



A Learning Progression-based System for Promoting Understanding of Carbon-transforming Processes (Carbon: Transformations in Matter and Energy)

Charles W. Anderson (Michigan State University); Daniel J. Gallagher (Seattle Public Schools); Kathleen Schwille (National Geographic Society); Karen Draney (Berkeley Evaluation and Assessment Research Center)



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Summary

We have developed and validated a suite of tools based on a learning progression for understanding key **carbon-transforming processes in socio-ecological systems** at multiple scales, including cellular and organismal metabolism, ecosystem energetics and carbon cycling, carbon sequestration, and combustion of fossil fuels. These processes generate, transform, and oxidize organic carbon. The primary cause of global climate change is the worldwide imbalance among these processes.

Suite of tools

1. Learning progression framework
2. Tools for principle-based reasoning
3. Teaching strategies for responsive teaching
4. Formative and summative assessment tools
5. Teaching materials and activities
6. Professional development materials

Research goals

1. Validate the learning progression framework
2. Identify sequences & mechanisms of learning
3. Determine effectiveness of teaching tools, strategies, and materials
4. Relate teacher knowledge, beliefs, classroom practice, and student outcomes to teacher support and professional development

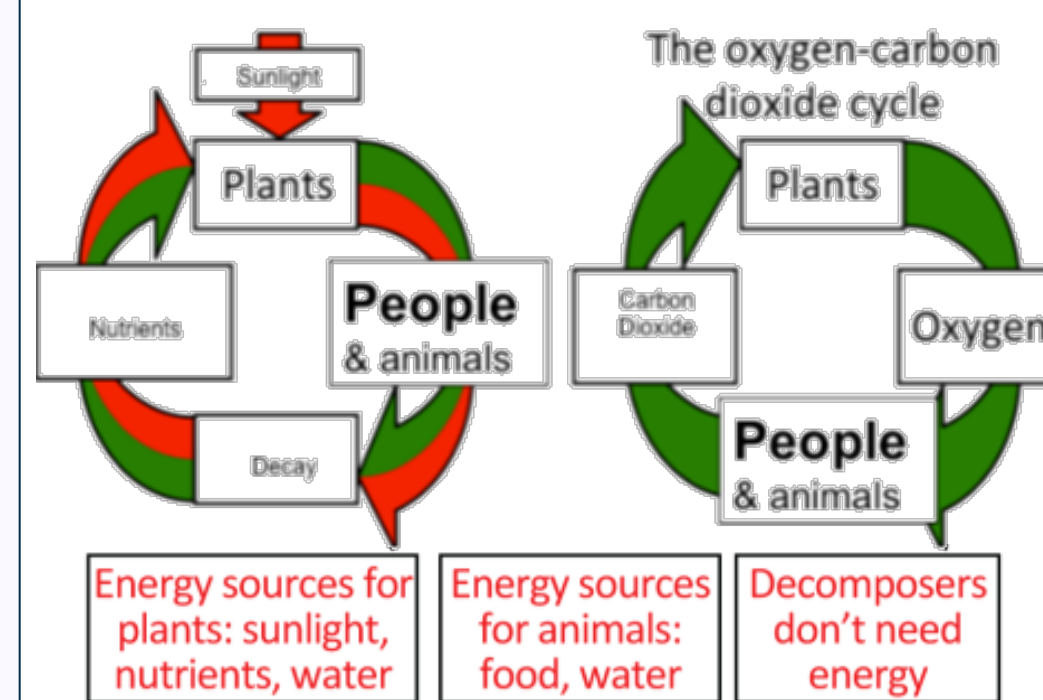
Participant locations



Learning progression framework

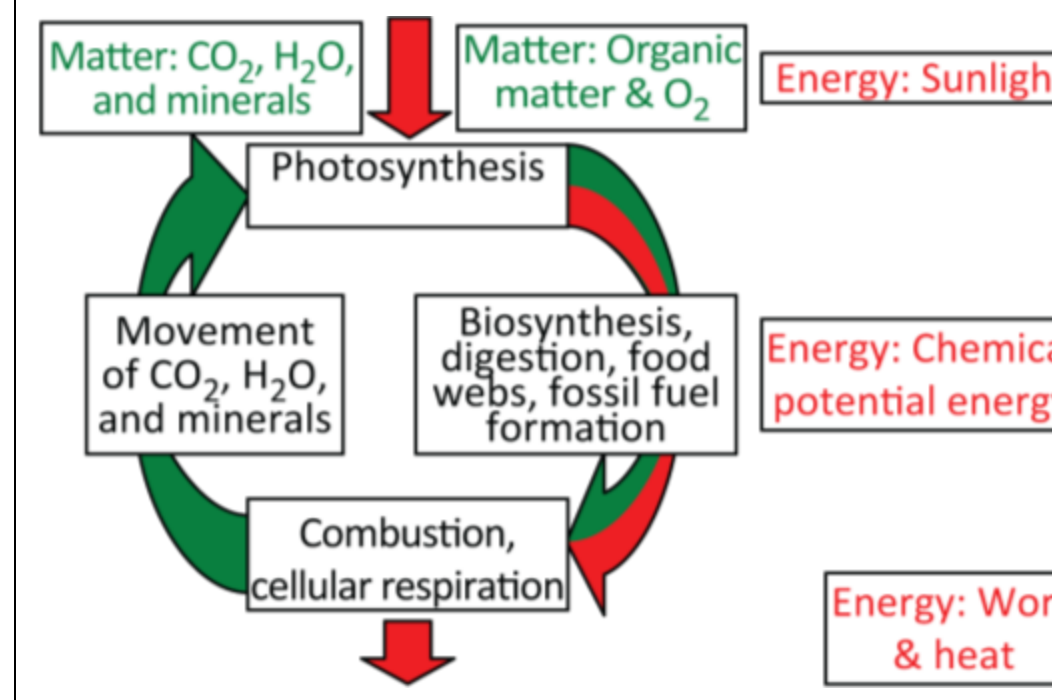
Level 2 Reasoning about the Carbon Cycle

Emphasis on actors and enabling conditions; conflation of energy and matter



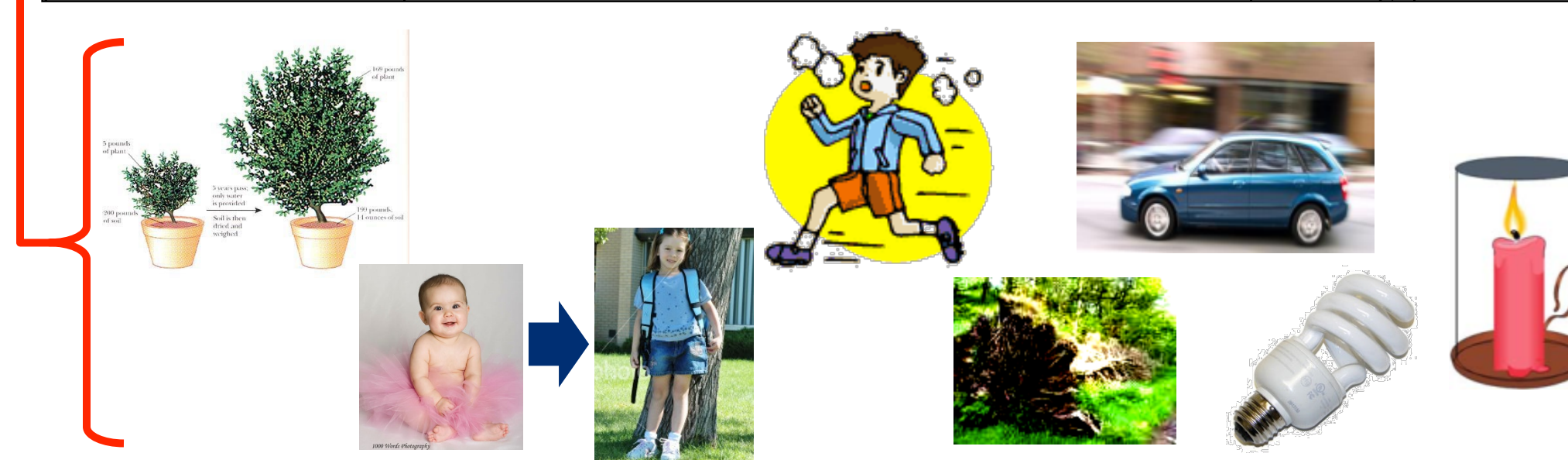
Level 4 Reasoning about the Carbon Cycle

Systems moving matter and energy, constrained by conservation principles



Formative and summative assessment tools

| Upper Anchor | Carbon-transforming process | Generating organic carbon | Transforming organic carbon | Oxidizing organic carbon |
|---------------------------------|--|---------------------------|----------------------------------|--------------------------|
| Scientific accounts | Photosynthesis | Biosynthesis | Digestion | Cellular respiration |
| Macroscopic Events | Plant growth | Animal growth | Breathing, exercise, weight loss | Decay |
| Lower Anchor: Informal accounts | Plants and animals accomplishing their purposes, enabled by food, water, sunlight, air, and/or other resources | | Natural process in dead things | Flame consuming fuel |



- Online and paper assessments, with interpretation guides linked to learning progression levels
- Student interview protocols

Teaching materials

Curriculum: Carbon Transformations in Matter and Energy (Carbon TIME)
Lessons in Carbon Transforming Processes



Six MS & HS Teaching Units

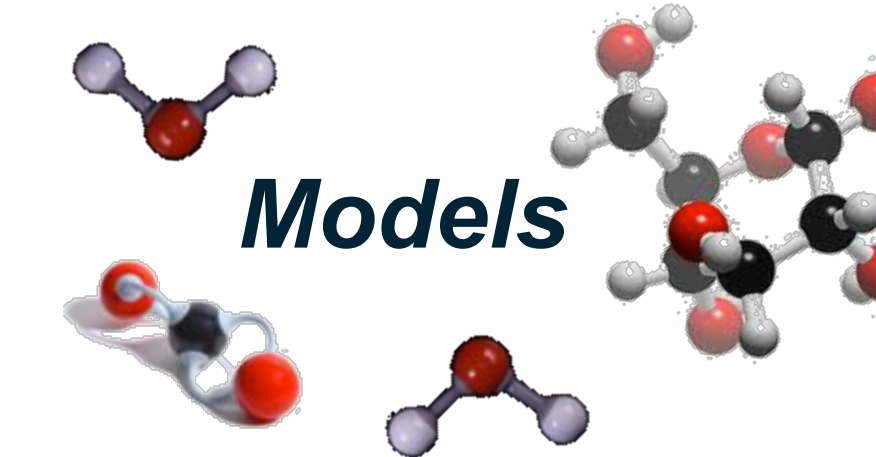
1. Systems and Scale
2. Plants
3. Animals
4. Decomposers
5. Ecosystems
6. Human Energy Systems

Connecting...

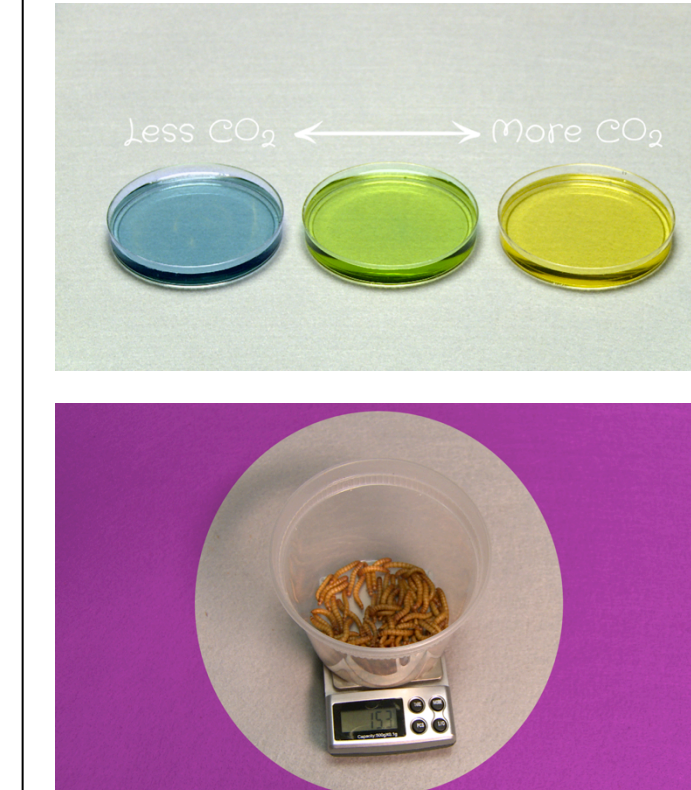
- LP levels
- Assessment outcomes
- Tools for Reasoning and multimedia resources
- Teaching strategies
- PD materials...using an online environment

Tools for Reasoning

Inquiry videos

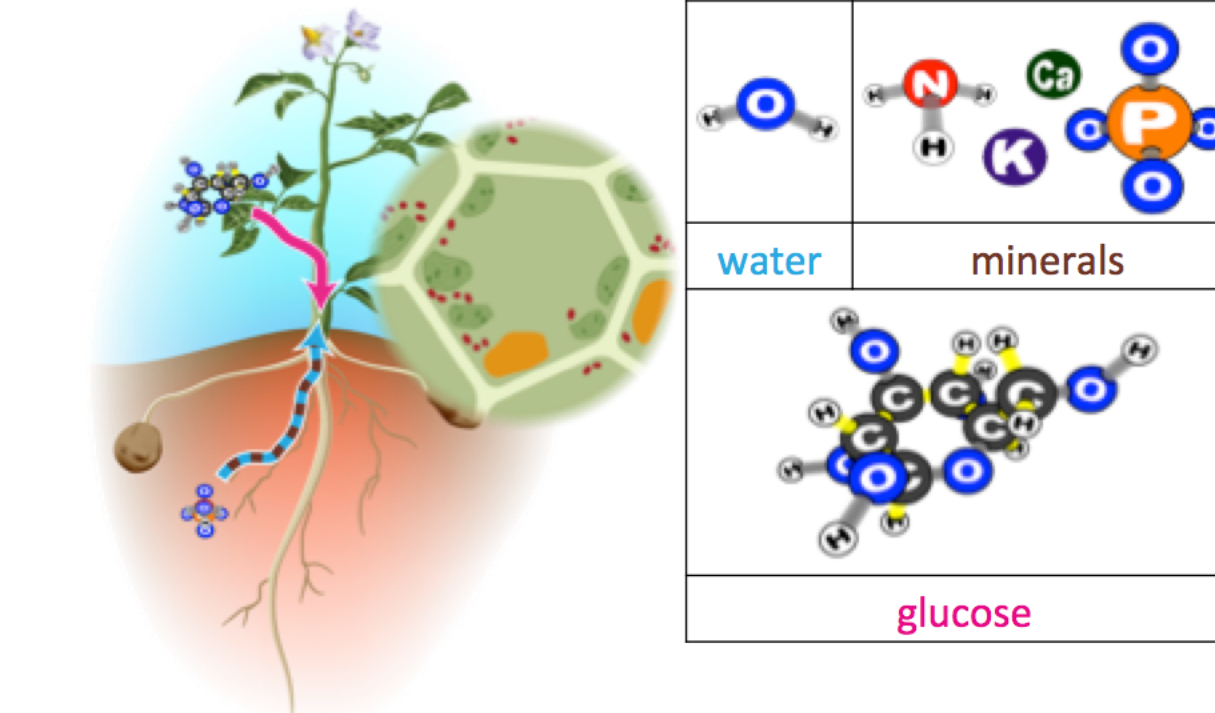


Measurement (gas, mass)



Animations

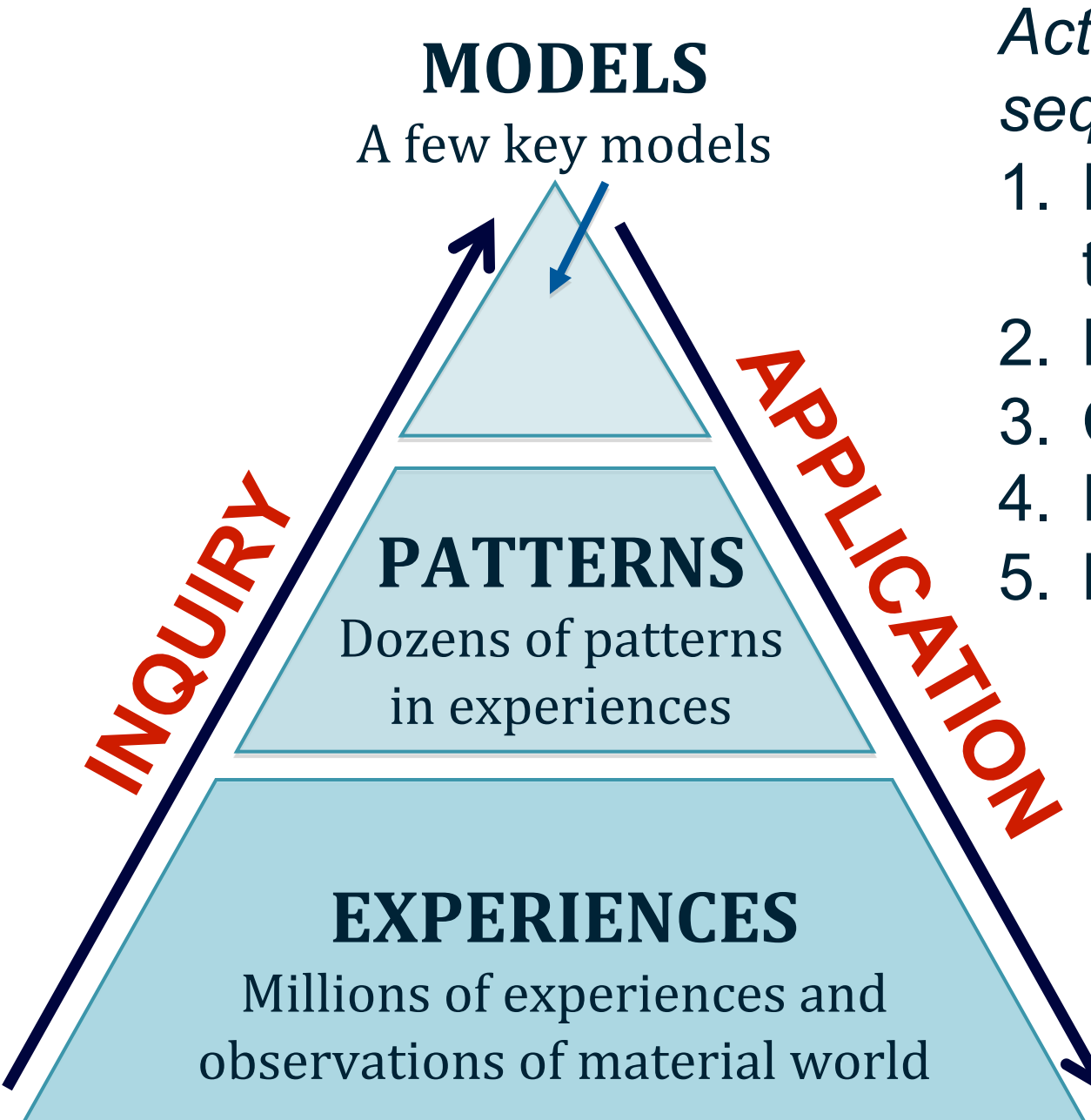
How do glucose, water, and minerals move for a plant stem cell to grow?



Teaching strategies

INQUIRY

- Activity sequence:
1. Predict
 2. Explain
 3. Observe
 4. Explain



APPLICATION/CITIZENSHIP

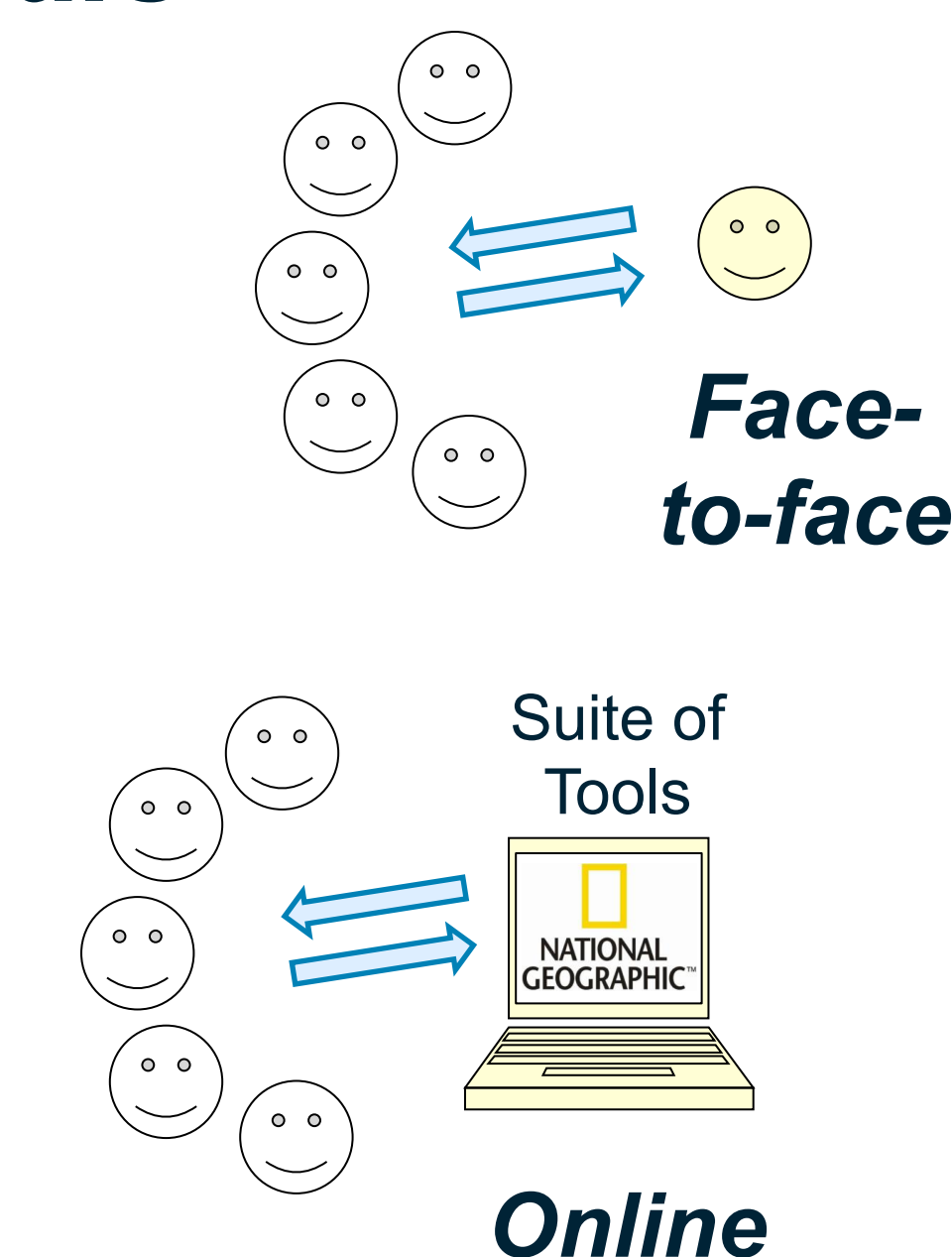
- Activity sequence:
1. Establishing the problem
 2. Modeling
 3. Coaching
 4. Fading
 5. Maintaining

Professional development materials

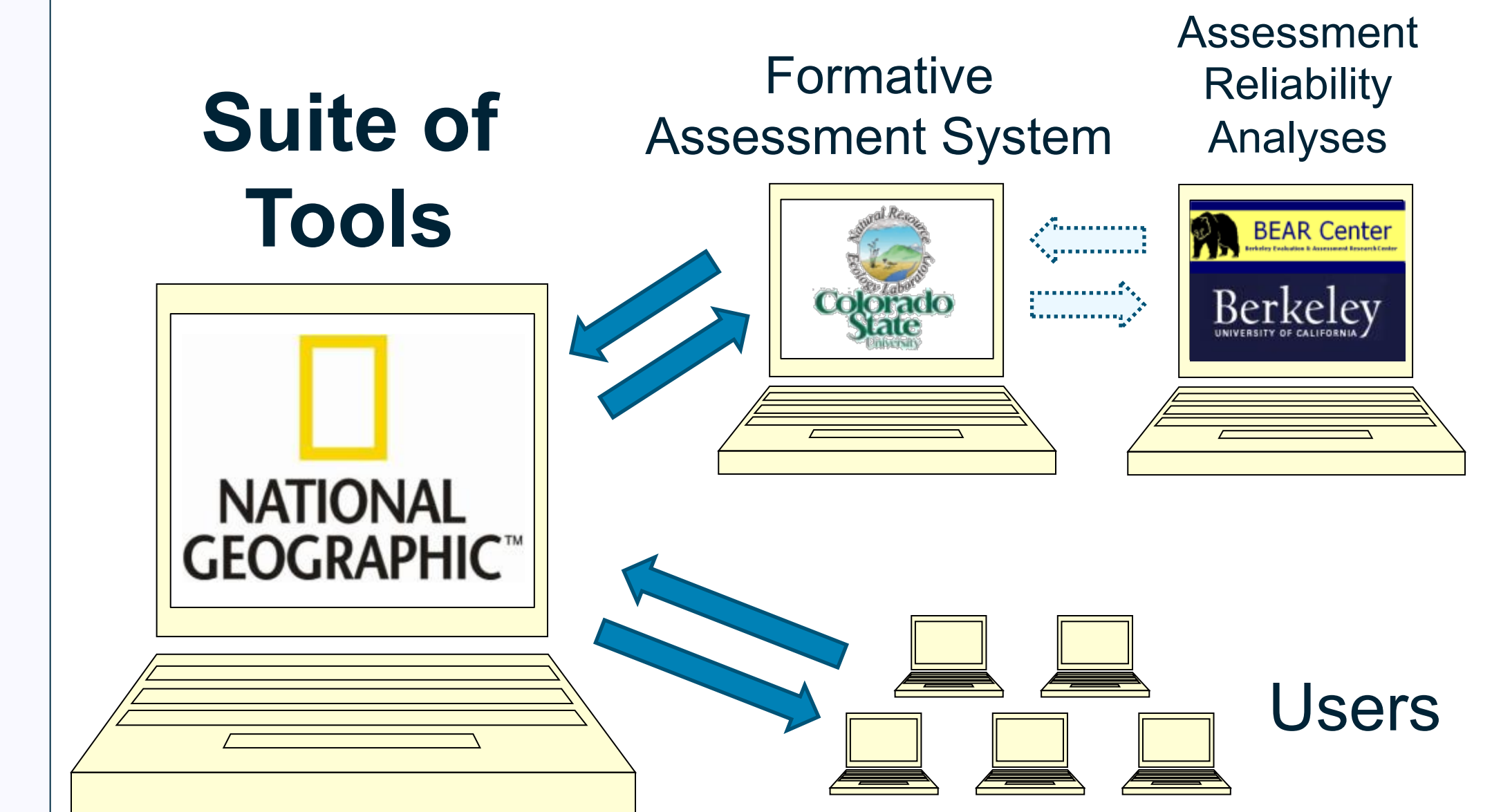
Student responses to interviews and written assessments, with learning progression-based interpretation guides

Teaching strategies for inquiry and application

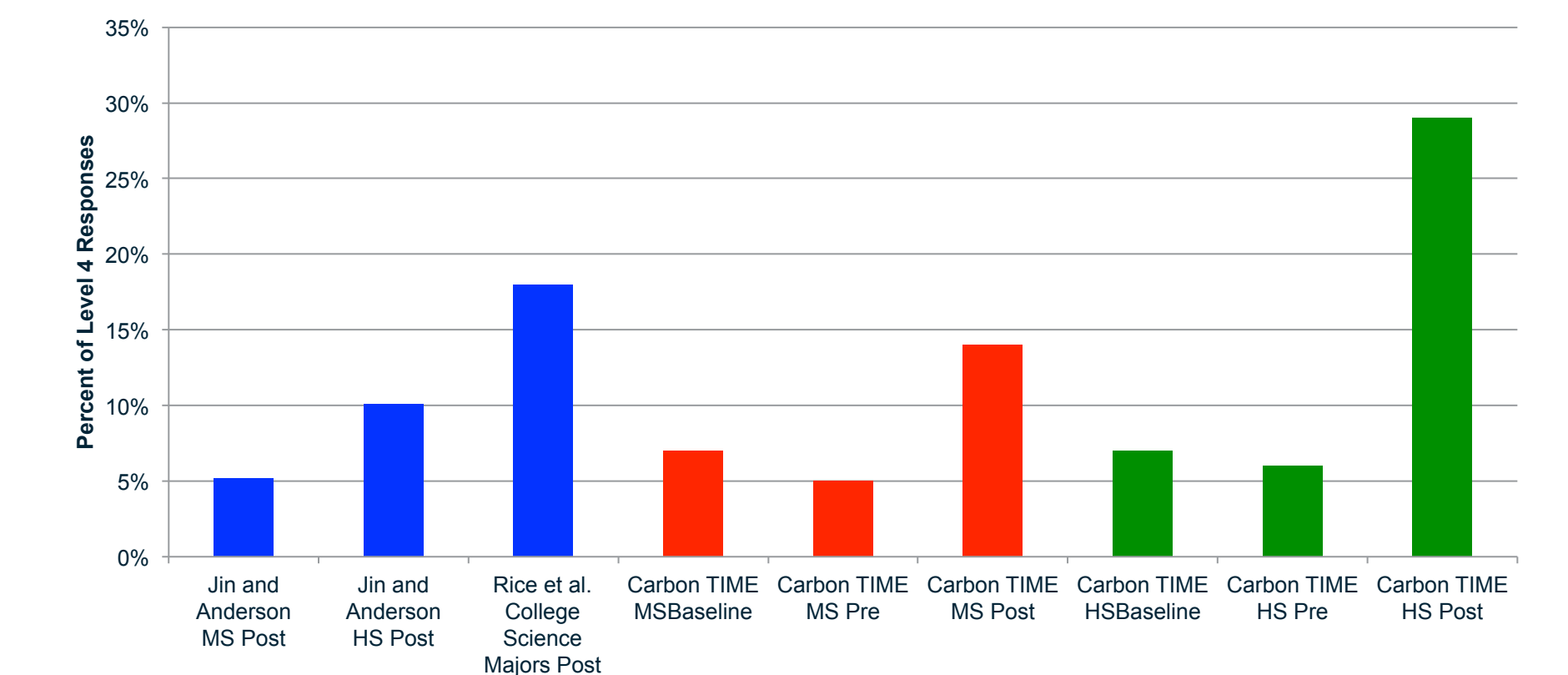
Assessment strategies, including clinical interview protocols



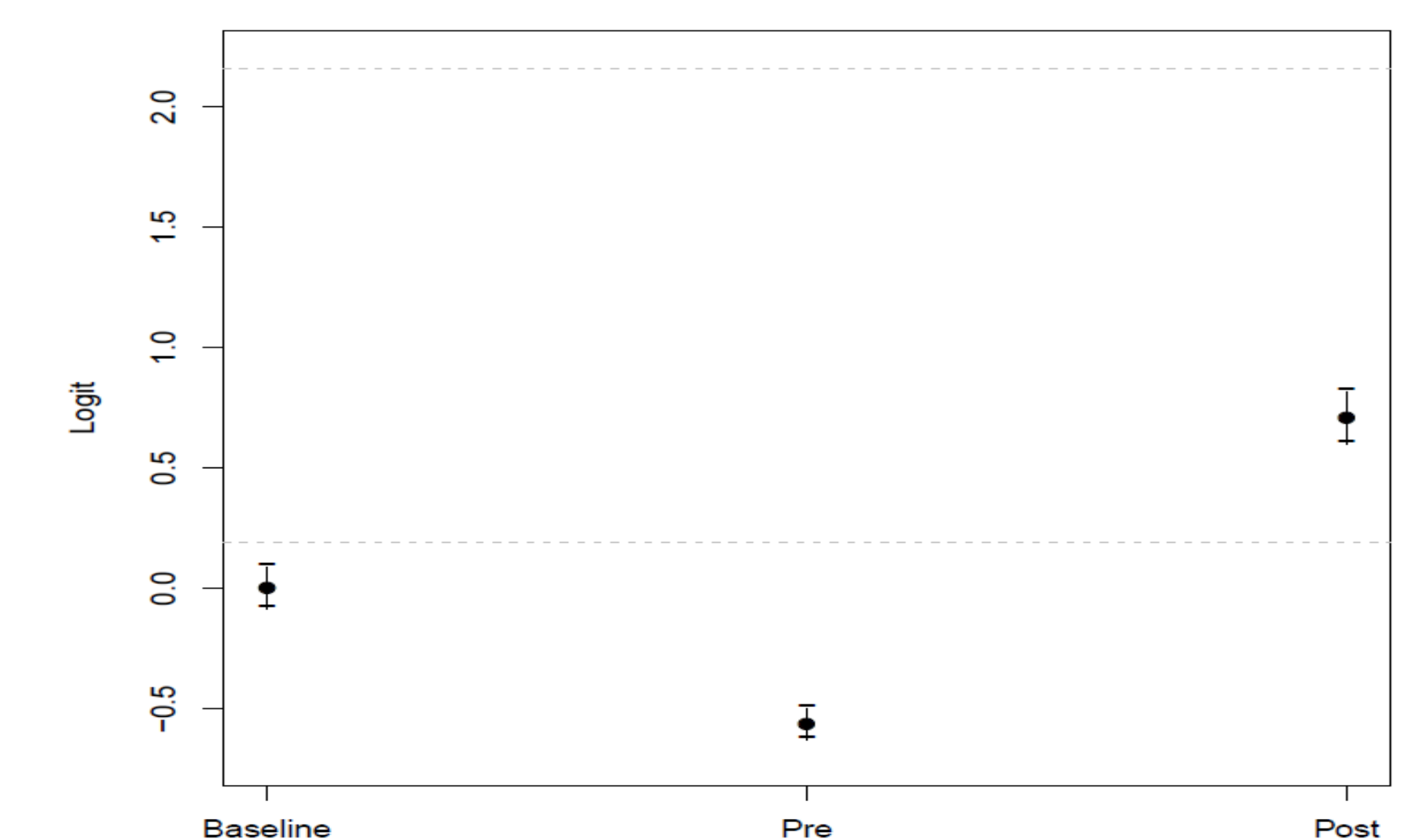
Website



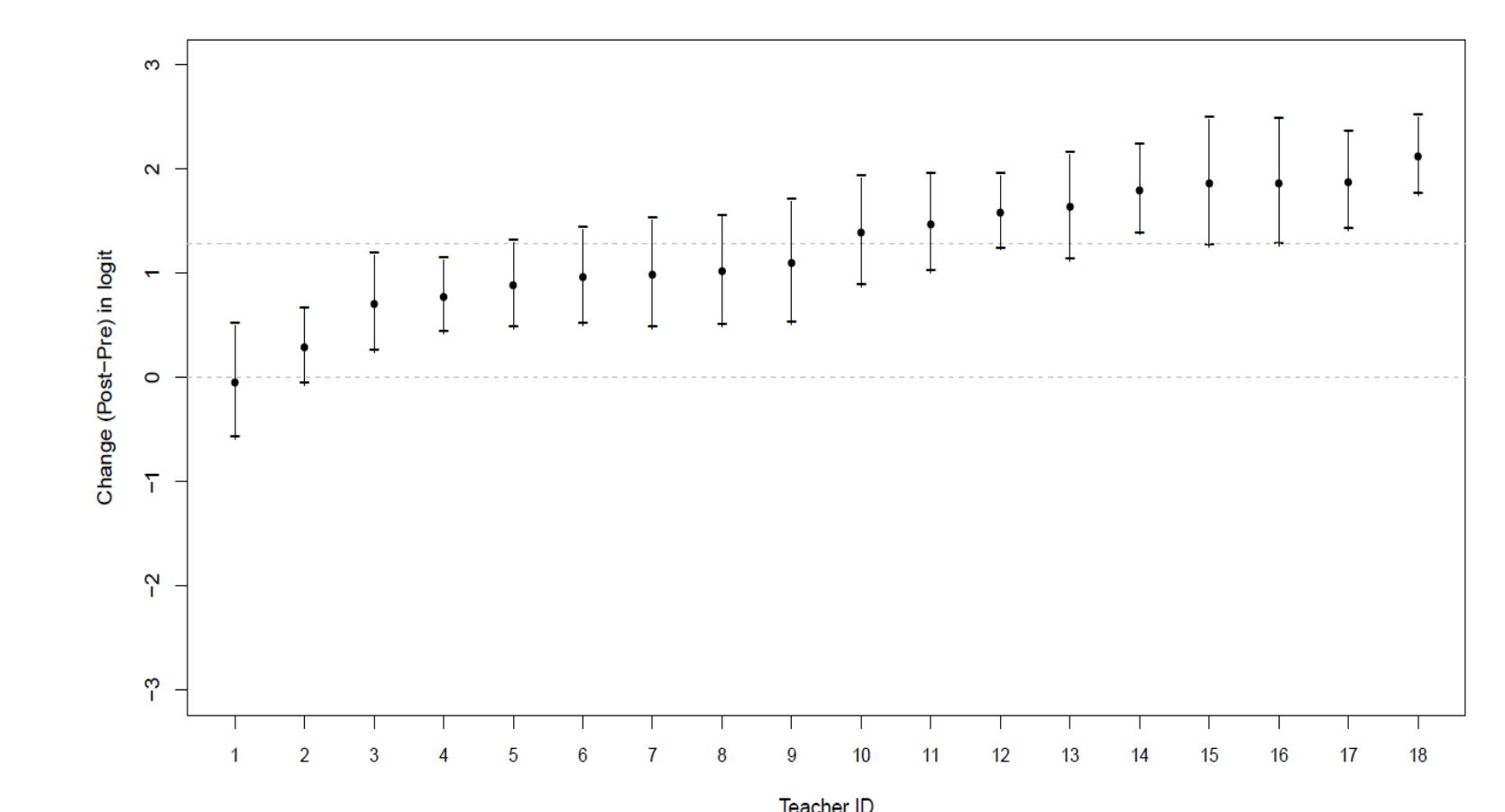
Selected Results



Percentages of responses coded as Level 4 explanations of carbon-transforming processes. Blue bars are end-of-course percentages in courses not using Carbon TIME materials. Red bars are from middle school teachers using Carbon TIME: baseline (spring of the year before using Carbon TIME, pretest (fall), and posttest (spring)). Green bars are baseline, pretest, and posttest from high school teachers using Carbon TIME.



Baseline, pre, and post achievement for Cohort 1 and Cohort 2 students. Error bars represent 95% confidence intervals. Dashed lines are mean thresholds for learning progression Levels 3 and 4.



Student learning for Cohort 2 teachers. Error bars represent 95% confidence intervals. Dashed lines represent (a) no learning and (b) average learning gain for all teachers.