Effects of the Teaching Science as Inquiry (TSI) Aquatic Professional Development Course for Middle- and High-School Teachers

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Teaching Science as Inquiry (TSI)

TSI grew out of need to define inquiry (Duncan Seraphin & Baumgartner, 2010)

- Inquiry difficult to define, and can be hard to understand

TSI philosophy

- In order to increase scientific literacy, science should be taught and learned as it is practiced within the discipline of science
- Students learn science by engaging in the authentic process of science

TSI Pedagogical framework articulates what inquiry is and how inquiry can be defined
TSI Pedagogical Framework

- Captures nature of science by emphasizing relationship between process and content
- Explicit instruction on interconnected components of inquiry allows teachers to access the scientific process and provides a structure to implementing inquiry in the classroom
- Common language to describe scientific process
Both a learning and instructional cycle

Multi-directional, no prescribed sequence or path, captures what actually happens during a scientific inquiry

Instruction, or communication, influences the other phases. This creates an environment where the teacher acts as a research director and is not the sole source of knowledge in the classroom

Tool to examine fine-scale acquisition of knowledge
TSI: Modes of Inquiry

10 modes: Reflect variety of ways to do scientific inquiry and the multiple approaches to knowledge generation

- Curiosity
- Description
- Authoritative Knowledge
- Experimentation
- Product Evaluation
- Technology
- Replication
- Induction
- Deduction
- Transitive Knowledge
Aquatic Science Content

- Water is critical to our survival
  - 72% of the surface of the planet is water
  - 50-75% of our bodies are composed of water
  - Impacts everything from weather and climate to economics and tourism

- Using aquatic science as a cohesive umbrella under which various content from different disciplines can be taught enhances inquiry understanding and allows for deeper understanding of the scientific process. (National Research Council, 2012)

- Content guided by the Ocean Literacy Principles (College of Exploration, 2008)
TSI Aquatic PD Goals

1) Increase teachers’ content knowledge in aquatic science

2) Improve teachers’:
   - understanding of scientific inquiry,
   - pedagogical content knowledge needed to create classrooms that function as a community of scientists, and
   - self-efficacy in using TSI pedagogy.

3) Improve student content knowledge and nature of science knowledge
TSI Aquatic
Accessible Professional Development Structure

- Introductory Meeting
- Online Follow-up
- Interactive Online Learning Community
- Workshop 1: Introductory & Physical Aquatic Science
  Pedagogical foundation module
- Workshop 2: Chemical Aquatic Science
- Workshop 3: Biological Aquatic Science
- Workshop 4: Ecological Aquatic Science
- Face to Face Follow-up

- 4 Modules embedded in and connected through asynchronous interactive online learning community
- In each module teachers have to implement a minimum of 3 activities
### TSI Aquatic PD Focus, Themes, and Content

<table>
<thead>
<tr>
<th>Module</th>
<th>TSI Aquatic focus</th>
<th>Themes</th>
<th>Content</th>
</tr>
</thead>
</table>
| Module 1 Physical | Begin to build understanding of disciplinary inquiry as a process  
Use TSI phases and modes to reflect and become more metacognitive | Metacognition  
Community  
Science as a human endeavor | Investigate the influence of density, wind, waves, tides and the ocean floor on global ocean circulation |
| Module 2 Chemical | Further understanding of disciplinary inquiry through the TSI phases and modes  
Guide students through the TSI phases to enhance learning | Observation and inference  
Modeling science | Build an understanding of the water molecule and the unique properties of water |
| Module 3 Biological | Guide students through the phases and modes of inquiry using TSI inquiry questioning strategies | Scientific language  
Questioning strategies | Explore aquatic diversity, focusing on structure, function, and the evolutionary connections between organisms |
| Module 4 Ecological | Further understanding of disciplinary inquiry by becoming familiar with the TSI practices of inquiry teaching and transferring TSI pedagogy to your own lessons | Connections | Apply physical, chemical, and biological principles to the investigation of an aquatic environment |

Module structure enables scaffolding of inquiry pedagogy and content and allows assessment of inquiry understanding over time.
TSI Professional Development Cohorts

- Kaua’i ★ 2012-13
- O’ahu ★ 2010-12 ★ 2012-13
- Maui ★ 2011-12
- Hawaiʻi ★ 2011-12

2012-2013 cohorts were pilot test of PD
Research Plan and Design

- **Years 1–2 (2010-2012):**
  - Developed, pilot-tested, and validated instruments with Cohorts I-III.
  - Provided formative evaluation feedback to PD developers.
- **Year 3 (2012-2013):**
  - Conducted a study of the pilot version of the PD using a pre/post within-participants design.
Instrument Foci

1. Teacher background (questionnaire)
2. Professional development activities (observations and a teacher questionnaire)
3. Teacher outcomes (two teacher assessments, questionnaires on pedagogical content knowledge, meta-cognition, and self-efficacy, and an interview)
4. Classroom implementation of TSI (observation, a teacher log, and a teacher interview)
5. Student outcomes (one content assessment and one nature-of-science assessment)
Data Collection

Pre

Teacher questionnaires and a classroom observation

Teacher assessments and questionnaires
Student assessments

Teacher background questionnaire

Teacher interview

Post
Data Collection in Each Module

Module 1

Mod 2

Mod 3

Mod 4

Lesson logs
Questionnaires

Teacher content assessment

Pre

Post

--Repeated each module--
The Research Topics Addressed in This Poster

- Pre-post changes in teacher outcome variables
- Extent to which teachers’ (a) prior experience, knowledge, and pedagogical practice and (b) program implementation variables affected student outcomes
Teachers’ Background ($N = 28$)

- **Grade Level**
  - Elementary School ($n = 2$)
  - Middle School ($n = 15$)
  - High School ($n = 11$)

- **Subjects Taught**

- **Majors**
  - Science: ($n = 14$)
  - Education: ($n = 9$)
  - Other: ($n = 5$)

- **No. Years Teaching Science**
  - 1–2 ($n = 6$)
  - 3–4 ($n = 2$)
  - 5–6 ($n = 3$)
  - 7–8 ($n = 3$)
  - 9–10 ($n = 4$)
  - > 10 ($n = 10$)
Analyses

- Descriptive teacher and student statistics
- Paired $t$-test on each teacher outcome
- Multilevel model on each of the two student outcomes
  - time (pre to post) nested within students nested within teachers’ classes
# Teacher Outcome Descriptive Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Time</th>
<th>N Items</th>
<th>M (SD)</th>
<th>Cronbach’s α</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedagogical Content Knowledge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pre</td>
<td>36</td>
<td>3.84 (0.36)</td>
<td>.87</td>
<td></td>
</tr>
<tr>
<td>post</td>
<td>36</td>
<td>3.93 (0.36)</td>
<td>.92</td>
<td></td>
</tr>
<tr>
<td>Self-efficacy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pre</td>
<td>15</td>
<td>3.52 (0.99)</td>
<td>.97</td>
<td></td>
</tr>
<tr>
<td>post</td>
<td>15</td>
<td>4.79 (0.67)</td>
<td>.96</td>
<td></td>
</tr>
<tr>
<td>Metacognition in Teaching</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pre</td>
<td>10</td>
<td>4.37 (0.42)</td>
<td>.86</td>
<td></td>
</tr>
<tr>
<td>post</td>
<td>10</td>
<td>4.48 (0.65)</td>
<td>.89</td>
<td></td>
</tr>
</tbody>
</table>

Note. Results are from the 28 teachers (15 on Oahu and 13 on Kauai) who completed the project.

*a* Response categories ranged from 1 (never) to 5 (always) (Hedges’ *g* = 0.24, *p* = .21).

*b* This questionnaire was administered in a retrospective pre-post design. Response categories ranged from 1 (low ability) to 6 (high ability). The pre-post mean difference was significant (Hedges’ *g* = 1.50, *p* < .01).

*c* Response categories ranged from 1 (strongly disagree) to 5 (strongly agree) (Hedges’ *g* = 0.18, *p* = .38).
# Teacher Content Assessment Results

<table>
<thead>
<tr>
<th>Instrument</th>
<th>N Teachers</th>
<th>N items</th>
<th>M&lt;sup&gt;a&lt;/sup&gt;</th>
<th>SD</th>
<th>KR-20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module 1 Pre</td>
<td>31</td>
<td>29</td>
<td>19.39 (67%)</td>
<td>5.33</td>
<td>.83</td>
</tr>
<tr>
<td>Module 1 Post</td>
<td>31</td>
<td>29</td>
<td>22.68 (78%)</td>
<td>4.58</td>
<td>.82</td>
</tr>
<tr>
<td>Module 2 Pre</td>
<td>29</td>
<td>38</td>
<td>25.14 (66%)</td>
<td>7.15</td>
<td>.87</td>
</tr>
<tr>
<td>Module 2 Post</td>
<td>29</td>
<td>38</td>
<td>30.10 (79%)</td>
<td>5.88</td>
<td>.86</td>
</tr>
<tr>
<td>Module 3 Pre</td>
<td>28</td>
<td>36</td>
<td>19.71 (55%)</td>
<td>5.62</td>
<td>.80</td>
</tr>
<tr>
<td>Module 3 Post</td>
<td>28</td>
<td>36</td>
<td>24.00 (67%)</td>
<td>5.58</td>
<td>.81</td>
</tr>
<tr>
<td>Module 4 Pre</td>
<td>28</td>
<td>32</td>
<td>15.25 (45%)</td>
<td>4.39</td>
<td>.66</td>
</tr>
<tr>
<td>Module 4 Post</td>
<td>28</td>
<td>32</td>
<td>19.96 (59%)</td>
<td>4.90</td>
<td>.75</td>
</tr>
</tbody>
</table>

*Note. All pre-post differences were significant (p < .0001).*

<sup>a</sup>Percents are percent-correct scores.
### Student Nature of Science and Content Assessments Results

<table>
<thead>
<tr>
<th>Instrument</th>
<th>N students</th>
<th>M</th>
<th>SD</th>
<th>Min, Max</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOS Pre&lt;sup&gt;a&lt;/sup&gt;</td>
<td>578</td>
<td>0.95</td>
<td>0.86</td>
<td>-1.14, 5.01</td>
<td>.89</td>
</tr>
<tr>
<td>NOS Post&lt;sup&gt;a&lt;/sup&gt;</td>
<td>440</td>
<td>1.07</td>
<td>1.05</td>
<td>-1.14, 3.77</td>
<td>.84</td>
</tr>
<tr>
<td>Content Pre&lt;sup&gt;b&lt;/sup&gt;</td>
<td>578</td>
<td>-0.32</td>
<td>0.71</td>
<td>-2.15, 1.66</td>
<td>.44</td>
</tr>
<tr>
<td>Content Post&lt;sup&gt;b&lt;/sup&gt;</td>
<td>440</td>
<td>-0.04</td>
<td>0.86</td>
<td>-2.93, 4.19</td>
<td>.56</td>
</tr>
</tbody>
</table>

*Note.* Respective pre and post scores are on a Rasch-modeled logit scale after equating. Reliability was based on the IRT test-information function.

<sup>a</sup>NOS = Nature of science assessment scores, comprising 27 items (16 multiple choice; 11 Likert scale items) scored using partial-credit Rasch modeling.

<sup>b</sup>Content = Content assessment scores, comprising 17 multiple-choice items that measured knowledge of physical, chemical, biological, and ecological science concepts and knowledge.
## Teacher-Level Predictors in the Multilevel Model

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Scale</th>
<th>M</th>
<th>SD</th>
<th>Cronbach’s α</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Years Teaching Science&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0 and up</td>
<td>9.25</td>
<td>6.96</td>
<td>—</td>
</tr>
<tr>
<td>Prior Research Experience&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1 to 5</td>
<td>1.57</td>
<td>1.45</td>
<td>—</td>
</tr>
<tr>
<td>No. Science PD Courses Taken&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1 to 4</td>
<td>2.35</td>
<td>1.19</td>
<td>—</td>
</tr>
<tr>
<td>Pre Pedagogical Content Knowledge&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1 to 5</td>
<td>3.84</td>
<td>0.36</td>
<td>.87</td>
</tr>
<tr>
<td>Pre Metacognitive Practice&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1 to 5</td>
<td>4.37</td>
<td>0.42</td>
<td>.86</td>
</tr>
<tr>
<td>Pre Aggregate Content Score&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0 to 100</td>
<td>58.74</td>
<td>14.63</td>
<td>.91</td>
</tr>
<tr>
<td>Adherence&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1 to 6</td>
<td>5.03</td>
<td>0.64</td>
<td>.91</td>
</tr>
<tr>
<td>Exposure&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1 to 6</td>
<td>4.61</td>
<td>0.79</td>
<td>.89</td>
</tr>
</tbody>
</table>

<sup>a</sup>Each variable was a single item on the background questionnaire. The range of no. years teaching science was 1 to 30; the scale for prior research was 1 = very little to 5 = extensive experience; the scale for no. of science PD courses taken was 1 = 0; 2 = 1–2 courses; 3 = 3–4 courses; 4 = 5 or more courses.

<sup>b</sup>The score was based on self-report data at the start of the project.

<sup>c</sup>Assessed at the start of each module. The reliability is of the four content scores in percentage points.

<sup>d</sup>These were sets of items self-reported at the end of the project. Adherence = mean response to 4 items asking about adherence to the TSI classroom activities; exposure = mean response to 10 items asking how often they included the modes.
## Multilevel Modeling Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>NOS</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate</td>
<td>SE</td>
</tr>
<tr>
<td>Intercept</td>
<td>0.85***</td>
<td>0.08</td>
</tr>
<tr>
<td>Time(^a)</td>
<td>0.11*</td>
<td>0.05</td>
</tr>
<tr>
<td>(School Level)*Time(^b)</td>
<td>-0.06</td>
<td>0.09</td>
</tr>
<tr>
<td>(No. Years Teaching Science)*Time(^c)</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>(Prior Research Experience)*Time(^c)</td>
<td>-0.10</td>
<td>0.05</td>
</tr>
<tr>
<td>(No. Science PD Courses Taken)*Time(^c)</td>
<td>-0.20***</td>
<td>0.05</td>
</tr>
<tr>
<td>(Pre Pedagogical Content Knowledge)*Time(^c)</td>
<td>-0.11*</td>
<td>0.05</td>
</tr>
<tr>
<td>(Pre Metacognitive Practice)*Time(^c)</td>
<td>0.01</td>
<td>0.06</td>
</tr>
<tr>
<td>(Pre Aggregate Content Score)*Time(^c)</td>
<td>-0.02</td>
<td>0.06</td>
</tr>
<tr>
<td>(Adherence)*Time(^c)</td>
<td>0.12*</td>
<td>0.05</td>
</tr>
<tr>
<td>(Exposure)*Time(^c)</td>
<td>0.03</td>
<td>0.06</td>
</tr>
</tbody>
</table>

*Note.* Time was Level 1, Student was Level 2 (random intercepts and slopes), and Teacher (random intercepts) was Level 3; * = \(p < .05\); ** = \(p < .01\); *** = \(p < .001\).
\(^a\)Time was coded 0 for pre and 1 for post.
\(^b\)School level was coded -1 for elementary, 0 for middle, and 1 for high school.
\(^c\)These predictors were standardized.
Next Steps in the Analyses

- Examine the results for additional quantitative variables (e.g., adherence for each module, ratings of teachers’ understanding of inquiry).
- Examine observation results collected on a subset of the teachers.
- Examine teacher interview results
- Refine the multilevel model, if necessary
Conclusions

- Teacher pre/post-project gains in science content knowledge and self-efficacy were significant.
- Accounting for the nesting of students within teachers’ classes, student pre/post-project gains were significant in:
  - understanding of the nature of science
  - knowledge of aquatic science content
- Teachers with lower levels of prior experience and training showed significantly greater student improvement than teachers with greater levels of experience and training.
- Teachers adhering more closely to the project showed significantly greater student improvement than teachers with weaker adherence.
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