Learning Progression-based Systems to Support Environmental Science Literacy

Poster Symposium at the NARST Annual Meeting
April 14, 2015

Discussion: Bill Penuel
Thanks to our funders

This research is supported by grants from the National Science Foundation: A Learning Progression-based System for Promoting Understanding of Carbon-transforming Processes (DRL 1020187), and Sustaining Responsive and Rigorous Teaching Based on Carbon TIME (NSF 1440988). Additional support comes from the Great Lakes Bioenergy Research Center, funded by the United States Department of Energy, and from Place-based Opportunities for Sustainable Outcomes and High-hopes, funded by the United States Department of Agriculture. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation, the United States Department of Energy, or the United States Department of Agriculture.

Carbon TIME
Transformations In Matter and Energy

Michigan State University

Great Lakes Bioenergy Research Center

BSCS

SeaTte Public Schools

Colorado School of Mines

Earth - Energy - Environment
Thanks to Contributors to this Research

• 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
• Laurel Hartley, University of Colorado, Denver
• Hui Jin, ETS
• RET’s: Marcia Angle, Lawton Schools, Rebecca Drayton, Gobles Schools, Cheryl Hach, Kalamazoo Math & Science Center, Liz Ratashak, Vicksburg Schools, Debi Kilmartin, Gull Lake Schools
• Mark Wilson, Karen Draney, JinHo Kim, Jinnie Choi, and HyoJeong Shin at the Berkeley Evaluation and Assessment Research Center
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

<table>
<thead>
<tr>
<th>Type of Data</th>
<th>Baseline Data</th>
<th>Pre-assessments</th>
<th>Post-assessments</th>
<th>Student levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon TIME written tests</td>
<td>1417</td>
<td>1923</td>
<td>1923</td>
<td>MS, HS</td>
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<tr>
<td>College written tests</td>
<td>50</td>
<td>75</td>
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<td>Non-science majors</td>
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<tr>
<td>Carbon cycling interviews</td>
<td>26</td>
<td>26</td>
<td></td>
<td>MS, HS</td>
</tr>
<tr>
<td>Sustainability interviews</td>
<td>33</td>
<td></td>
<td></td>
<td>MS, HS</td>
</tr>
</tbody>
</table>
## Student learning practices and contexts

<table>
<thead>
<tr>
<th></th>
<th><strong>Application: Models &amp; Explanations</strong></th>
<th><strong>Inquiry: Data &amp; Arguments from Evidence</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Macroscopic scale</strong></td>
<td>Model-based explanations in macroscopic contexts: burning, plant &amp; animal growth &amp; movement, decay</td>
<td>Macroscopic-scale investigations and arguments from evidence, focused on tracing matter through chemical changes</td>
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<tr>
<td></td>
<td><em>(Poster 1)</em></td>
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</table>
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**

- Powers of 10
- Combustion
- Photosynthesis
- Biosynthesis
- Cellular respiration
- Digestion
- Biosynthesis
- Cellular respiration
### 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
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.
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?
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?

Draft Framework for Principle-Oriented Classroom Discourse
1. Teacher Interviews
2. Classroom Videos

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

LP Level | Teachers (Interview) | Teachers (Videos)
--- | --- | ---
4 | Ellen | Ellen
3 | Ian | Fiona
2 | Ian | Fiona
1 | Richard | Richard
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

- 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*

<table>
<thead>
<tr>
<th>Principle</th>
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<tbody>
<tr>
<td>Children are born investigators</td>
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<tr>
<td>Focusing on practices, crosscutting concepts, and core ideas</td>
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<td>Understanding develops over time</td>
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<td>Connecting to students’ interests and experiences</td>
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<td>Promoting equity</td>
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## Principles and Posters

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<th>Poster</th>
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<tr>
<td>Children are born investigators</td>
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<tr>
<td><strong>Focusing on practices, crosscutting concepts, and core ideas</strong></td>
<td>Anchoring discussions in focus questions around matter and energy: Miller, Johnson, and Anderson 3D LP Dev’t: De Los Santos, Stapleton, Anderson</td>
</tr>
<tr>
<td><strong>Understanding develops over time</strong></td>
<td>Examining growth over time using LP: Freed, et al., Parker, et al.</td>
</tr>
<tr>
<td><strong>Science and engineering require both knowledge and practice</strong></td>
<td>Argumentation about where plants get their mass: Freed, Dauer, Tomkins, Anderson</td>
</tr>
<tr>
<td>Connecting to students’ interests and experiences</td>
<td>Responsiveness to students’ ideas about investigations: Johnson, Miller, Anderson</td>
</tr>
<tr>
<td><strong>Promoting equity</strong></td>
<td>Variation in implementation across classrooms (implicit): Doherty, Scott, Draney, Kim, &amp; Anderson; Gallagher &amp; Welch</td>
</tr>
<tr>
<td>Principle</td>
<td>Questions for Team and Room</td>
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<td>-------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Children are born investigators</td>
<td>What questions do students bring? Where do they start with investigations?</td>
</tr>
<tr>
<td><strong>Focusing on practices, crosscutting concepts, and core ideas</strong></td>
<td>How might the model for orchestrating discussions related to matter and energy developed here be adapted for other crosscutting concepts?</td>
</tr>
<tr>
<td>Understanding develops over time</td>
<td>How can you put LPs “in harm’s way” (e.g., by comparing alternate pathways)?</td>
</tr>
<tr>
<td>Science and engineering require both knowledge and practice</td>
<td>How do you conceive of curriculum’s role in LP?</td>
</tr>
<tr>
<td>Connecting to students’ interests and experiences</td>
<td>How can you identify what students care about and want to know about climate change?</td>
</tr>
<tr>
<td>Promoting equity</td>
<td>How might an equity frame become more explicit in the shift to DBIR?</td>
</tr>
</tbody>
</table>
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