Abstract Title Page

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

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Abstract

Background:

We are completing the development and evaluation of a series of professional development (PD) modules consisting of in-person trainings coupled with online learning support. Our PD is grounded in the Teaching Science as Inquiry (TSI) pedagogical framework, which is centered on learning through authentic application of knowledge and skills (Duncan, Seraphin, & Baumgartner, 2010). The TSI framework balances content, context, inquiry, and pedagogy to create classroom settings that foster student self-regulation and intentional learning through cycles of learning and instruction. These cycles are reflected in five TSI phases, which represent different aspects of the inquiry process: *initiation, invention, investigation, interpretation,* and *instruction*. Like other learning cycles, the TSI phases are represented in a circular model (see Bybee et al., 2006). Unlike other learning cycles, TSI refutes a lockstep sequence through the cycle and promotes fluidity between the phases. In addition, instruction influences the other phases, creating an environment where the teacher acts as the leader and research director but not the sole source of knowledge in the classroom (see Figure 1).

The practices of scientists, including multiple approaches to knowledge generation and acquisition, an important aspect of disciplinary inquiry, are represented by the TSI modes (see Windschitl, Dvornich, Ryken, Tudor, & Koehler, 2007; see Table 1). Our TSI Aquatic PD supports acquisition of scientific and ocean literacy through a scaffolded set of themes, including: metacognition, science as a human endeavor, communities of learners, modeling, observation and inference, scientific language, connections, and questioning strategies (see Table 2). Promoting scientific literacy across this researched-based set of themes helps teachers teach science not only as a body of facts, but also as a dynamic, knowledge-creation process using scientific habits of mind such as critical analysis, curiosity, openness to new ideas, and inventiveness (see National Research Council, 1996). Our TSI themes also allow teachers to more easily connect with and teach inquiry-based learning, which has been associated with improving student self-regulation (Schraw, Crippen, & Hartley, 2006), such as metacognitive abilities (Dinsmore, Alexander, & Loughlin, 2008; Schraw et al., 2006).

Purpose and Objectives:

The purpose of the TSI Aquatic PD module series is to increase teachers' content knowledge in aquatic science disciplines and to improve teachers' (a) understanding of scientific inquiry, (b) pedagogical content knowledge needed to create classrooms that function as a community of scientists, and (c) self-efficacy in using TSI pedagogy. Ultimately, our goal is to improve student content and nature of science knowledge. Our PD focuses on aquatic systems to provide a cohesive set of content gained through inquiry. Learning general science through the lens of aquatic science can help students form a more complete understanding of the scientific process, as outlined in *A Framework for K-12 Science Education* (National Research Council, 2012). To guide our choice of aquatic science content we used the Ocean Literacy Principles, overarching concepts that guide K–12 teaching and learning of ocean sciences (College of Exploration, 2008). These concepts constitute the knowledge needed by someone to be considered "ocean literate" and are reflected in the Next Generation Science Standards (Achieve Inc., 2013).

The modular structure of our TSI Aquatic PD allows us to scaffold research-based inquiry pedagogy and assess teachers' inquiry understanding over time. As part of our structure,

we have developed an online curriculum website and an online learning community (OLC) that enhance the features of our TSI modules, support teachers in their use of inquiry-based practices, and create a sustained peer community. This hybrid approach, with face-to-face training combined with online extension, aligns with the recent shift in online PD from computer-based feedback towards collaborative interaction and reflection, where the best approach is a combination of face-to-face and online PD (Vrasidas & Glass, 2004). Our OLC is aimed at providing an alternative venue for the communication and collaboration, which is valued by many teachers in PD programs (see Leach, Harrison, McCormick, & Moon, 2004).

Setting:

Our PD targets science teachers of heterogeneous groups of students in middle and high schools throughout the state of Hawaiʻi. Our teachers represent a diverse ethnic student population in public, private, and public charter schools from urban and rural settings in general and special education classrooms from six islands in Hawaiʻi: The Big Island, Oʻahu, Maui, Molokaʻi, Lanaʻi, and Kauaʻi. Teachers were recruited in partnership with local education departments and organizations. Teachers were accepted on a first-come basis provided their application was complete and applicants certified their commitment to completing the entire TSI Aquatic PD course, including evaluation requirements.

Participants:

In July 2013 we will have conducted five PD cohorts, with 62 teachers and four teacher-leaders completing the program. We have collected data on 1,176 middle- and high-school students across the state. In this poster, we report on the final two cohorts because they represent the PD in its final form. These two cohorts include 346 middle-school students (in 19 teachers' classes) and 232 high-school students (in 12 teachers' classes), totaling 578 students and 31 teachers.

Intervention:

Our PD is focused on inquiry instruction in the practices of science. The TSI Aquatic course material is organized into four content modules, (a) Physical, (b) Biological, (c) Chemical, and (d) Ecological Aquatic Science. The course begins with an introductory meeting, followed by the four modules. Each module consists of a two-day workshop (16 hours), a face-to-face follow-up training (3 hours), and an online follow-up (2 hours) where teachers share results of their implementation (see Figure 2). The modules are united by TSI's unique OLC that is built into our partner curriculum website, *Exploring Our Fluid Earth* (www.exploringourfluidearth.org).

The workshop portion comprises the bulk of the TSI Aquatic PD face-to-face instruction. After each module's workshop, teachers implement a required minimum of three module-related lessons in their classrooms, totaling at least three hours of classroom instruction per module. The face-to-face follow-up provides additional instruction and peer-mentoring time for teachers. The OLC is focused on self-directed learning, interactive competence, and technology skills; the OLC includes feedback mechanisms as well as links to current events and master materials. The online follow-up meeting is the culminating activity of each module and promotes teachers' sharing of their TSI implementation with additional peer-mentoring. The four modules total more than 88 contact hours spread throughout the academic year.

Research Design:

Using a pretest–posttest within-participants design, we are investigating changes that occurred during the final two cohorts of the year-long PD. The teacher-outcome constructs under investigation are content knowledge, understanding of what inquiry looks like in the classroom, pedagogical content knowledge, and self-efficacy in using TSI pedagogy. To understand whether within-participant changes might also be explained in part by covariates, we collected background data on teacher characteristics, fidelity of implementation, and contextual influences.

In addition to teacher outcomes, we investigated students' changes in content knowledge and understanding of the nature of science. Students' Rasch-modeled scores on measures of these constructs were collected for the pre- (Fall) and post- (Spring) instruments. To account for clustered data (students in classes), we employed a multilevel-model framework and investigated relationships between teacher background variables and student gain scores. In particular, to account for teacher-level prior experience in teaching nature-of-science concepts (to strengthen the quasi-experimental design), we administered the student instruments in participating PD teachers' classes the spring prior to the start of the PD (472 non-TSI students); thus, for examining student level data in these final two cohorts, we have an estimate of how well each teacher taught nature of science concepts in a class that had not participated in the TSI Aquatic program.

Data Collection and Analysis:

We administered teacher and student questionnaires and assessments at the beginning of the academic year, before the first PD workshop, and at the end of the academic year, after the final PD workshop. To ensure high reliability and strong content and internal validity, we conducted careful instrument development procedures during the administration of the PD to the first three cohorts. This included content-expert review, revisions with content and assessment experts, and analyses of item functioning, invariance, and item bias. Posttest data collection for the final two cohorts will be complete in July 2013.

In addition to background questionnaires, interviews, and measures of teachers' fidelity of implementation, the teacher instruments included (a) four pre-post content assessments (one for each module, administered pre- and post-module), (b) the Inquiry Teaching Assessment (a constructed-response assessment of teachers' understanding of what inquiry looks like in the classroom, adapted from Schuster et al. [2007] and scored using a multi-facet Rasch modeling framework), (c) the Pedagogical Content Knowledge Scale (self reports of classroom practices, modified from Scarlett, 2008), and (d) the Self-efficacy Scale (a pre-post measure with a retrospective pretest of teachers' ability to include the TSI phases and modes in their instruction). To collect qualitative data on teachers' metacognitive and pedagogical growth, we asked teachers to write reflections on their use of the TSI phases and modes, their teaching of the TSI phases and modes to students, as well as their planning of lessons using the TSI phases and modes. The student instruments included (a) the Nature of Science Assessment (a 19-item best-answer multiple-choice test), (b) the Nature of Science Scale (a 10-item Likert-scale questionnaire (Ayala, 2004), and (c) the Student Content Assessment (a 12-item multiple-choice test of content in the four modules, administered pre- and post-module).

In analyzing the final two cohorts, we are expanding upon the methods we used for previous. With the earlier cohorts, we examined teachers' and students' change scores using paired *t*-tests. The student Nature of Science data were first Rasch-modeled to ensure unidimensionality and to permit equating across occasions with item variations. In these final two cohorts, we are examining the relationships among covariates and the teacher- and student-level change scores. To account for systematic variability due to clustering in the student data, we are using multilevel modeling of the pre- to post-PD changes within classrooms. To account for covariates that might explain growth (to better examine causality claims in the absence of a true control group), we are examining cluster-level covariates. For example, scores from the Nature-of-Science assessment with students *not* participating in the TSI Aquatic program are being included as teacher-level (the mean within the teacher's class) covariates; scores from measures of teachers' quality of implementation are being included as well.

Results:

Our poster will report findings from our final two cohorts. We will share the results of our analyses of changes in teacher's content knowledge and teachers' understanding and implementation of inquiry-based science teaching in the classroom. Because we observed statistically significant improvements in earlier cohorts' scores, and because the PD has been further refined, we expect to find similar results with our final two cohorts (which conclude July 2013). For example, we expect teacher content gains will likely be significant because earlier cohorts showed significant gains across each of the four content modules (Physical, Chemical, Biological, and Ecological aquatic science) at the .05 alpha level. Similarly, we expect significant improvements in teachers' understanding of inquiry-based teaching because with the earlier cohorts, the Inquiry Teaching Assessment pre-post gain was significant ($t = 2.25$; $p = 0.034$). Likewise, changes in teachers' self reports about their pedagogical content knowledge and about their self-efficacy were both positive and significant at the .05 level; thus, we expect similar findings for our final two cohorts.

We will also share the results of our analyses of changes in students' content and nature of science knowledge. We have evidence that earlier cohorts of students improved in their scientific process knowledge ($t = 6.38; p < .001$); thus, we expect similar changes with the final two cohorts. Furthermore, we expand upon this by examining whether clustering (students within classrooms) and contextual effects (such as teachers' prior skills in teaching the nature of science and in their degree of fidelity of implementation of the PD) explain these gains; thus, the multilevel model will shed light on whether these teacher-level covariates further explain students' gains in scores.

Conclusions:

Preliminary findings suggest that the TSI Aquatic PD has positive, significant effects on teachers' and students' scientific process knowledge. Qualitative analyses of teacher reflections and narratives also suggest that explicit instruction in metacognitive strategies to teachers and their students has increased the ability of both groups to become more aware of their observations, decisions, and thought processes needed to do and understand science. Quantitative analysis on pre-to-post effects in teachers' and students' scores suggests a robust, effective program. We believe that the TSI pedagogical structure coupled with disciplinary inquiry has the potential to effect change in the teaching of scientific process and scientific thought, with the result that students become better critical thinkers and more scientifically literate.

Appendices

Appendix A. References

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Appendix B. Tables and Figures

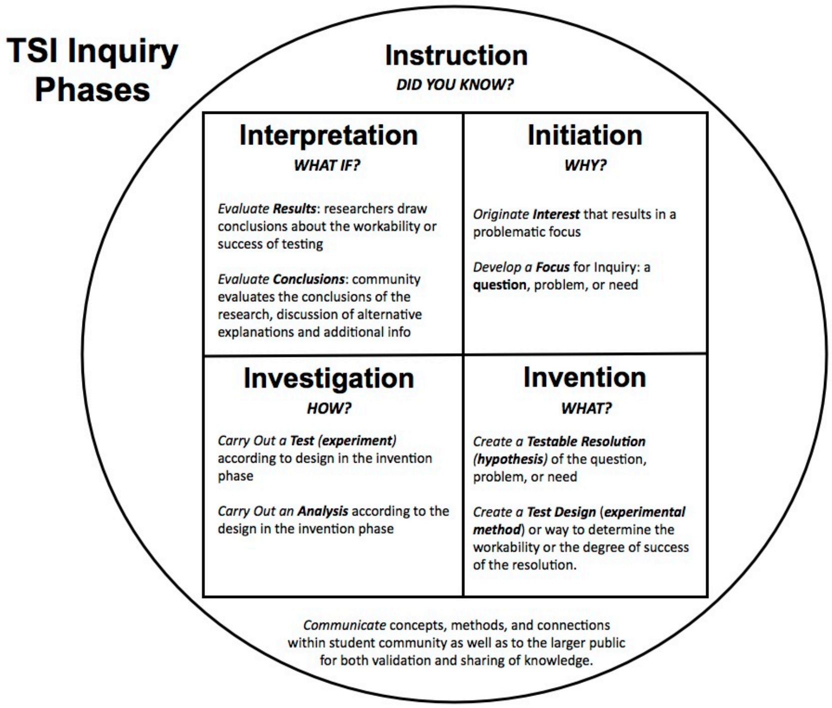

Figure 1. The TSI phase square-in-circle diagram, which lacks arrows, provides the ability for each phase to connect with each of the other phases to illustrate the interconnected nature of the five phases of inquiry. The instruction phase encircles the other phases, emphasizing the role of communication in teaching and learning through inquiry.
Note. This figure is adapted from Duncan Seraphin, Philippoff, Kaupp, & Vallin (2012).

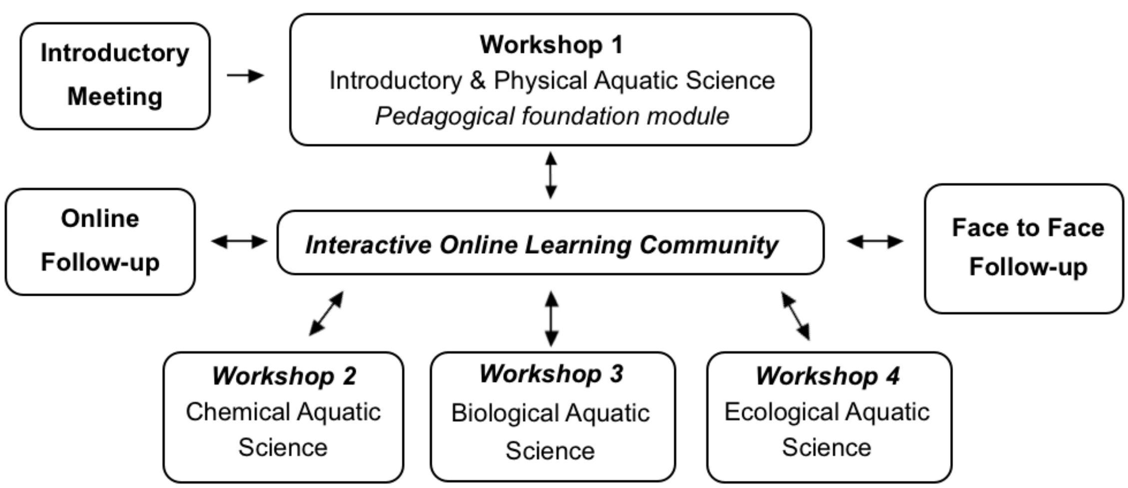

Figure 2. Structure of the four modules in the TSI Aquatic PD series, including the introductory meeting. Each module includes a two-day workshop (16 hours), a face-to-face follow-up (3 hours), an online follow-up (2 hours), and is connected by an online learning community.

Table 1. *Modes of Inquiry Addressed in TSI Pedagogy*

Mode (Inquiry learning through use of ____________)	**Description** Search for new knowledge…
Curiosity	in external environments through informal or spontaneous probes into the unknown or predictable
Description	through creation of accurate and adequate representation of things or events
Authoritative knowledge	through discovery and evaluation of established knowledge via artifacts or expert testimony
Experimentation	through testing predictions derived from hypotheses
Product evaluation	about the capacity of products of technology to meet valuing criteria
Technology	in satisfaction of a need through construction, production and testing of artifacts, systems, and techniques
Replication	by validating inquiry through duplication; testing the repeatability of something seen or described
Induction	in data patterns and generalizable relationships in data association – a hypothesis finding process
Deduction	in logical synthesis of ideas and evidence – a hypothesis making process
Transitive knowledge	in one field by applying knowledge from another field in a novel way

Note. This table is adapted from Duncan Seraphin, Philippoff, Parisky, Degnan, & Papini Waren (2012).

Table 2. *TSI Aquatic Focus, Themes, and Content by Module*

	TSI Aquatic focus	Themes	Content
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