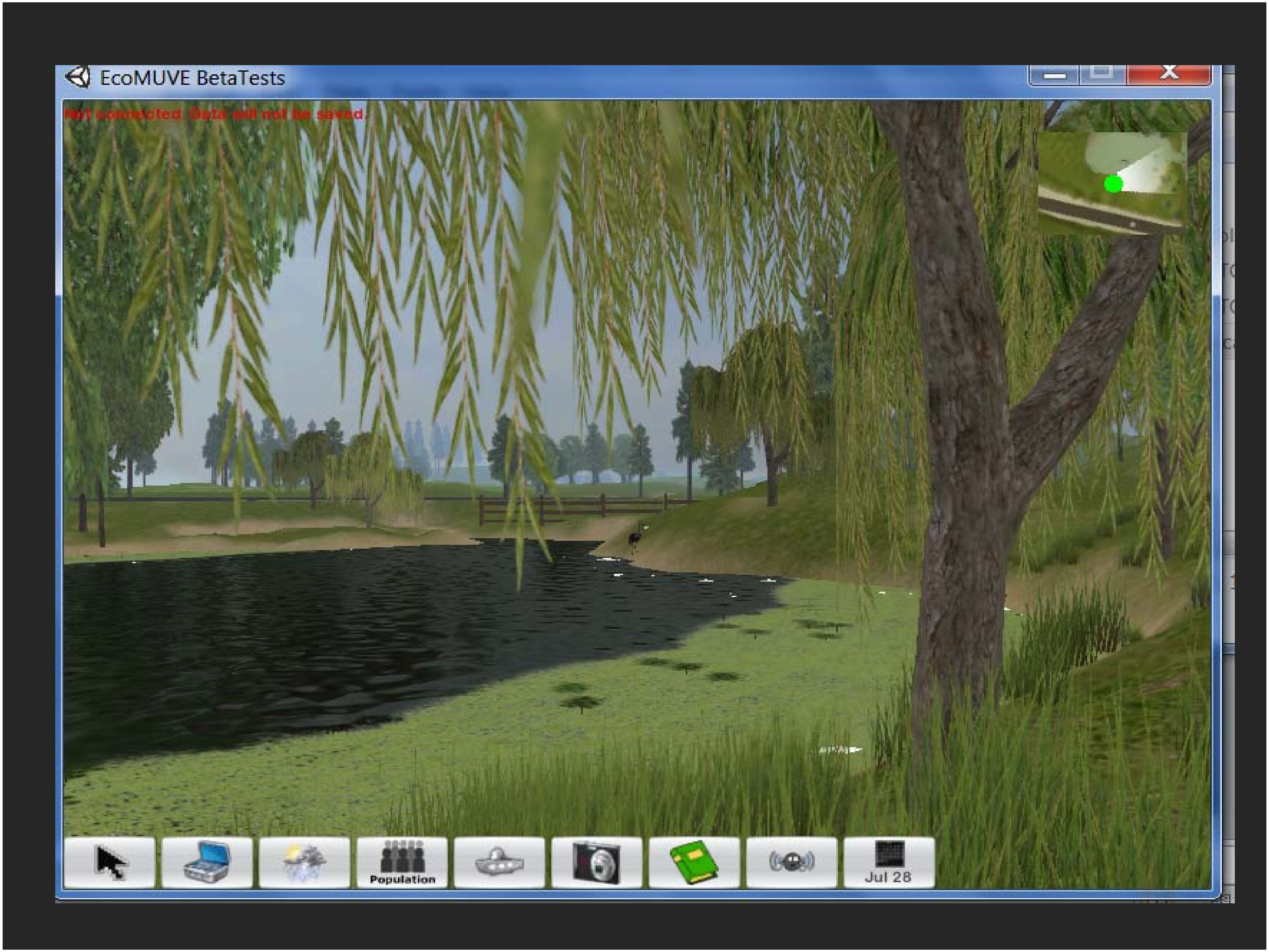
Expert Reasoning About Ecosystems Involves Reasoning About:

- spatial scales involving action at a distance, where impacts are felt far from their causes.
- time delays between causes and their effects.
- causes that can be non-obvious or act in concert with obvious causes.
- events in the context of processes and steady states in contrast to event-based reasoning.

Why is EcoMUVE promising for helping students' learn to recognize how their default assumptions interact with how they understand what is going on scientifically?

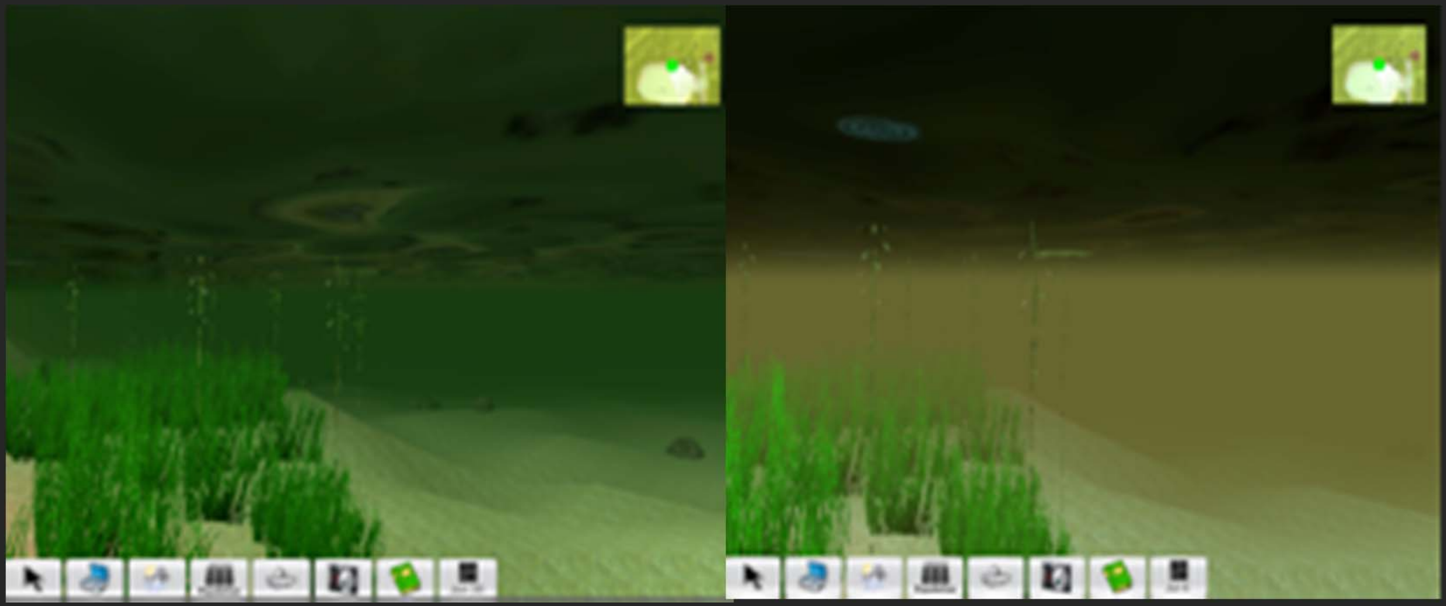

EcoMUVE BetaTests
Not connected. Data will not be saved.
Population
Jul 28

Action at a Distance: Runoff From Housing Development

Non-Obvious Causes

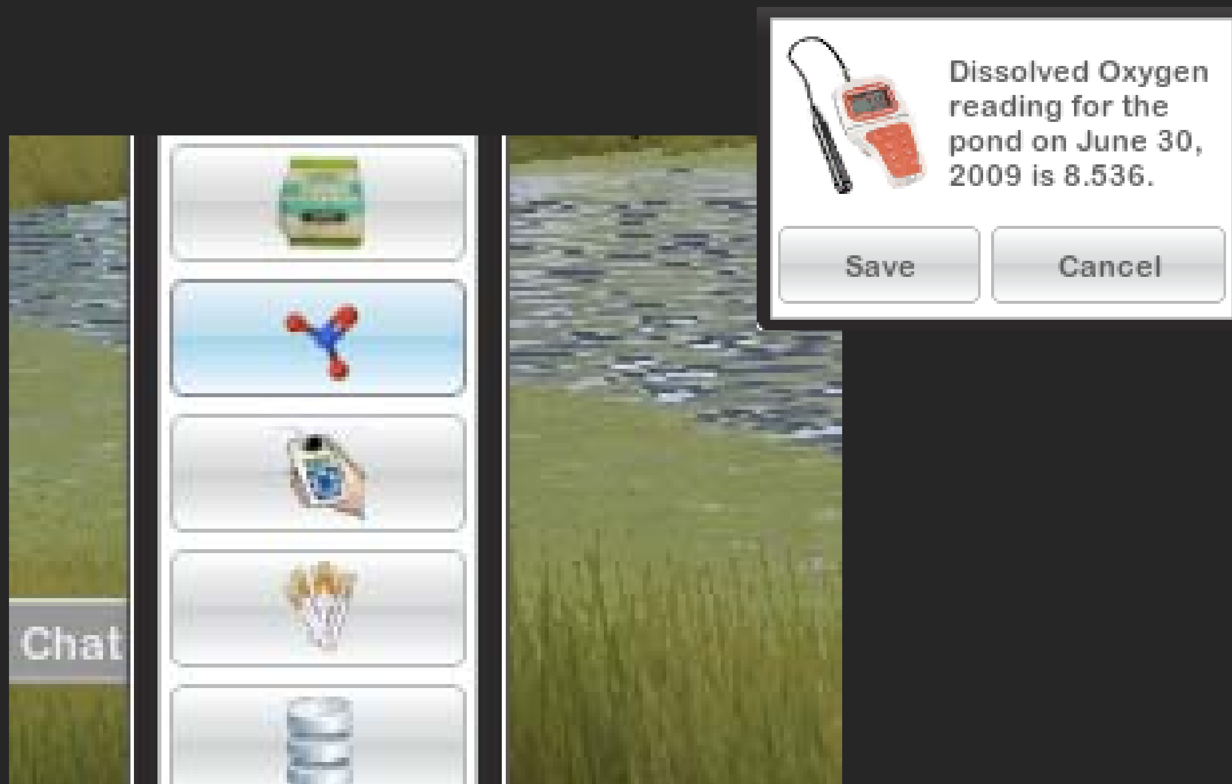
A submarine tool explores the microscopic organisms in the pond, helping students understand that organisms that they cannot see play a critical role in the pond ecosystem

Changes in Turbidity Over Time: Noticing Processes/ Change Over Time

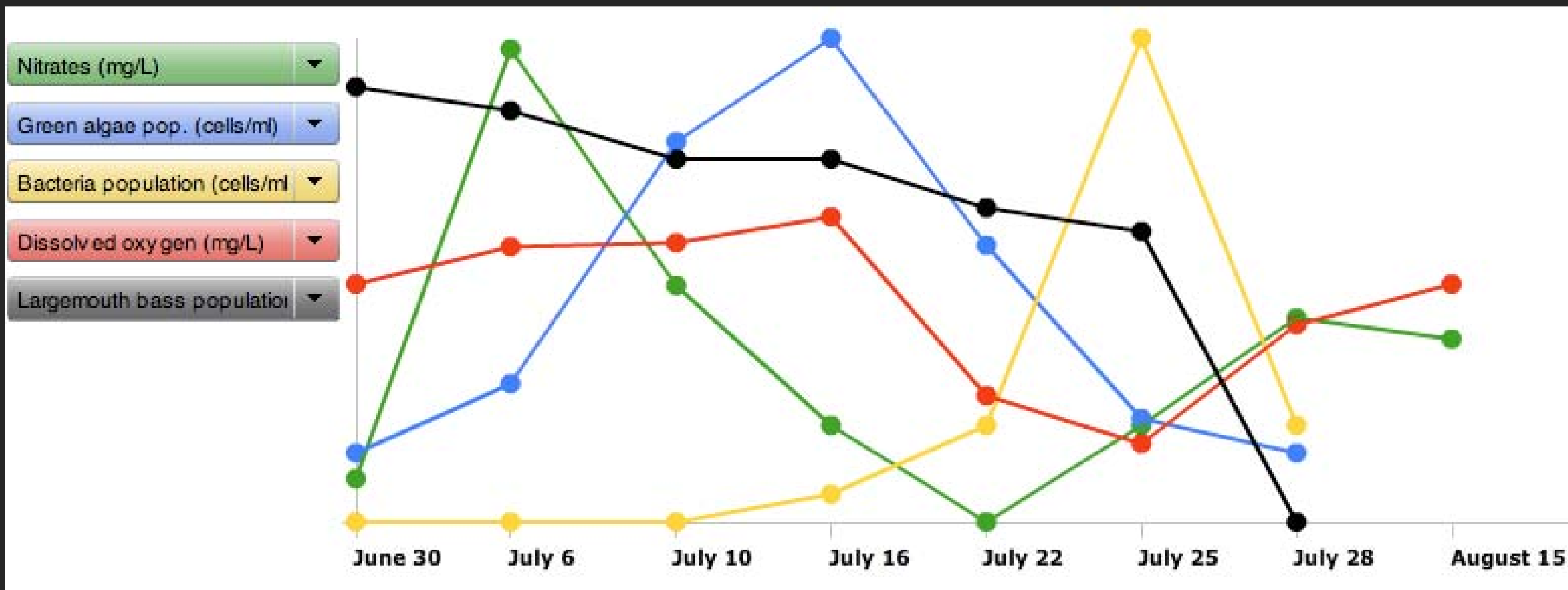


One can move back and forth in time.

Measurement and Monitoring



Students collect physical, chemical, and population data over time, graphing patterns to see relationships between behaviors and outcomes.



Nitrates (mg/L)
Green algae pop. (cells/ml)
Bacteria population (cells/ml
Dissolved oxygen (mg/L)
Largemouth bass populatio
June 30
July 6
July 10
July 16
July 22
July 25
July 28
August 15

Research Questions

- What initial assumptions would students' reasoning reveal?

- What shifts, if any, could be discerned as students further explored the EcoMUVE using the affordances designed to help them develop more expert conceptions?
- …..(and to reflect upon their initial conceptions)?

Design

- Seventh and eighth graders (n = 81) in three middle school classes participated in the study
- Introduced to the EcoMUVE at the beginning of the week and given an opportunity to explore it
- After an ecological problem was discovered, students took a written assessment (their initial insights into what might have happened and what patterns of inquiry they might undertake.)
- Students continued working with EcoMUVE and at the end of the week were given a parallel written assessment.

Scoring

- The data was scored blind as to whether it was a pre- or post-assessment by removing identifying information.
- Two coders: one coded 100% and the other coded a randomly selected 20%. Reliability was assessed on the categorization of each response (ex. EBC or PPCT) using Cohen's Kappa, to account for instances of agreement by chance, yielding an agreement level of 0.837.
- Answers were coded for whether they reflected causes that were/had: a) obvious versus non-obvious causes; b) local versus non-local causes; and c) event-based versus patterns, processes and change over time.

Comparisons of Reasoning Tendencies on Each Measure: Pre and Post-test

	Pretest		Post-test	
Spatially Local vs. Spatially Distant Causes	M = 3.45 SD = 1.35 M = .59 SD = .79	Mean difference = 2.89 t(73) = 13.20, p < .0001**	M = 2.77 SD = 1.29 M = .55 SD = .78	Mean difference = 2.25 t(76) = 11.68, p < .0001**
Obvious vs. Non-Obvious Causes	M = 1.66 SD = 1.02 M = 2.46 SD = 1.23	Mean difference = -.79 t(77) = -3.56, p < .0006**	M = .74 SD = .77 M = 2.65 SD = .55	Mean difference = -1.91 t(80) = -10.37, p < .0001**
Event-Based Explanation vs. Patterns, Processes and Change Over Time	M = 2.72 SD = 1.50 M = 1.41 SD = 1.31	Mean difference = 1.31 t(77) = 4.47, p < .0001**	M = 1.89 SD = 1.49 M = 1.49 SD = 1.66	Mean difference = .40 t(78) = 1.25, p > .05

Event-Based Reasoning Results

- On the post-test, there were no significant differences between the number of EBC and PPCT-based explanations (EBC: <u>M</u> = 1.89, (<u>SD</u> = 1.49); PPCT: <u>M</u> = 1.49, (<u>SD</u> = 1.66), Mean difference = 0.40 $t(78) = 1.25$, $p > 0.05$).

- Students gave significantly fewer event-based responses on the post-test than the pretest (Mean difference = 0.83 $t(75) = 3.75$, $p < 0.0003$).

An Initial Event-based Focus: “What happened”

- Was there “an explosion” or “an oil spill”? (S159).
- “The water got contaminated and the fish jumped out.” (S141).
- “Oil from a factory went into the water and killed the fish” (S129).

A Focus on Events and Levels of Variables Contextualized with Broader Processes…

- [I would find out if there are] “too little phosphates; too little oxygen, population change in organisms in food chain, amount of algae in the food chain changes” (s135)

- “The fertilizer run-off went into the stream and then into the pond and then the algae grew a ton. Bacteria thrived. When fertilizer wore off, algae stopped growing. With all the CO2 released from the decomposition of the algae, the fish went back to their maker. (s167)

A Disturbance Eventually Captures Students' Attention: A Fishkill

The complex causality of the fish kill mystery

- Development upstream over-fertilizing lawns.
- Excess rainfall causes more runoff into pond.
- Fertilizer causes algal bloom.
- As algae dies, increase in dead plant matter causes increase in bacteria decomposers.
- Bacteria uses up dissolved oxygen (DO) in water.
- Other conditions also contribute to decrease in DO - cloudy hot days with no wind.
- Eventually, fish kill event just before dawn.
- Further effects – population shifts after the fish kill.

For more information:

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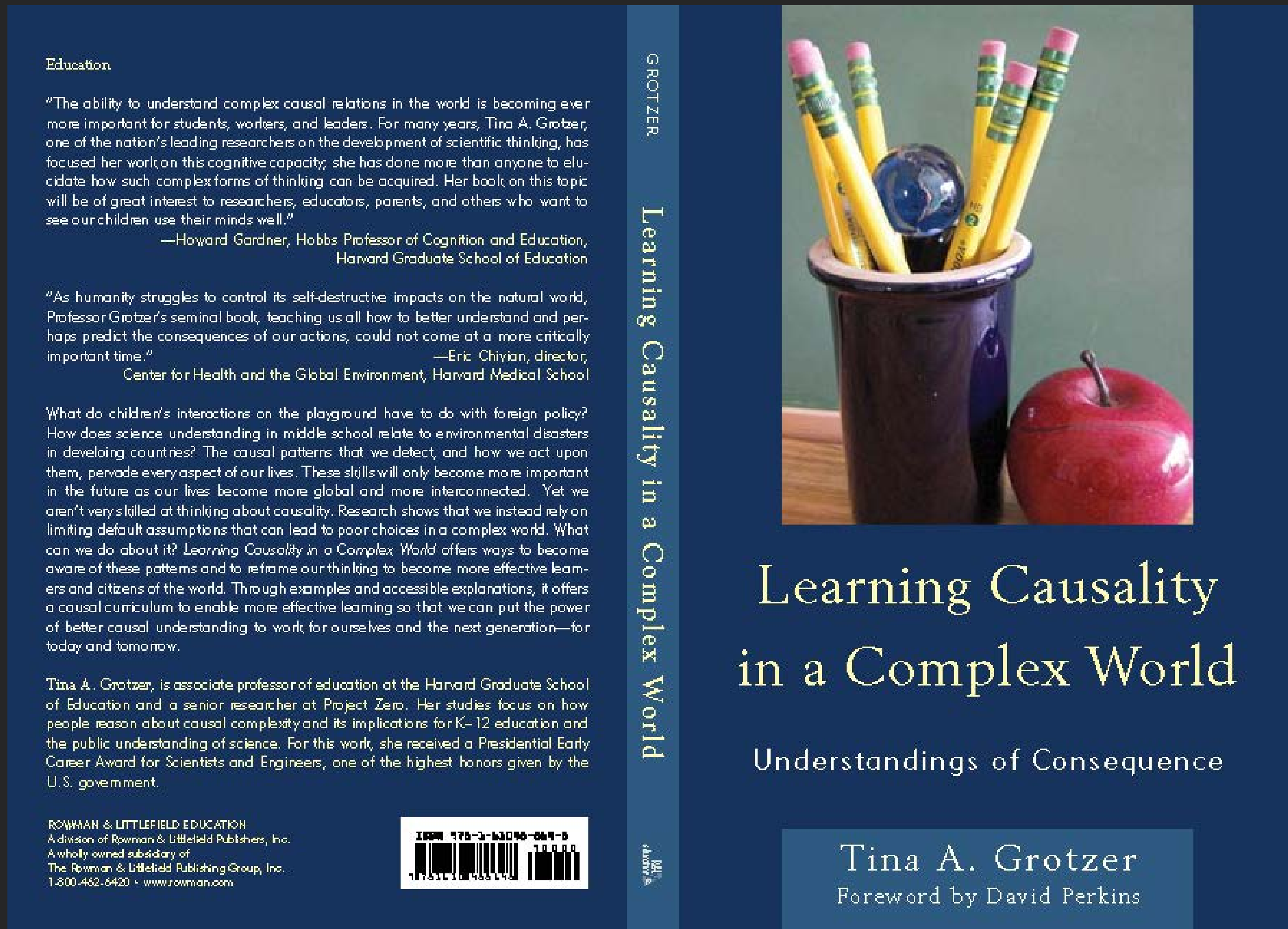

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