How Can the History and Philosophy of Science Contribute to Contemporary U.S. Science Teaching

Friday, 07 December 2012

Sponsored by the National Science Foundation’s Division of Research on Learning in Formal and Informal Settings under REESE grant 1205273. 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.

Organized by the School of Education and the Center for Philosophy and History of Science at Boston University.

All slides are copyright the author(s). Please contact the author(s) directly for further information and permissions.
Can Science Studies Help Shift Teachers into a More Sophisticated View of Learning? Toward an R & D Agenda

John J. Clement
U. of Massachusetts, Amherst

This material is based upon work supported by the National Science Foundation under Grants DRL-1222709 and DRL-0723709, John J. Clement, PI. Any opinions, findings, and conclusions or recommendations expressed in this presentation are those of the author and do not necessarily reflect the views of the National Science Foundation.
Questions

• **Problem:** Many teachers and trainees do not understand:
  – Central role of explanatory models in science
  – How complex model construction occurs as a progressive cycle of generation, evaluation, and modification
  – How learning can depend on the student’s prior knowledge resources

• How can we find transparent visual images of such learning processes to discuss with teachers that are:
  – Memorable
  – Simple
Think Aloud Studies of Science Experts

What Processes Do Experts use in Scientific Model Construction?
Spring Problem
General Model Development Pattern as a Learning Process

Can HPS/Science-Studies Help Shift Teachers to a More Sophisticated View of Learning?

MODEL DEVELOPMENT IN THEORIES OF THE SOLAR SYSTEM

**PRIOR KNOWLEDGE SOURCES**
- Aesthetic Symmetry of Circle

**DEVELOPING MODELS**
- **Ptolemy:**
  - Earth Centered Crystalline Spheres w. Epicycles
  - Explained by Planets Wander
  - Discounts Comets Pass Through Spheres

- **Copernicus:**
  - Heliocentric: Circular Orbits w. Epicycles
  - Conflicts with Light Analogy to Sun's Force Decreasing w. Distance
  - Discounts Mercury and Venus Stay Near Sun in Sky
  - Explained by Galileo: Moons of Jupiter, phases of Venus

- **Kepler:**
  - Ellipses; Force from Sun Moves Planets

**EMPIRICAL CONTRIBUTIONS**
- Magnetism analogy constructed analogy

Themes
- Progressive Sequence of Partially Correct Hypothesized Models
- Cycle of Generation, Evaluation, and Modification
- Cycle Fed by both Empirical Contributions and Rationalistic Prior Knowledge Sources
Model Development in 7th Grade Unit on Lungs

S = STUDENT
T = TEACHER

G = Model Generation
E = Model Evaluation
M = Model Modification

ANALOGIES AND PRIOR KNOWLEDGE RESOURCES
S: HIGHWAY WITH ROADS BRANCING
T: GRAPES

EVOLVING EXPLANATORY MODEL
AIR
HEART

Dissonance

OBSERVATIONS, SOME DISSONANT
T: WHY DO LUNGS HOLD YOUR DEEP BREATH?
S: MEASURE LARGE VOLUME OF LUNGS
S: PIG'S LUNGS OBSERVATIONS
**Initial Model Generation**

- **Student Ideas:**
  - Lung, trachea, cells, blood vessels, circular cavities, air in hollow part

**Student Model Modification**

- Student: Close it up!

**Completes Teacher's Analogy**

- S: In capillaries it seeps through the walls...so why can't it do that in the lungs!!!

**Student Analogy Driven Modification**

- S: Analogy to grapes on vines

**Student Model Modification**

- S: They have little holes that the oxygen goes through...the blood vessels are running by...little attachments

**Extension of Applicability of "Seeping" to Air-Blood Exchange:**

- S: The oxygen didn't go through passages—it just seeped through the walls [of the round cavities]

**Student Modifies & Combines Elements in Final Model**

- Student individual drawing

---

**1 Hole at Bottom of Hollow Lung**

- **Dissonance:** You have this space that all the air can sink out of, what do you want to do about that?

**2 Closed Lung with some Vessels in Walls**

- **Dissonance:** Wasted space in middle of lung; T: Vessels throughout lung; T: Analogy to oxygen diffusion from vessels to toe cells;

**3 Vessels Throughout 2 Lungs**

- **Gap:** There are little round cavities in the lung. How can air get to the cavities?

**4 Branching Tubes to Capillaries**

- **Gap:** Can you put those little round things and the oxygen together in any way?...Somebody said that there is all these veins out here.

**5 Attachments from Cavities to Blood Vessels**

- **Dissonance:** Blood vessels close to the intestine analogy

**6 O2 Seeps from Cavities Adjacent to Vessels**

- **Dissonance:** Grape and string model/analogy; animation of O2 diffusing to blood cells

**7 Final Model**

---

**TEACHING STRATEGIES**

- **Discrepant Question:**
- **Analogy:**
- **Request for Explanation:**
- **Teacher Input:**
- **Request for Explanation:**
- **Analogy:**
- **Group Builds Physical Model:**
- **Sees Animation**
Can HPS/Science-Studies Help Shift Teachers to a More Sophisticated View of Learning?

Themes
- Progressive Sequence of Partially Correct Hypothesized Models
- Cycle of Generation, Evaluation, and Modification
- Cycle Fed by both Empirical Contributions and Rationalistic Prior Knowledge Sources
There are many possible avenues of applying HPS/Expert Studies findings to education. The avenue I happen to be working on is in row 3.

J. Clement, 10/10/12
Can HPS/Science-Studies Help Shift Teachers to a More Sophisticated View of Learning?

Draft of Research Agenda

1. Find Clearest Accessible HPS / Science Studies Examples of Model Construction
2. Analyze Key Embedded Constructivist Elements in Model Development Trajectory
3. Develop Transparent Representations of Learning Process
4. Design Professional Development Activities Using These Materials
5. Do Initial Prof. Development Trial with Formative Evaluation
6. Do Larger Trials with Formative and Summative Evaluation
Adapted from:

"I think the charge is just getting changed into heat in the light bulbs"

"Charge is like energy"

"That something's moving and they moved the same"

"It would get less hot"

Electric Charge can be converted to heat by light bulbs

and Electric Charge is a type of energy

Compass deflection indicates same movement

Subsequent Bulbs would be cooler due to less charge flow

"So, here's the big question - how do bulb filaments, the thing that glows, influence moving charge?"

"But is heat the same as charge?"

"What did the compass needle tell you was.. the rate of change movement through these wires?"

"If charge is being changed into heat, what would you see..as you moved further..in the circuit?"
6) Student Statements:
"The more filaments there are, it's the same amount of electricity flowing through the wires but they're in more filaments, so each bulb is going to be dimmer."

"Yes"

"I think the charge is just getting changed into heat in the light bulbs"

"Charge is like energy"

"That something's moving"

"They moved the same"

5) Evolving Explanatory Model:
"Electricity" is a constant quantity that gets divided among "users" in a circuit.

Electric Charge can be converted to heat by light bulbs

Electric Charge is a type of energy

Compass deflection indicates movement within circuits

The movement of "something" is uniform throughout series circuits

4) Teacher Statements:
"So, here's the big question - how do bulb filaments, the thing that glows, influence moving charge?"

"Okay. I see... So each bulb is getting less than what it got before?"

"Okay, yes?" (responds to a student who wishes to speak)

"That's probably true. But is heat the same as charge?"

"Does charge get changed into heat?.."

"When you tested the wires in section one, what did the compass needle tell you..?"

"Something's moving. But what else?" (draws a diagram of the circuit on the board)

"You had a compass under this wire, one under this wire, and one here. What did you notice about all three wires?"

3) Teacher Moves - Dialogical Level:
- Paraphrases student statement to clarify
- Seeks input to the model from another student
- Supports student contribution with partial agreement
- Repeats student response & requests additional input

2) Cognitive Teacher Moves - Micro Level:
- Requests Explanation
- Requests Concept Differentiation
- Requests Concept Differentiation
- Requests Discrepant Result
- Requests Patterns in Observations

1) Cognitive Teacher Moves - Macro Level:
- G Model Generation
- M Model Modification
- E Model Evaluation
- O Observations
Three Nested Levels of Processing in Experts

Model Evolution in an Expert

Prior Knowledge Contributions

Evolving Explanatory Model

Thought Experiments or New Observations
1. Hole at Bottom of Hollow Lung

2. Closed lung with some Vessels in Walls

3. Vessels Throughout 2 Lungs

4. Branching tubes to capillaries

5. Attachments from cavities to blood vessels

6. O2 Seeps from Cavities Adjacent to Vessels

7. Final Model

Dissonance

Gap

Dissonance

Gap

Dissonance

Dissonance

You have this space that all the air can sink out of, what do you want to do about that?

Wasted space in middle of lung; T: Vessels throughout lung

T: Analogy to oxygen diffusion from vessels to toe cells;

There are little round cavities in the lung. How can air get to the cavities?.. Can you put those little round things and the oxygen together in any way?...Somebody said that there is all these veins out here.

Blood vessels close to the intestine analogy

Grape and string model/analogy; animation of O2 diffusing to blood cells

Discrepant Question

Request for Explanation;

Analogy

Teacher Input;

Request for Explanation

Request for Explanation

Analogy

Group Builds Physical Model;

Sees Animation
HPS / Expert Studies

Ed Theory for Teachers

New Teaching Technique

Student Outcomes

Analyzed Learning Processes

Image of Science Learning Processes: e.g. Model Construction

Model Generating Discussions, Experiments

Conceptual Understanding