Metacognition as Means to Increase the Effectiveness of Inquiry-Based Science Education

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Why Inquiry?
Teaching Science as Inquiry
Why Metacognition?
Teaching Science as Inquiry–Aquatic Professional Development
Implementation of Metacognition in Professional Development
Preliminary Results
Implications

State of Education

Of Every 100 9th Graders in Hawaii...

Hawai‘i State Assessment: Science

<table>
<thead>
<tr>
<th>Proficiency</th>
<th>Grade 4 N = 14,489</th>
<th>Grade 8 N = 12,719</th>
<th>Grade 10 N = 11,852</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exceeds</td>
<td>8%</td>
<td>5%</td>
<td>3%</td>
</tr>
<tr>
<td>Meets</td>
<td>36%</td>
<td>26%</td>
<td>19%</td>
</tr>
<tr>
<td>Approaches</td>
<td>44%</td>
<td>41%</td>
<td>46%</td>
</tr>
<tr>
<td>Well Below</td>
<td>11%</td>
<td>28%</td>
<td>32%</td>
</tr>
<tr>
<td>Not Meeting</td>
<td>55%</td>
<td>69%</td>
<td>78%</td>
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</tbody>
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Lack of Scientific Literacy

- 77% of Americans can not explain what it means to study something scientifically
- 75% of Americans hold a pseudoscientific belief

Inquiry–Part of the Solution

- 58 students aged 14–16 years in two groups
- Same teacher
  1. Inquiry group
  2. Other group teaching guided by national teacher survey data
- Inquiry-based group = significantly higher levels of achievement
  - Consistent across a range of learning goals
    - knowledge, reasoning, and argumentation
  - Consistent across time frames
    - immediately following the instruction and four weeks later
  - Positive gains across race

Study by Wilson et al., 2010, Journal of Research in Science Teaching

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What is inquiry?

Inquiry became a buzzword, loaded with misconceptions

- Open-ended discovery all the time
- Must be hands-on
- Experiments all the time
- Minimizes role of teacher
- Does not include lecture

Leading teachers to believe inquiry cannot be done with:

- Large classes
- Short class periods
- ELL or SPED students
- Elementary or college students

And cannot be done without:

- Lots of materials
- Mayhem

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What is inquiry?

Teaching Science as Inquiry (TSI)

- Grew out of the need to re-define inquiry

Definition of Inquiry

- No one correct way to define
- Rooted in science as a discipline
  - Authentic practice of science
  - Science practiced in many different ways

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TSI Theoretical Framework

Phases of Inquiry

- Multi-directional learning process
- Based on constructivist learning theory
- Building knowledge rather than memorizing facts
- Process vs. Product
Phases of Inquiry

- Process
- Reporting

Cycle of Learning & Teaching

Scientific Method
- Question
- Hypothesis
- Experiment/Results
- Conclusion
- Communication

Lab Reports
Publications

Modes of Inquiry

- Ways of carrying out scientific processes, different operations

- Curiosity
- Description
- Authoritative knowledge
- Experimentation
- Product Evaluation

- Technology
- Replication
- Transitive Knowledge
- Induction
- Deduction

Implementing TSI

- TSI framework provides common language to describe scientific process
  - helpful in building community
  - metacognitive tool
- Metacognitive approaches can promote science literacy by improving concept durability from school to outside the classroom (Ormrod, 2011)

Metacognition

- “the process of reflecting on and directing one’s own thinking” (National Research Council, 2001)
- involves both awareness and control

Metacognition and Learning

- Self-regulation—“expert” students have better self-regulation
- Motivation—active learning is more effective and enjoyable
- Complex process
  - Multiple steps
  - Iterative


TSI Aquatic Professional Development Structure

Workshop 1
Introduction & Physical Aquatic Science
Pedagogical foundation module

Workshop 2
Chemical Aquatic Science

Workshop 3
Biological Aquatic Science

Workshop 4
Ecological Aquatic Science

Online Follow-up
Interactive Online Learning Community
Face to Face Follow-up
Module 1 Focuses

- **Teaching Science as Inquiry (TSI) focus:**
  - Begin to build an understanding of disciplinary inquiry as a process
  - Use TSI phases and modes to reflect and become more metacognitive

- **Content focus:**
  - Investigate the influence of density, wind, waves, tides and the ocean floor on global ocean circulation

- **Themes:**
  - Community
  - Science as a human endeavor

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**Soda & Scientific Reasoning**

**Activity Goal**

- Use your metacognitive skills while engaging in the practices of science

**This activity:**
- Is open-ended
- Initiates a new concept
- Has multiple pathways to knowledge generation
- Avoids front-loading too much content

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**Water density: Station Rotations**

**Activity Goals**

- Use your metacognitive skills to think about how your learning experience is impacted by the design of the activity
- Focus on PROCESS vs. content.

**This activity:**
- Was designed for adults
- Demonstrates how there are multiple pathways to generate knowledge

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**TSI as tool to examine fine-scale acquisition of knowledge**

- phases have no prescribed sequence or path
- diagramming highlights unique cognitive paths even when engaged in same activity

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**TSI Professional Development Cohorts**

- **Kaua‘i** ★2012-13
- **O‘ahu** ★2010-12 ★2012-13
- **Maui** ★2011-12
- **Hawai‘i** ★2011-12

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**TSI as tool to examine fine-scale acquisition of knowledge**

- Connect thinking with thoughts and actions
- Demonstrate multi-directional scientific process
**Scaffolding Metacognition: Classroom Implementation**

<table>
<thead>
<tr>
<th>Module</th>
<th>Activity</th>
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<tbody>
<tr>
<td>1</td>
<td>Use TSI phase diagram as reflection tool to infer students metacognitive processes</td>
</tr>
<tr>
<td>2</td>
<td>Narrative descriptive phase diagram using TSI language</td>
</tr>
<tr>
<td>3</td>
<td>Teach TSI phases to students using metacognitive activity</td>
</tr>
<tr>
<td>4</td>
<td>Plan lessons using TSI phases, repeat metacognitive activity to review phases and teach modes</td>
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</tbody>
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**Preliminary Results**

- Concept of metacognition new for many teachers
- Concept of metacognition helped create a community of teachers focused on bettering their teaching practice
- Teaching metacognitive strategies using TSI best approached with patience, effort, and repetition
- Context, e.g. aquatic science, is needed to generate the thought processes necessary for metacognitive reflection.

**Preliminary Results: Reflective TSI phase diagram**

Allowed teachers to:
- Demonstrate their understanding of the non-linear process of science
- Critically observe their students process of knowledge acquisition

**Preliminary Results: TSI reflections**

Evidence that teachers:
- Became less thoughtful in their reflections over time
- Had lingering misconceptions about TSI philosophy

**Preliminary Results: Student TSI Metacognition Activity**

- Many teachers and students initially had trouble with activity
- Some teachers circumvented intent of activity
- Teachers that supported student understanding:
  - Taught TSI words as science vocabulary words
  - Shared their own reflective TSI phase diagrams
  - Allowed students to work together
- Repeating activity was beneficial

**Modifications Implemented in TSI Aquatic PD**

- Increased time spent on TSI vocabulary and feedback
- Reduced reflective diagramming requirements in favor of focusing more on using TSI to plan
- Moved student metacognitive activity to earlier in the PD sequence
- Adapted subset of statements from Metacognition Awareness Inventory (MAI) and added these to pre & post PD instruments for both teachers and students (Schraw & Dennison, 1994)
Summary & Implications

• Results indicate use of TSI as tool to teach metacognitive strategies improved understanding of the scientific process and ability to actively engage in the process using metacognition.

• TSI gave teachers and students common language to become aware of, communicate, and reflect on the process of science.

• Metacognition valuable addition to teacher PD and classroom instruction.

• Teachers need to be supported in their metacognitive development.

Mahalo!