Learning Progression-based Systems to Support Environmental Science Literacy

Poster Symposium at the NARST Annual Meeting

April 14, 2015

Introduction: Charles. W. (Andy) Anderson

Discussion: Bill Penuel

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Carbon TIME
Transformations In Matter and Energy

BSCS
A SCIENCE EDUCATION CURRICULUM STUDY

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- Hannah Miller, Joyce Parker, Wendy Johnson, Staci Starck, Allison Freed, Elizabeth de los Santos, Sarah Stapleton, Liz Tompkins, Jing Chen, Li Zhan, Lindsey Mohan, Michigan State University
- Jennifer Doherty, University of Washington
- Beth Covitt, University of Montana
- Jonathon Schramm, Goshen College
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Issues addressed in these posters

- Rigor and responsiveness in three-dimensional science learning
- “Three legs of the stool” for responsive and rigorous teaching
  - Student learning and assessment
  - Teacher learning
  - Professional support networks
- Moving toward design-based implementation research: responsiveness and rigor at scale
- Poster introductions and plan for the session

“New professionalism” in teacher education (Brantlinger & Smith, 2013)

Old professionalism

- Advocated by teachers’ unions and university-based teacher preparation programs
- Multiculturalism
- Understanding students’ subject matter reasoning
- Teacher autonomy
- Relatively lax standards
- Focus on experience and credentialing rather than teacher quality
- Responsiveness to students

New professionalism

- Advocated by alternative teacher education programs (e.g., Teach for America), some charter schools (e.g., KIPP), Arne Duncan (e.g., proposed teacher education regulations)
- Technical proficiency in specific teaching strategies
- Mandated curriculum
- High-stakes accountability for teachers and students
- Generally not subject-specific

NGSS Framework: Three-dimensional science learning

The Challenge of *NGSS*

Old professionalism

- Responsiveness without rigor (teacher as mentor)
- Best suited for somewhat loose, inquiry-oriented teaching

New professionalism

- Rigor without responsiveness (teacher as drill sergeant)
- Best suited for learning facts and definitions and test preparation

Needed for *NGSS:* Both rigor and responsiveness in classroom discourse (teacher as coach) for three-dimensional science learning (easier said than done).

Essential support system for three-dimensional science learning

Research and development goals: "Three legs of the stool," each necessary but not sufficient

- *Goal 1: Student learning (Posters 1-4)*
  - Research: learning progression frameworks and assessments
  - Development: teaching tools
- *Goal 2: Teachers' knowledge and classroom discourse (Posters 5 and 6)*
  - Research: classroom discourse progression
  - Development: online PD
- *Goal 3: Design-based implementation research and professional networks (Poster 7)*
  - Research: relationships and boundary objects in professional communities
  - Development: sustained professional networks

Steps in Building the Support System for Responsive and Rigorous Teaching

1. Drawing on experience and literature to develop initial ideas about goals, issues, and essential performances (Poster 7 for networks)
2. Qualitative analyses of interviews and classrooms to clarify goals and contrast more and less successful performances (Posters 5 and 6 for teaching and classroom discourse)
3. Development of learning progression (LP) frameworks and assessment systems (Posters 2 and 3 for student learning)
4. Design-based research, using LP frameworks and assessments to develop and test teaching units and strategies (Posters 1 and 4)
5. Design-based implementation research, developing and testing all components of the system at scale (where we're going)

Posters 1-4

Focus on student learning

NGSS focus for these posters

- Four key *practices*: interpreting and analyzing data, engaging in arguments from evidence, constructing explanations, and environmental decision-making.
- Two *crosscutting concepts:* systems and system models, and energy and matter: flows cycles, and conservation.
- *Disciplinary core ideas* in the life sciences (LS 1: From molecules to organisms: Structures and processes; LS 2: Ecosystems: Interactions, energy, and dynamics), Earth sciences (ESS 2: Earth's systems; ESS 3: Earth and human activity), and physical sciences (PS 1: Matter and its interactions; PS 3: Energy)

Data Sources

Type of Data	Baseline Data	Pre-assessments	Post-assessments	Student levels
Carbon TIME written tests	1417	1923	1923	MS, HS
College written tests		50	75	Non-science majors
Carbon cycling interviews		26	26	MS, HS
Sustainability interviews	33			MS, HS

Student learning practices and contexts

	Application: Models & Explanations	***Inquiry: Data & Arguments from Evidence***
Macroscopic scale	Model-based explanations in macroscopic contexts: burning, plant & animal growth & movement, decay **(Poster 1)**	Macroscopic-scale investigations and arguments from evidence, focused on tracing matter through chemical changes **(Poster 4)**
Ecosystem & global scale **(Poster 3)**	Modeling and explaining carbon pools & fluxes (carbon cycling and energy flow) at ecosystem and global scales	Interpreting global & local CO_2 & climate-related data
Sustainability & decision making **(Poster 2)**	Life cycle analysis of products, lifestyles, production systems Dealing with uncertainty & preparation for future learning	Cost/benefit analysis with environmental, social, & economic dimensions Dealing with uncertainty & preparation for future learning

Poster 2: Students' ideas about the sustainability of agricultural and fuel production systems

By Elizabeth de los Santos, Sarah Stapleton, and Andy Anderson

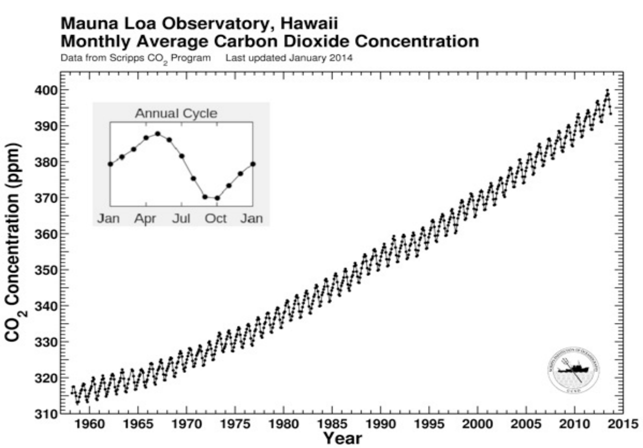
Decision-making about the sustainability of corn and fuel production systems:

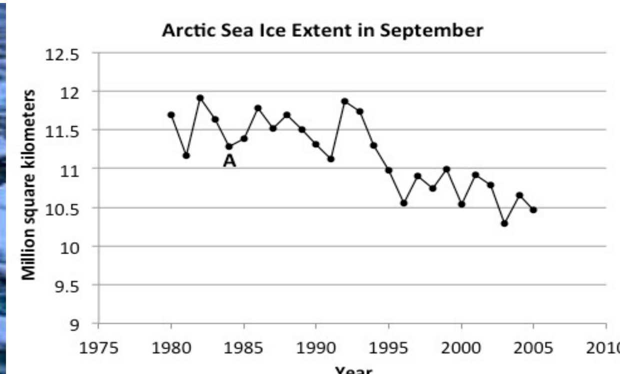
1. What do students know about the production systems?
2. How do students weigh costs and benefits?
3. How do students reason about spatial, population, and temporal scales?
4. How do students consider uncertainty?

Poster 3: Student sense making about climate-change relevant data

By Joyce Parker, Beth Covitt, Jenny Dauer, & Andy Anderson

A hopeful look at college students – How non-science majors interpret and explain graphs and seek information related to climate change





Carbon: Transformations in Matter and Energy (Carbon TIME)

Systems AND *Scale Teacher's Guide*

How our systems depend on Carbon and chemical energy: Finding chemical change in life and lifestyles

The Environmental Literacy Project
Carbon: Transformations in Matter and Energy
(Carbon TIME)
2011-2012

Plants AND THE Carbon Cycle

How seeds grow to trees and plants transform Carbon

The Environmental Literacy Project
Carbon: Transformations in Matter and Energy
(Carbon TIME)
2011-2012

Animals AND THE *Carbon Cycle*

How animals use and change Carbon and chemical energy

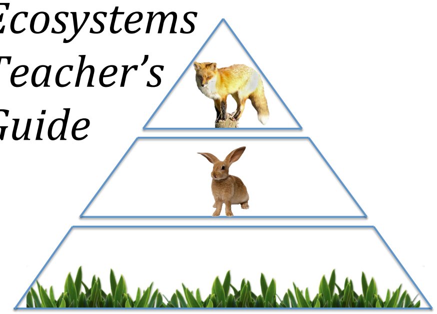
The Environmental Literacy Project
2011-2012

PROCESSES

Systems and Scale	Plants and the Carbon Cycle	Animals and the Carbon Cycle
Powers of 10 Combustion	Photosynthesis Biosynthesis Cellular respiration	Digestion Biosynthesis Cellular respiration

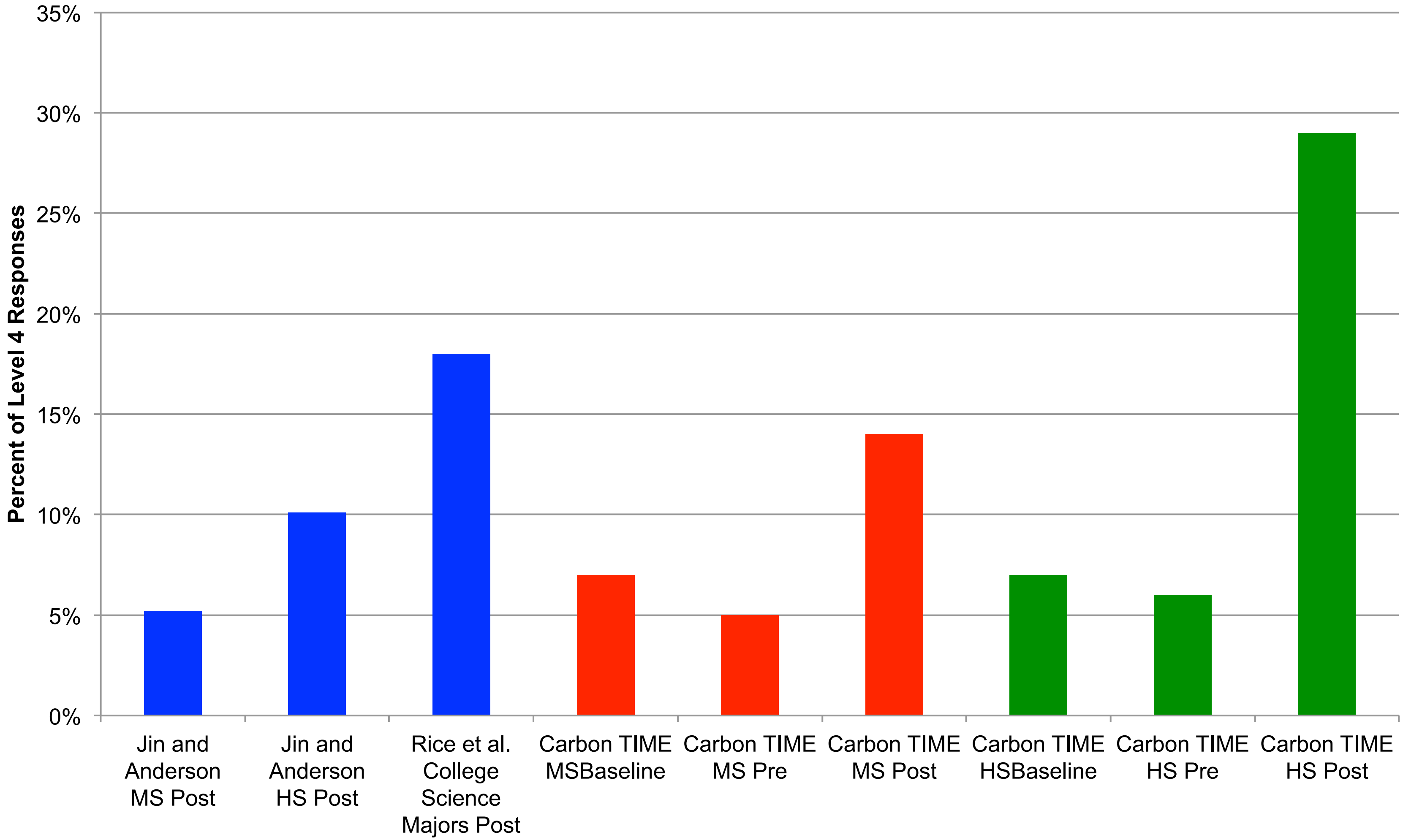
KBS LTER
Kellogg Biological Station
Long-term Ecological Research

Carbon TIME Units, cont.

	Decomposers And The Carbon Cycle	Ecosystems	Human Energy Systems
	Decomposers AND THE *Carbon Cycle*  *How decomposition changes* *Carbon and chemical energy* **The Environmental Literacy Project 2011-2012**	*Ecosystems Teacher's Guide*  *How ecosystems store and cycle Carbon and chemical energy* **The Environmental Literacy Project Carbon: Transformations in Matter and Energy (Carbon TIME) 2011-2012**	*Human Energy Systems* *Teacher's Guide*  *How humans use chemical energy stored in Carbon bonds* **The Environmental Literacy Project Carbon: Transformations in Matter and Energy (Carbon TIME) 2011-2012**
PROCESSES	Digestion Biosynthesis Cellular respiration	All processes except combustion in ecosystems	Combustion of fossil fuels for energy

KBS LTER
Kellogg Biological Station
Long-term Ecological Research

Percentages of Level 4 Responses

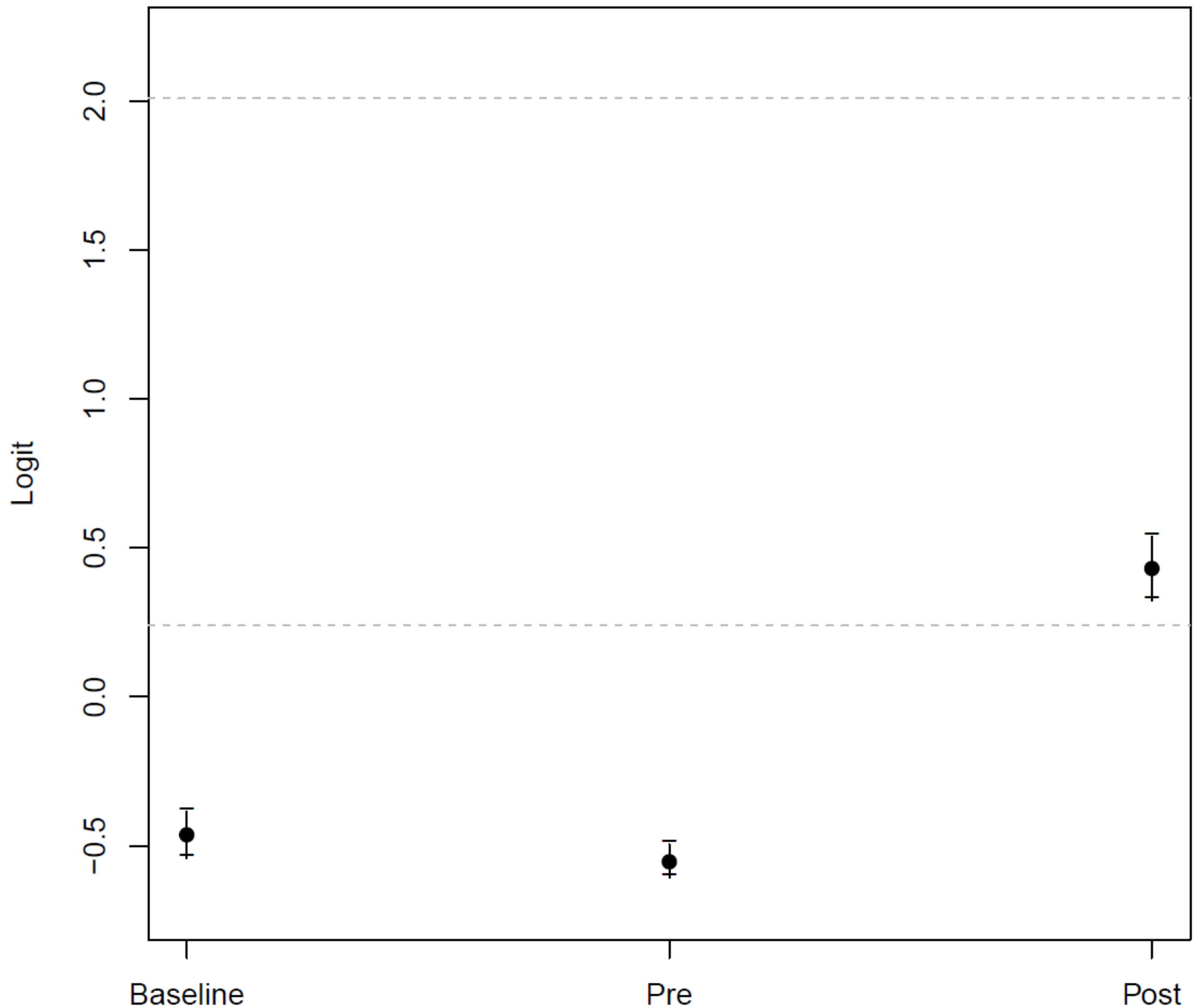


Blue: Comparison groups: Middle school, high school, college science majors

Red: Carbon TIME middle school: baseline, pre, post

Green: Carbon TIME high school: baseline, pre, post

IRT-based Analyses of Cohort 3

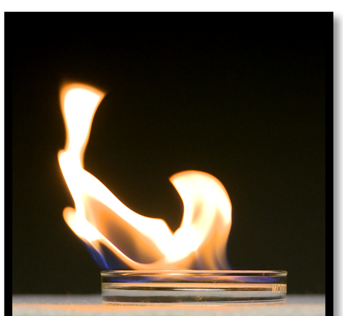


Baseline, pre, and post achievement for Cohort 3 students. Error bars represent 95% confidence intervals. Dashed lines are mean thresholds for learning progression Levels 3 and 4.

Poster 1: **Does Principle-oriented Instruction Improve Student Performance in Novel Contexts?**

By Jennifer H. Doherty, Emily E. Scott, Karen Draney, Jinho Kim, and Andy Anderson

Can principle-orientated instruction help students see the underlying similarity in principles and models across contexts with very different surface features, such as alcohol burning and plants growing?



Poster 4

Do Students Improve Their Inquiry Practices After Carbon TIME Instruction?

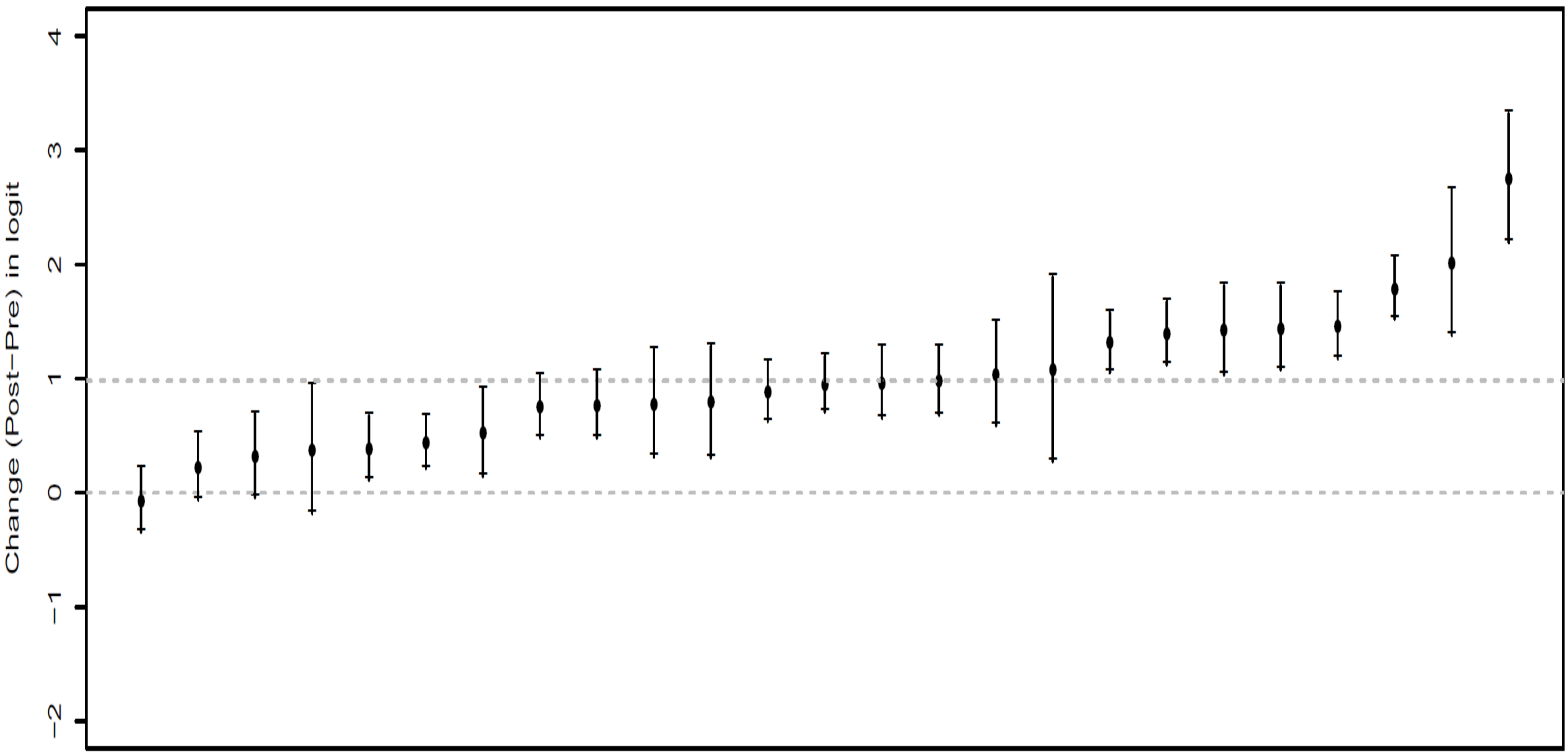
Allison Freed, Jenny Dauer, Elizabeth Tompkins, & C.W. (Andy) Anderson

We examine middle and high school students' ability to interpret arguments from evidence about plant growth before and after Carbon TIME instruction.

Posters 5 and 6

Focus on teaching and classroom discourse

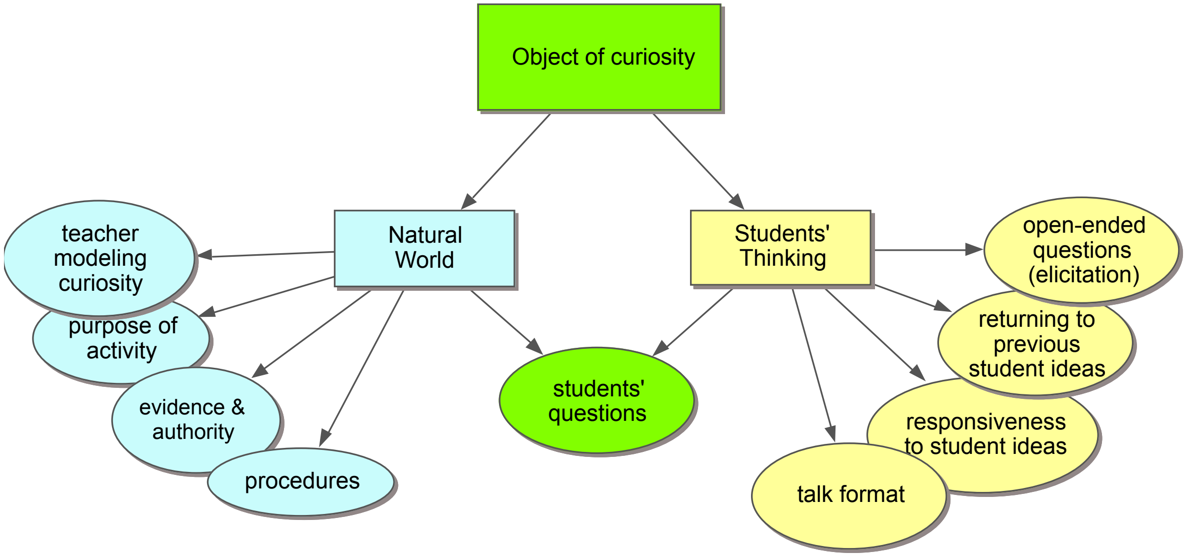
Comparing Student Learning for Different Teachers



Student learning for Cohort 3 teachers. Error bars represent 95% confidence intervals. Dashed lines represent (a) no learning and (b) average learning gain for all teachers.

Poster 5
The Role of Scientific Curiosity and Curiosity about Student Thinking in Classroom Discourse

Wendy R. Johnson, Hannah K. Miller, Charles W. Anderson



1. How do Carbon TIME teachers represent scientific curiosity in the classroom and encourage and scaffold students' scientific curiosity?
2. How do teachers differ in their expression of curiosity about student thinking, and what are the effects on classroom discourse?
3. To what extent are teachers' curiosity practices in the clinical interviews reflective of their classroom teaching practices?

Poster 6: A Draft Learning Progression for Principle-Oriented Classroom Discourse

Hannah Miller, Wendy Johnson, Andy Anderson

Previous research: most student reasoning about carbon-transforming processes was not principle-oriented at the end of the year.

New questions

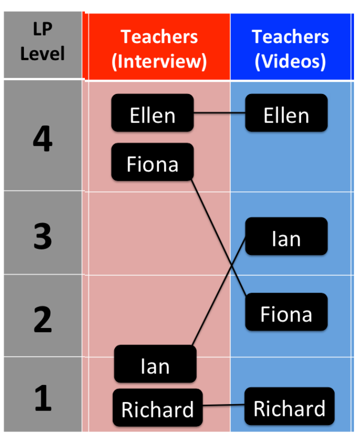
All teachers used Carbon TIME curriculum. How are teachers using the curriculum differently?

New analysis of classroom videos and interviews for signs of principle-oriented instruction

New unit of analysis

Draft Framework for Principle-Oriented **Classroom Discourse**

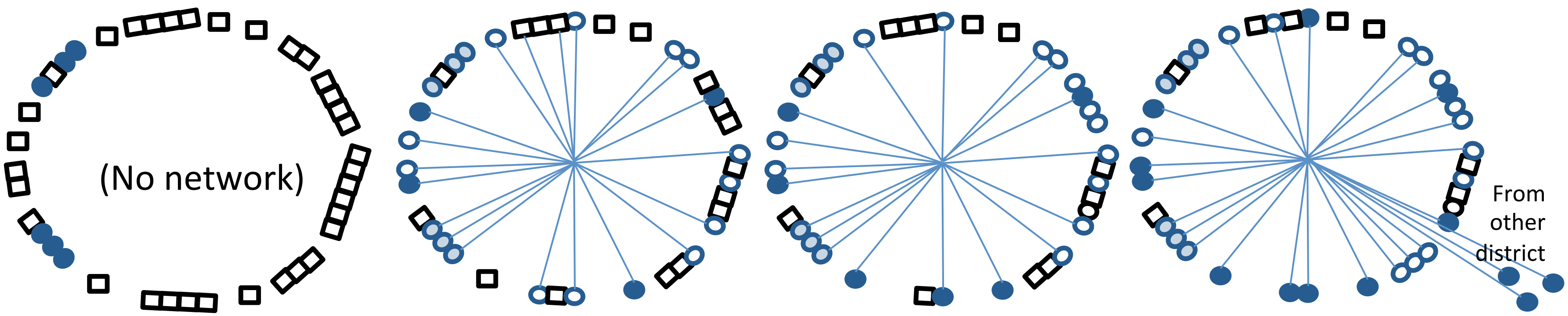
1. Teacher Interviews
2. Classroom Videos



Poster 7: Focus on Networks

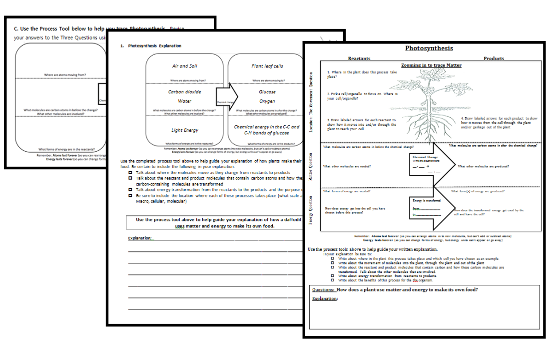
Poster 7: *Implementing a learning progression-based educational system at large scales*

- ***NETWORK THEORIES*** of social capital inform the ***DESIGN*** and ***RESEARCH*** of a sustained, scalable system



6 formal participants | 4 formal participants | 6 formal participants | 13 formal participants

- Project structures and roles ensure tight collaboration between practitioners and researchers in ***DESIGN-BASED IMPLEMENTATION RESEARCH***



"Process tool"

- Version 1: ***Teacher thought tool redundant and unnecessary***
- Version 2
- Version 3: ***Teacher expressed value of new version with network teachers; others adopted use***

Plan for the rest of this session

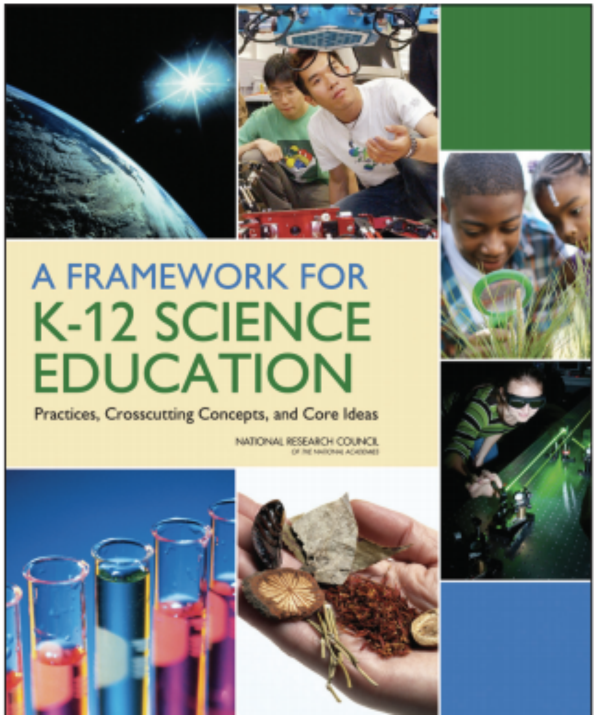
- Now to 3:45: Circulate and discuss posters
- 3:45 to 4:15: General discussion led by Bill Penuel

Framing Comments and Questions

William R. Penuel
University of Colorado Boulder

Principles of the *Framework for K-12 Science Education*

Principle
Children are born investigators
Focusing on practices, crosscutting concepts, and core ideas
Understanding develops over time
Science and engineering require both knowledge and practice
Connecting to students' interests and experiences
Promoting equity



Principles and Posters

Principle	Poster
Children are born investigators	
Focusing on practices, crosscutting concepts, and core ideas	*Anchoring discussions in focus questions around matter and energy:* Miller, Johnson, and Anderson *3D LP Dev't:* De Los Santos, Stapleton, Anderson
Understanding develops over time	*Examining growth over time using LP:* Freed, et al., Parker, et al.
Science and engineering require both knowledge and practice	*Argumentation about where plants get their mass:* Freed, Dauer, Tomkins, Anderson
Connecting to students' interests and experiences	*Responsiveness to students' ideas about investigations:* Johnson, Miller, Anderson
Promoting equity	*Variation in implementation across classrooms (implicit):* Doherty, Scott, Draney, Kim, & Anderson; Gallagher & Welch

Principles and Questions

Principle	Questions for Team and Room
Children are born investigators	*What questions do students bring? Where do they start with investigations?*
Focusing on practices, crosscutting concepts, and core ideas	*How might the model for orchestrating discussions related to matter and energy developed here be adapted for other crosscutting concepts?*
Understanding develops over time	*How can you put LPs "in harm's way" (e.g., by comparing alternate pathways)?* *How do you conceive of curriculum's role in LP?*
Science and engineering require both knowledge and practice	
Connecting to students' interests and experiences	*How can you identify what students care about and want to know about climate change?*
Promoting equity	*How might an equity frame become more explicit in the shift to DBIR?*

Contact Us

- *Carbon TIME* website: carbontime.bscs.org
- Environmental literacy website: http://envlit.educ.msu.edu/ (will have posters up soon, papers later)
- andya@msu.edu