**Defining Learning Progressions for Scientific Inquiry**

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### Theoretical Framework: The Example of Coherence Seeking

#### Characterizing a Learning Progression in Inquiry

**Students possess resources for engaging in scientific inquiry.**
- Students' activation of these resources is context-sensitive. (Hammer, 2004)

**Characterizing Progress**
- Progress will be episodic, with students spontaneously engaging in sophisticated inquiry practices before doing so stably.
- Define progress as more stable (frequent & sustained) engagement in inquiry practices over a wider variety of contexts (disciplinary & social).

#### Preliminary Work in Coherence Seeking

**Students possess resources for C-S:**
- HS students can attend to causal coherence with technological scaffolding (Sandoval, 2003)
- Elementary students can "recognize inconsistency in the thoughts of others" (Smith, Maclin, Houghton, & Hennessy, 2000, p. 364)

**Example from Classroom Data**
- A student finds that, contrary to his prediction, the asphalt from which a puddle evaporated is cooler than the surrounding asphalt. He offers a reconciliation: "I think the water kind of acted like a cover for the asphalt for a few moments. So it, so it, so this [asphalt] started to heat up, so it was like putting a cover over this so this doesn't heat up as fast..."

**Identify an inconsistency**
- Two or more pieces of information
- A claim, prediction, or explanation and two or more pieces of information
- "...how could a magnet have electricity in it because, isn't a magnet metal too? sort of? If it had electricity in it, it would go out. Because once electricity hits metal it goes, it keeps going in the metal until it goes—until there's no other metal on for it to travel through and then it goes out."

**Offer reconciliation of an inconsistency**
- "She said that it was heat coming up. Me and Robert were thinking maybe it's like um cause and effect. Heat is the cause and the water vapor is the effect."

**Identify a relationship between ideas, i.e.**
- cause and effect
- part-to-whole
- category and example
- temporal/chain of events
- "...If they [clouds] need to get rid of their energy and it turns into electricity, why does that only happen in certain areas?...Some areas they have like storms and rain and uh everyday. Um, why does that not happen here?"

**Identify an unexplained phenomenon**
- The student identifies an inconsistency between two pieces of information (electricity goes through metals, magnets are metal) and another student's claim that magnets have electricity in them.

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### Emerging Questions

- In what contexts do students seek, or not seek, coherence? What features of a situation cue, or tend to inhibit, coherence seeking?
- What empirical methods are necessary to describe a learning progression that is episodic in nature?

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### Methods

- **Participants**
  - 6 elementary teachers & their students
  - 2 middle school teachers & their students

- **Curriculum Modules**
  - Motion (3rd and 4th grade)
  - Electricity and circuits (4th grade)
  - Water cycle (5th grade)
  - Ecology (6th grade)

- **Data Sources**
  - Classroom video from module implementations
  - Field notes
  - Classroom artifacts
  - Additional classroom video at teachers' discretion

- **Data Analysis**
  - Review data sources for evidence of student C-S.

- **Evidence of Coherence Seeking (C-S)**
  - Looking for Consistency:
    - Identify an inconsistency, request or offer reconciliation for an inconsistency, indicate that a result or observation is unexpected
  - Looking for Meaningful Relations:
    - Request or identify a meaningful relationship between ideas, identify an unexplained phenomenon, offer reconciliation of an inconsistency

- **Identify contextual features that facilitate/impede C-S, and other inquiry aspects linked to students’ C-S.**

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**Extended Example: Raphael and the Cold Clouds**

In response to Raphael's question about clouds being cold, students enter into period of relatively stable engagement* in coherence seeking:

Raphael: And also, I know this is kind of off our main question but, I just thought like since the the clouds are so high, high up and it’s cold, and the sun, and they’re closer to the sun than we are, why is it cold? [identify inconsistency]

Nick: Um, actually, might because the atmosphere and the cloud cover um that it won’t be—that it could get cold. And um, the sun probably isn't right where we are at that point. It could be somewhere else around the Earth. [offer reconciliation]

Raphael: Yeah but they’re still freezing. And it’s still freezing above the Earth with or without the clouds. (Student: okay) So why? I mean cuz the sun is right there closer and we still have the hottest days when the clouds are sitting up there freezing. [request reconciliation]

Evan: That’s because of the sun rays are straight (Raphael: What?) when it’s hot. [offer reconciliation]

Dante: Yeah, because the sun rays are straight they’re hotter. When they’re diagonal they’re cooler. [offer reconciliation]

Louis: Well in space, even if you’re facing the sun it’s freezing. (To Raphael) Why do you think that? It’s closer to the sun. [identify inconsistency]

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*2 ½ minute excerpt taken from a 5th grade water cycle module discussion.