The background is a dark blue gradient with faint, light blue geometric patterns. These include several concentric circles of varying sizes, some with arrows indicating a clockwise or counter-clockwise direction. There are also curved lines and small dots scattered across the background, giving it a technical or scientific feel.

Linking Evidence and Concept Maps in Virtual Environments for Ecosystems Science Learning

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OVERVIEW

- Virtual worlds offer opportunities to provide immersive, inquiry-based learning experiences within simulated environments.
- We need to support students in organizing and reasoning with the evidence they collect, and in using that evidence to support causal claims.
- This paper presents a virtual environment designed to scaffold evidence-based concept mapping by integrating in-world tools for data collection, experimentation, analysis and hypothesis-building in order to support students in constructing representations of their understanding of complex systems.

EXPERIMENTATION AND SCIENCE LEARNING

- Prior studies in science education indicate experiment-based learning can enhance students' mental models of science concepts.
 - e.g., Duit & Treagust, 1998; McElhaney & Linn, 2011; Rea-Ramirez, 2008
- Experimentation is promoted in the Next Generation Science Standards (NGSS) middle grades standards for ecosystem science.
- Immersive virtual learning environments can enhance learning of science concepts by situating the students' investigations in realistic, yet scaffolded contexts.
 - Collela, 2000; Ketelhut et al, 2010; Dawley & Dede, 2013.
- Situated experimental tools let students interpret results contextually and integrate their findings with other sources of evidence--including observations and data collected in the virtual world--to build hypotheses.

CONCEPT MAPPING

- Concept maps, as external representations of knowledge:
 - Can clarify thinking, focus a task, facilitate collaboration, and reduce cognitive load (Cox, 1999; Jonassen, 2003; Sandoval & Reiser, 2004).
 - Effective mechanism for students to express their conceptual understanding (Novak, 1990; Rice, Ryan, & Samson, 1998; Toth, Suthers, & Lesgold, 2002).
- Causal map of causal relationships between factors in a system:
 - Allow individual causal claims to be represented and examined.
 - Decompose complex system into more manageable elements.

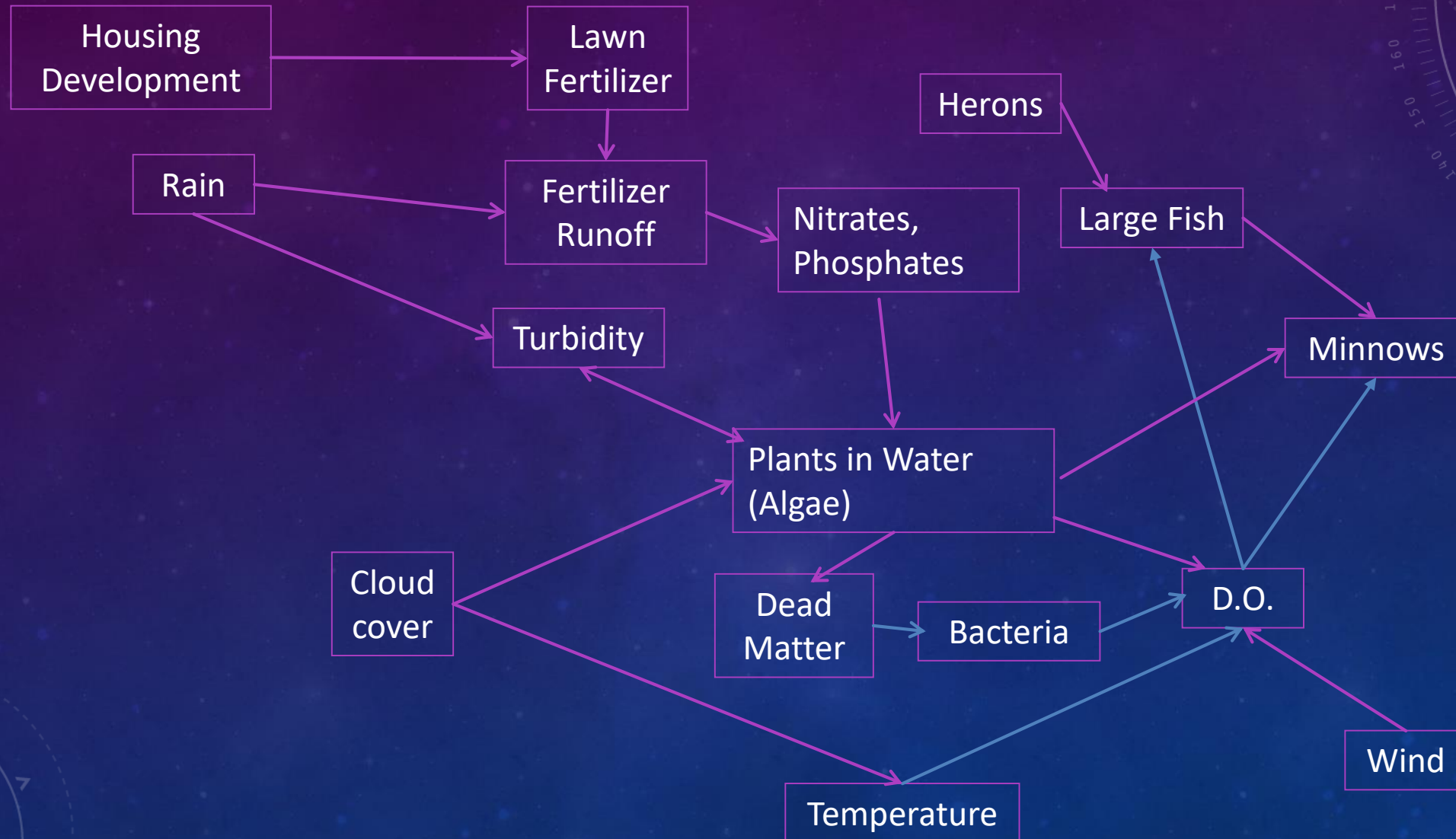
ECOXPT

Expands upon earlier research with EcoMUVE

- Immersive, multi-user virtual environment (MUVE)
- Middle school science curriculum
- Learning about the causal dynamics of ecosystems through observation and exploration in a virtual world.
- Inquiry-based: Students discover one day that many fish have died and are challenged to figure out what happened.
- Experimental tools allow students to gather confirming evidence and to test misconceptions.
- Notebook and concept mapping tools support students as they develop hypotheses about why the large fish died.



MANY POSSIBLE CAUSAL CONNECTIONS



Range of tools for observation, data collection, and analysis



Field Guide

35 of 36 Found

Show Index

Largemouth bass
Micropterus salmoides

Save to Notebook

Description
Largemouth bass are large fish with a dark stripe down the length of their body.

Where they live
You can find largemouth bass in the water near the edge of the pond. Largemouth bass usually live in lakes and ponds that have a lot of aquatic plants around the edges. They often can be found in groups hiding near dead logs, plants or docks.

What they eat
Largemouth bass are consumers. Largemouth bass eat Bluegills, minnows, frogs, tadpoles, snakes or aquatic invertebrates like chaoborus. Sometimes largemouth bass may even eat small ducks or squirrels when they are in the water.

What eats them
Largemouth bass are usually eaten by herons or other fish and birds. They are also eaten by humans.

Fun Facts

Amphipod
Bacteria
Black willow
Bluegill
Bluegreen algae
Bullfrog
Caddisfly larvae
Cattail
Chaoborus
Copepod

Version: 2.1.2 Jul 16

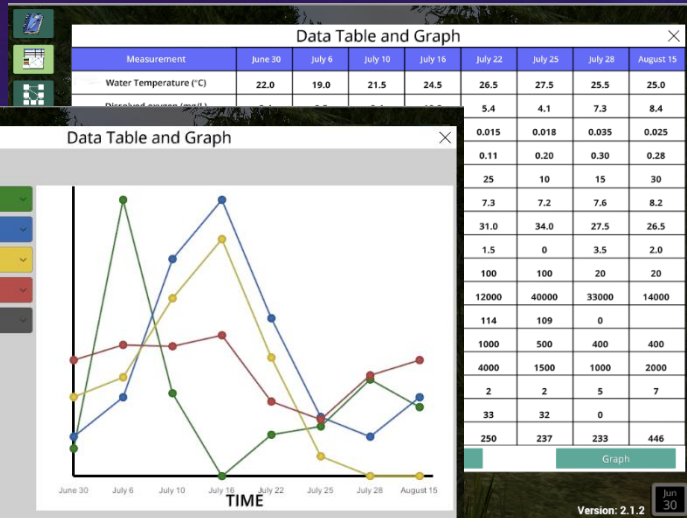
Oxygen Atom

I've been floating around in the atmosphere for a while. Whoa! Here comes a big wind! The wind just mixed me into the water in the pond! I guess that makes me DISSOLVED OXYGEN!

Save to Notebook

Close

Version: 2.1.2 Jul 16



Tommy Bract

Hi, I'm Tommy. We've been working really hard to get the new housing development ready for the open house. I'm probably going to have to work overtime every day this week to get these lawns in shape! I think this extra fertilizer I picked up should do the trick.

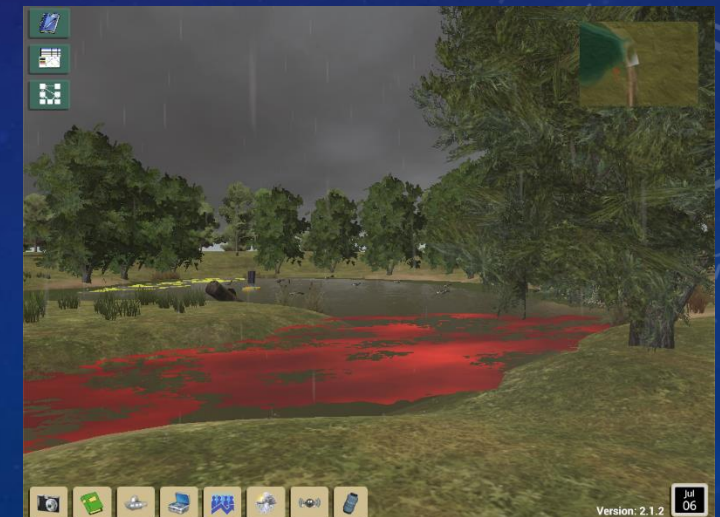
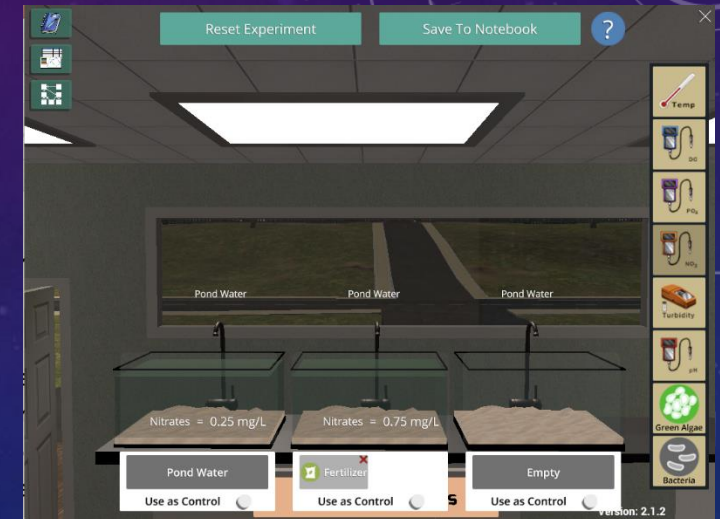
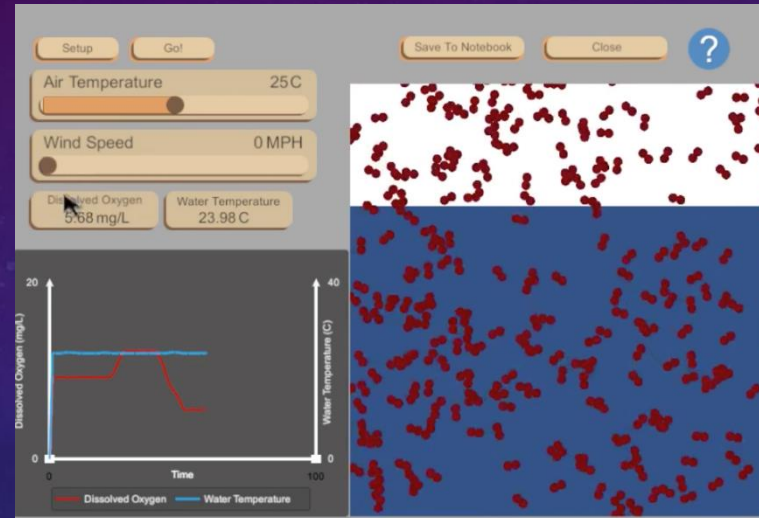
Save to Notebook

Ok

Version: 2.1.2 Jun 30



Epistemologically authentic experimental tools allow students to gather confirming evidence and to test misconceptions.



SUMMARY: TYPES OF EVIDENCE

- Observation – visual information, e.g., rain, bags of fertilizer, dead fish
- Testimony – information from non-player-characters (NPCs) in the world
- Reference – information from field guide, atom tracker, other resources
- Data – information from measurement tools, data table/graph, buoy
- Experimental evidence
 - Tolerance tanks
 - Comparison tanks
 - Weather simulator
 - Tracer tool
 - Sensor buoy
 - Mesocosm

All evidence is stored and organized in a Notebook tool.

Notebook tool

- “Save to Notebook” button lets students save all types of evidence to notebook.
- Notebook pages include data representation and field for student to add notes.
- Notebook index shows icon for type of note, and text of student note.
- Notebook index can be filtered by type of data.

Comparison Tank Results 1 / 1

	Left Tank	Middle Tank	Right Tank
Factors	Pond Water	Fertilizer	
Nitrates	0.25 mg/L	0.75 mg/L	

Our notes about this information :

nitrates are higher in the tank with the fertilizer

< Previous Delete Save Next >

Version: 2.1.2

Notes

Show notes from: Everything

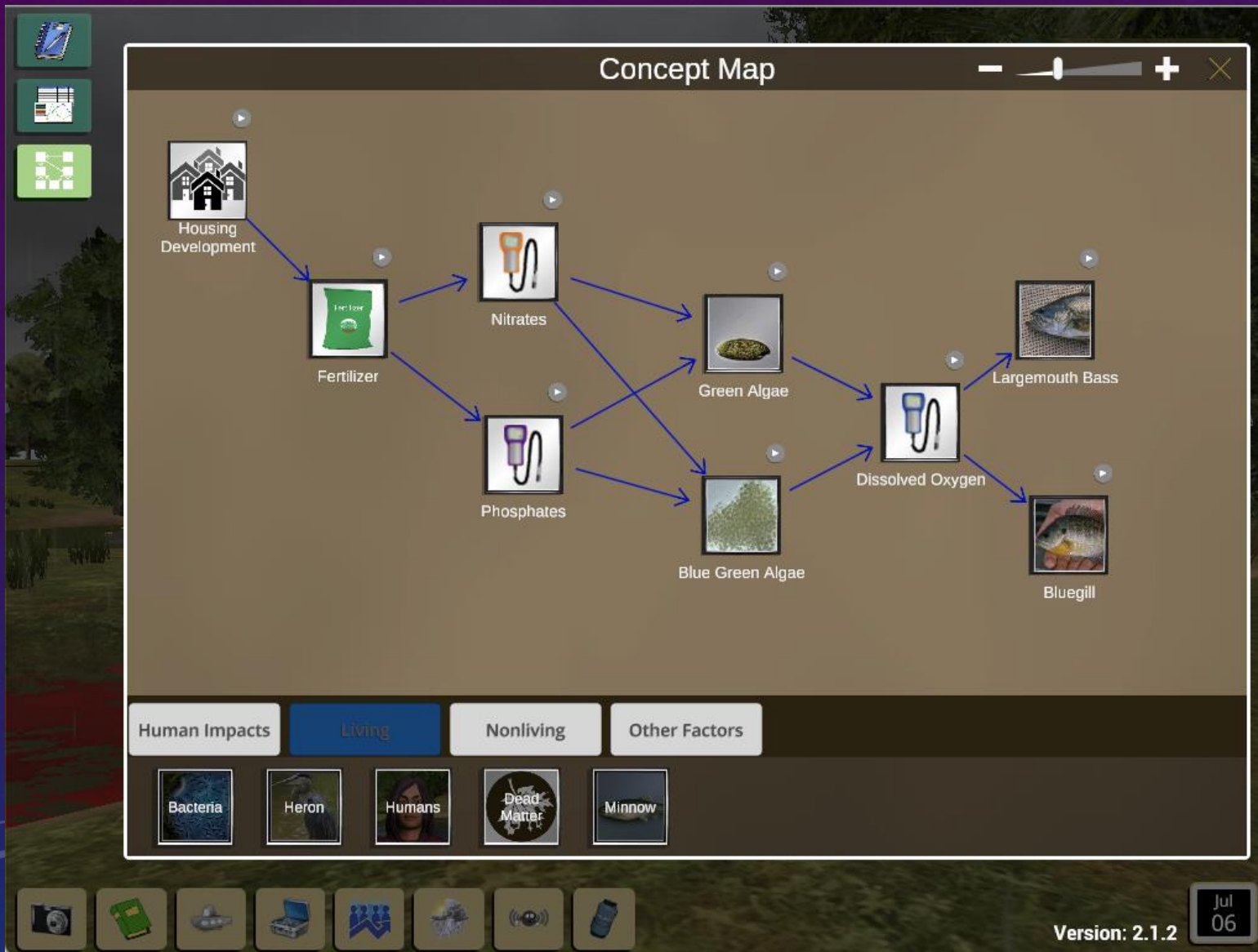
- wind mixes oxygen into the water
- the fertilizer bag has nitrates and phosphates in it
- The dissolved oxygen went below 4 before the fish died
- fertilizer from the housing development
- nitrates are higher in the tank with the fertilizer
- nitrates went up on July 6 after it rained
- It's raining on July 6
- he says he's putting fertilizer on the lawns

Version: 2.1.2 Jun 30

CONCEPT MAP TOOL

- Icons represent factors (measureable variables in system).
 - Pre-defined, but also option to create new factors
- Arrows represent relationships between factors
- Double-click on arrows to open dialog to explain relationship
- Claim, Evidence, Reasoning model
 - Claim is arrow
 - Evidence is linked from Notebook
 - Reasoning text entered by student

Concept Map tool



Fertilizer Affects Nitrates

Claim: Fertilizer affects Nitrates

Evidence: +

- ☒ nitrates went up on July 6 after it rained -
- ☐ he says he's putting fertilizer on the lawns -
- ☐ the fertilizer bag has nitrates and phosphates in it -

Reasoning:

the fertilizer has nitrates in it, and when it rained the nitrates in the pond went up because the rain washed the fertilizer into the pond

Save Delete Cancel

USING EVIDENCE TO SUPPORT CLAIMS

Example: **fertilizer** affects **nitrates**

Student might support this claim with one or more of the following:

- **Testimony** from the groundskeeper
- **Observation** of the rain washing runoff into the pond
- **Reference** information from the fertilizer bag label
- **Graphs** of nitrate levels over time
- Experiments using the **comparison tank** (fertilizer affects nitrates)
- Experiments using **tracer tool** (path of fertilizer runoff)

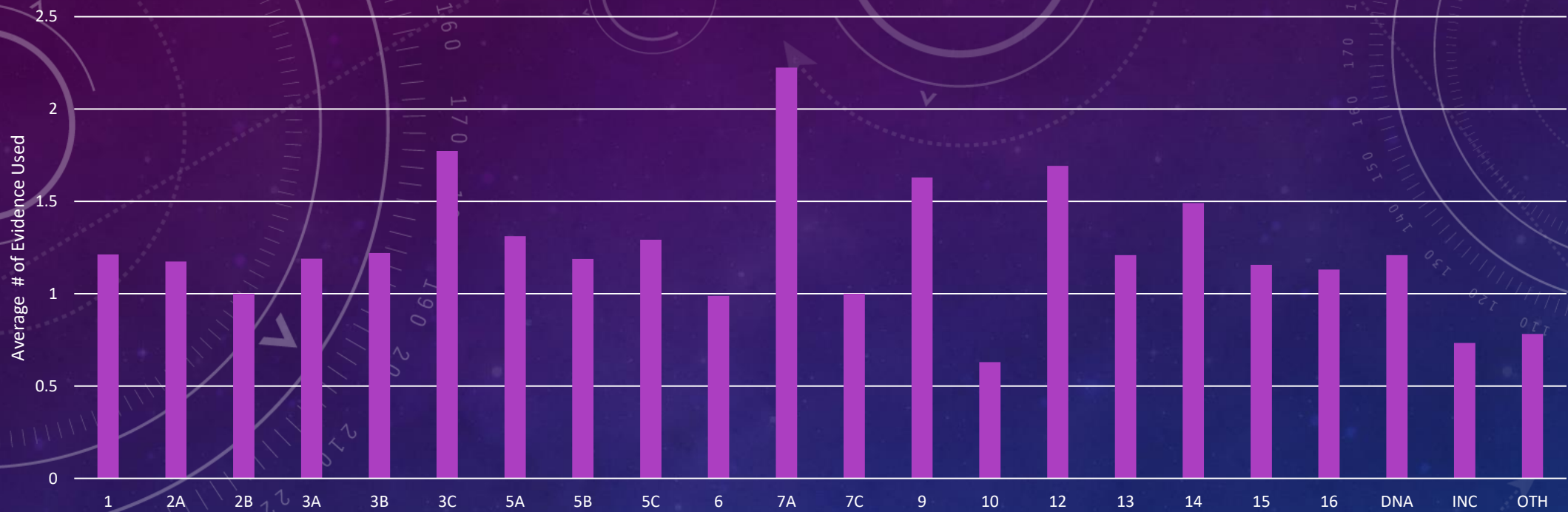
METHODS

- 213 concept maps generated by groups of two or three students from 10 teachers across five schools in three different school districts in the northeastern United States during the 2017-2018 school year
- Claims were automatically coded based on cause-effect relationship represented by each connection.
- Source of evidence coded as observation, testimony, reference, data, or experimental.
- All experimental evidence subcoded for the six types of experiments in EcoXPT: tolerance tanks, comparison tanks, weather simulator, fertilizer tracers, sensor buoy, and mesocosm studies.
- All coding done in Python 2.7 with JSON objects storing concept map data

DATA OVERVIEW

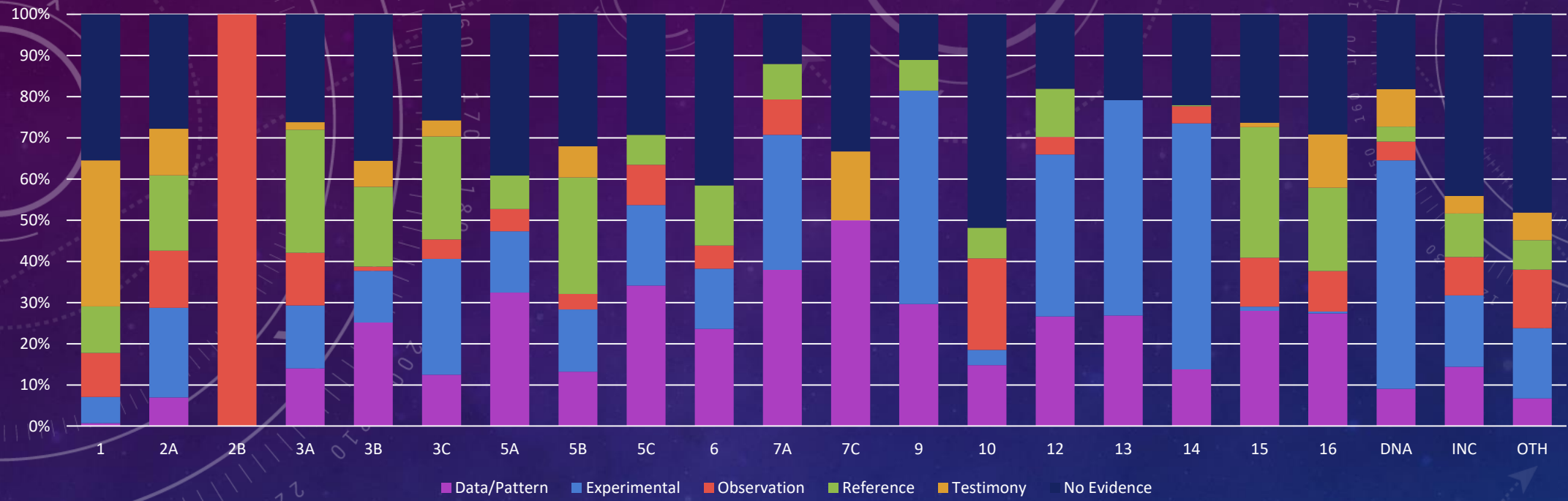
- Student groups used the concept map tool to construct concept maps with an average of 10.3 nodes per map and 12.5 connections (1.21 c/r ratio).
- Claims were justified with an average of 1.2 pieces of evidence.

Average Amount of Evidence Used per Claim



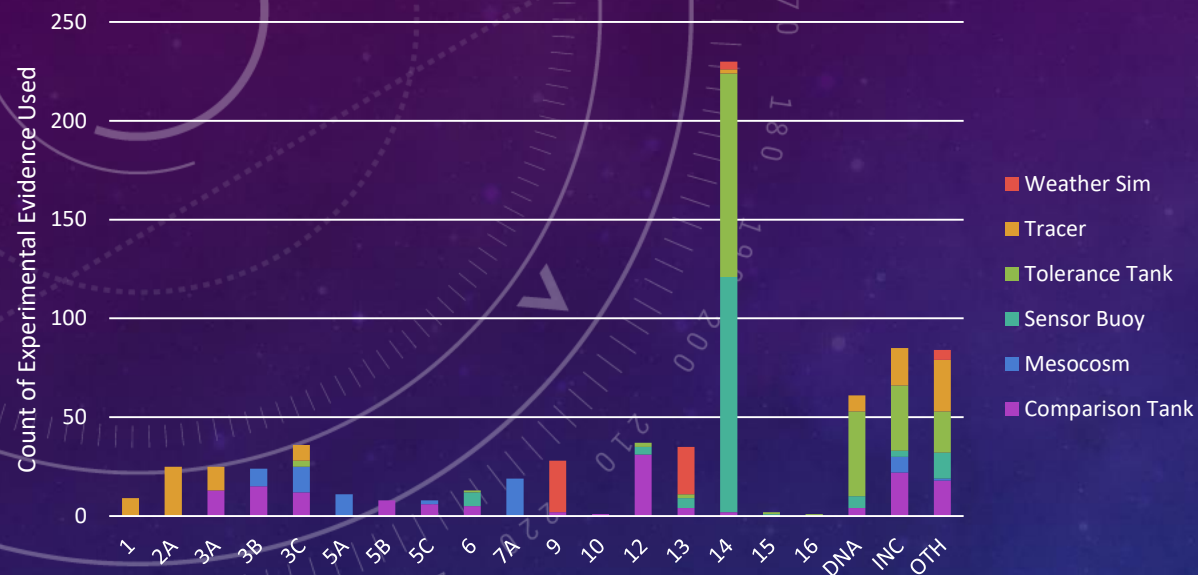
AMOUNT OF EVIDENCE

Type of Evidence Used by Claim

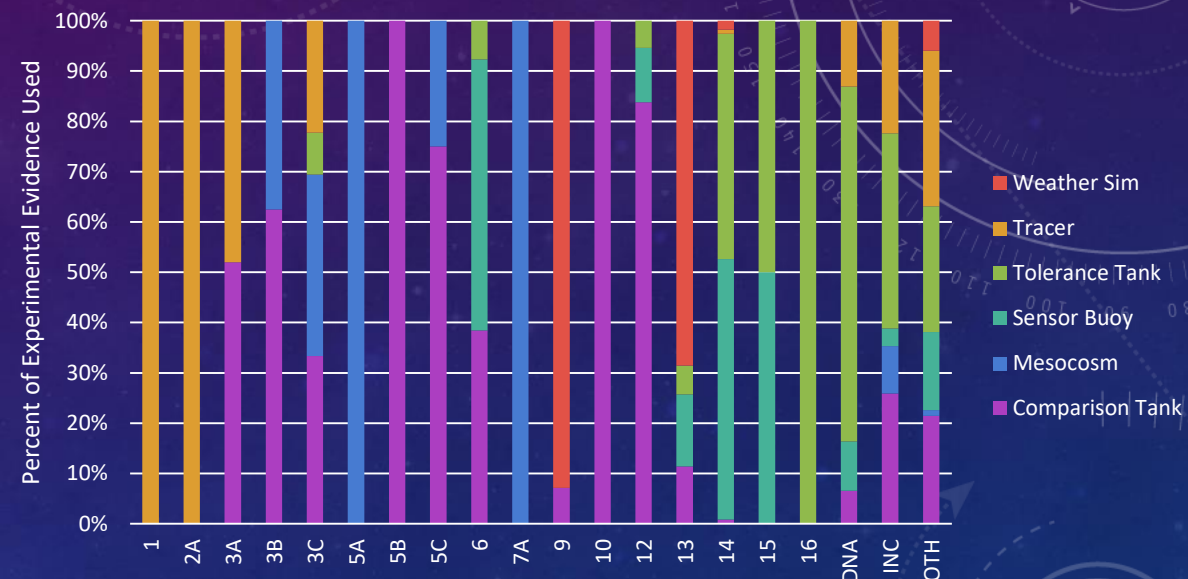


SOURCE OF EVIDENCE

Experimental Tool Use by Claim



Experimental Tool Use by Claim



EXPERIMENTAL EVIDENCE

DISCUSSION

- Students successfully used a variety of types of evidence to support their claims, and the types of evidence used varied significantly depending on the claim.
- Difference in flexibility of experimental tools: The comparison tanks were the most flexible; students used comparison tank evidence the most often, to support claims that, e.g., fertilizer affects algae, algae affects dissolved oxygen, dead matter affects bacteria, etc. On the other hand, the weather simulator more specifically supported just two claims, that both wind and temperature affect dissolved oxygen.

FUTURE WORK

- Improving scaffolding for comparison tanks
- Using concept maps to generate formative feedback for groups
- Automated analyses: completeness, correctness (forthcoming AERA paper)
- Analysis of causal reasoning

ACKNOWLEDGMENTS

For more information, please visit our website at

ecolearn.gse.harvard.edu

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Claim	Description	Claim	Description
1	Source (e.g., housing dev, people) affects fertilizer	8	Night affects dissolved oxygen (via algae) **
2A	Rain washes fertilizer into pond (runoff).	9	Wind affects dissolved oxygen (mixing from the air)
2B	Wind causes fertilizer to get into the pond.	10	Dead matter/algae increases turbidity
3A	Fertilizer affects N, P in the pond	11	Less sunlight (due to turbidity) decreases algae **
3B	N,P in the pond affect algae (nutrients)	12	Bacteria affects dissolved oxygen (respiration)
3C	Fertilizer affect algae (3A+3B combined)	13	Temperature affects dissolved oxygen
4	Lack of nutrients causes algae to die**	14	Dissolved oxygen affects fish (respiration)
5A	Algae affects dead matter (decomposition)	15	Big fish and minnows all affect each other
5B	Dead matter affects bacteria (food)	16	Big fish and herons affect each other
5C	Algae affects bacteria (5A+5B combined)	DNA	Does not affect claim (can be correct or incorrect)
6	Algae affects dissolved oxygen (photosynthesis)	OTH	Correct claim, but not one of the core numbered claims above
7A	Clouds/sunlight affect algae (photosynthesis)	INC	Incorrect claim
7C	Clouds/sunlight affect dissolved oxygen (via algae)		** = only appears if user enters new claim