Students' Reasoning Tendencies about the Causal Dynamics of Ecosystems and the Impacts of MUVE vs. Non-MUVE Instructional Contexts

M. Shane Tutwiler[1], Tina A. Grotzer[1], Amy M. Kamarainen[1], Katarzyna M. Derbiszewska[2], Shari J. Metcalf[1], & Christopher J. Dede[1]

[1]Harvard University, [2]Center for Applied Special Technology

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What are our research questions?

Students make a different set of assumptions about the nature of the complex causal dynamics and systemic structure than ecosystems scientists do when reasoning about ecosystems dynamics (e.g. Grotzer & Basca, 2003; Grotzer et al., 2013; Grotzer & Solis, 2015; Hmelo-Silver, Pfeffer, & Malhotra, 2003). EcoMUVE (Metcalf et al, 2011) was designed to simulate ecosystems patterns and structural causalities.

RQ1: What reasoning tendencies were revealed in students' initial explanations?

RQ2: Did students using the EcoMUVE and comparison curricula demonstrate gains in the proportion of complex causal responses?

RQ3: What was the effect of the use of the EcoMUVE on gains in complex causal responses, controlling for student and teacher-level fixed effects?

Where was the study conducted?

- 4 urban and suburban schools in New England
- ~60% Caucasian, 15% Black/African American, 15% Latino, 5% Asian
- All schools had sufficient technology resources to support the study
  - i.e. relatively affluent (FRPL ~25%)

Whom did we include in our study?

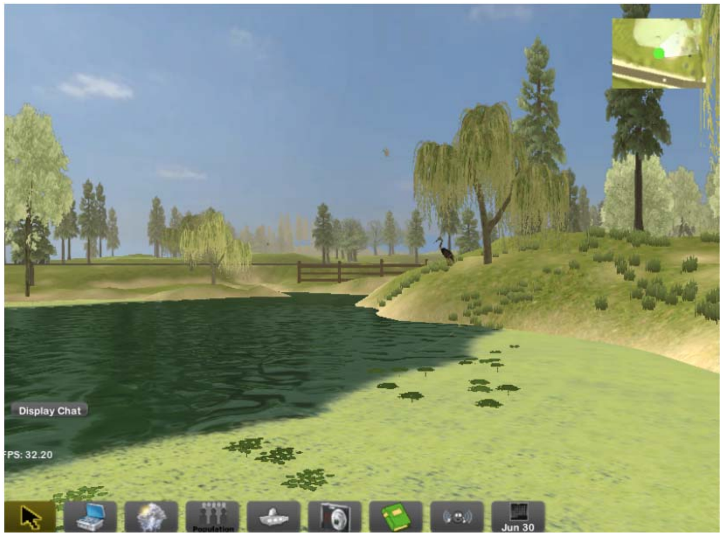
- Target Population
  - Middle School (grade 7&8) science students
- Sample
  - 5 Teachers included, students could opt-out
  - 263 Middle School students who were clustered in the 5 teachers
  - 142 Female, 121 Male
- Statistical Power Analysis
  - Given the sample size and number of clusters, we had a power of .80 to detect an effect size of 0.40 standard deviation units at a Type I error rate of .05.

What procedures did we employ?

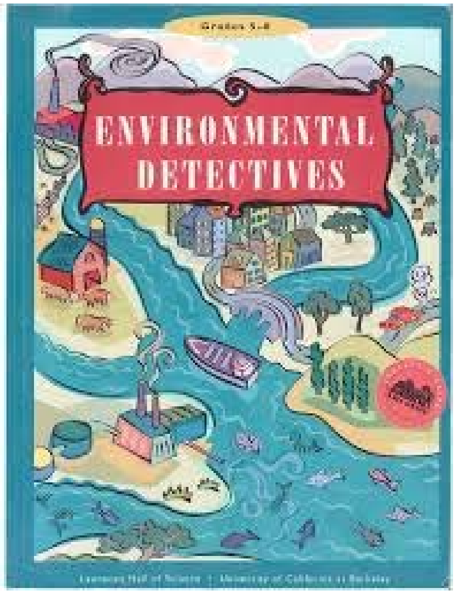
- Block Cluster Randomized Experiment
  - Classes (two per teacher) randomly assigned to the treatment (n=10) or control (n=10) conditions
  - Students in the treatment used EcoMUVE pond curriculum
  - Students in the control used comparison curriculum
- Causal, Attitude, and Content Knowledge assessments prior to and after the intervention (before students or teachers knew the assignment).

What procedures did we employ?

- EcoMUVE Pond
  - Two week experience
  - Complex ecosystem mystery
  - Students took on roles and worked in teams



- Comparison
  - Two week
  - Co-taught with researcher
  - Environmental Detectives (GEMS Series – Lawrence Hall of Science)



What are our measures?

- Outcome Variables
  - Gain in the proportion of non-obvious responses
  - Gain in the proportion of spatially distant responses
  - Gain in the proportion of attentionally distant responses

- Question Predictor
  - EcoMUVE (1=yes, 0=no)

- Covariates
  - Pre proportion of non-obvious, spatially/attentionally distant responses
  - Pre Content Knowledge
  - Female (1=yes, 0=no)
  - Vector of Teacher Fixed Effects

Table 1. Descriptive statistics

	EcoMUVE (n=127)	Compare (n=133)	Difference
FEMALE	0.546 (0.499)	0.520 (0.502)	0.026
KNOW.PRE	23.248 (5.976)	22.945 (5.996)	0.303
TEACH1	0.195 (0.398)	0.283 (0.452)	0.088
TEACH2	0.120 (0.327)	0.118 (0.324)	0.002
TEACH3	0.241 (0.429)	0.244 (0.431)	0.003
TEACH4	0.218 (0.414)	0.260 (0.440)	0.042
TEACH5	0.226 (0.420)	0.094 (0.294)	0.132**
NOPR.PRE	0.289 (0.151)	0.293 (0.165)	0.004
SDPR.PRE	0.007 (0.033)	0.006 (0.026)	0.001
ADPR.PRE	0.046 (0.067)	0.036 (0.066)	0.010
NOPR.GAIN	0.165 (0.193)	0.129 (0.198)	0.036
SDPR.GAIN	0.048 (0.072)	0.052 (0.076)	0.004
ADPR.GAIN	-0.006 (0.078)	0.046 (0.102)	0.040***

Note: **p<0.01, ***p<0.001

What data analyses did we conduct?

- Multi-level and fixed-effects models
  - Checked for linearity
  - Usual residual assumptions

- RQ2:

$$\text{e.g., NOPR.GAIN}_{ij} = \boxed{\beta_0} + \varepsilon_{ij}$$

$$\beta_0 = \pi_{00} + \xi_{0j}$$

- RQ3:

$$\text{e.g., NOPR.GAIN}_{ij} = \alpha + \boxed{\beta_1} Eco_{ij} + \delta_{ij} + \omega\tau_j + \varepsilon_{ij}$$

RQ1: Trends in initial responses

- Low proportion of complex initial responses were in the expected direction of novice type responses.

- Gains in proportion of complex responses supports prior work (Grotzer et al., 2013).

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Note: **p<0.01, ***p<0.001

RQ2: Both groups showed gains

Table 2. Null multilevel models predicting gain in proportion of complex causal explanations for students who used the comparison curriculum.

	Gain Scores		
	Non-Obvious	Spatial Distance	Attentional Distance
Intercept	0.129***	0.053***	0.046***
	(0.017)	(0.009)	(0.009)
Variance Components			
Residual	0.196822	0.0739252	0.1018579
Intercept (Teacher)	0	0.01476279	0
Observations	127	127	127
-2LL	-52.45532	-297.789	-219.7706

Cells are estimates (s.d.)
Note: ***p<0.001

Table 3. Null multilevel models predicting gain in portion of complex causal explanations for students who used the Ec UVE pond unit.

	Gain Sc		
	Non-Obvious	Spatial Distan	Attentional Distance
Intercept	0.165***	0.048***	0.006
	(0.017)	(0.006)	(0.009)
Variance Components			
Residual	0.192097	0.0720962	0.07770718
Intercept (Teacher)	0	0	0.003656026
Observations	133	133	133
-2LL	-61.39714	-322.0768	-301.8554

Cells are estimates (s.d.)
Note: ***p<0.001

RQ3: Comparison showed more gains in attentional distance

Table 4. OLS regression models predicting effect of the use of the EcoMUVE on the gain in proportion of complex causal explanations, controlling for student and teacher fixed-effects.

	Final Models (Ga		
	Non-Obvious	Spatial Distance	Attentional Distance
EcoMUVE	0.026 (0.025)	-0.004 (0.009)	-0.054*** (0.012)
Student Fixed-Effects	✓	✓	✓
Teacher Fixed-Effects	✓	✓	✓
Constant	0.102* (0.058)	0.067*** (0.023)	0.043 (0.028)
Observations	260	260	260
R^2	0.031	0.052	0.108

Cells are estimates (s.d.)
Note: *p<0.05, ***p<0.001

What are possible threats to validity?

- Internal Validity
  - Roles may have been related to student gains
  - Researchers tracked fidelity of implementation
- External Validity
  - Teachers self-selected
  - Low FRPL
  - High technology infrastructure

What are the take-aways?

- Both conditions revealed the initial assumptions that were consistent with the trends seen in the literature.
- Both conditions made significant gains.
- Comparison condition performed as well on non-obvious and spatial distance and *better* on action at an attentional distance.
  - Students navigate through the MUVE with ease.
  - Students don't experience distance in the same way in the MUVE.
  - *MORE RESEARCH*

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Thank you!

Questions?

tina_grotzer@harvard.edu

michael_tutwiler@mail.harvard.edu