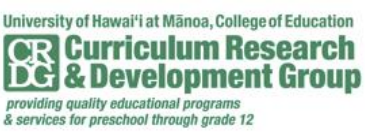
Accessible Professional Development for Teaching Aquatic Science Inquiry: Final Report

Curriculum Research & Development Group
College of Education
University of Hawai'i at Mānoa
Honolulu, Hawai'i

August 2014





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Edited by Kanesa Duncan Seraphin

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This is the final report of a project funded by the U.S. by the Institute of Education Sciences, U.S. Department of Education, through Grant R305A100091 to the University of Hawai‘i (UH) at Mānoa Curriculum Research & Development Group (CRDG), College of Education, Kanesa Duncan Seraphin, Principal Investigator (PI), Paul R. Brandon, co-PI, Thanh Truc Nguyen, co-PI. Supplementary funding was provided by the National Oceanic and Atmospheric Administration to the University of Hawai‘i (UH) Sea Grant College Program, Kanesa Duncan Seraphin, PI, Darren Okimoto, co-PI, and Darren Learner, co-PI. Authors of this final report include members of the TSI Aquatic PD project team (Duncan Seraphin and Philippoff), the learning technology team (Nguyen), and the evaluation team (Brandon, Harrison, Vallin, and Lawton). The project team developed and provided the professional development and associated materials for the PD recipients in addition to working with the learning technology team and the evaluation team. The learning technology team developed and assessed the online learning community. The research team conducted research and evaluation activities. Chapters of this summative final report were prepared by their corresponding team members. The project itself was an inquiry-based, year-long, modularized professional development (PD) for middle and high school teachers focused on aquatic science. The evaluation of the project was an eclectic, mixed-method study, which used instruments for collecting both formative-evaluation and summative-evaluation information. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education or NOAA. This research was approved by the UH committee on Human Subjects CHS # 15657.

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ACCESSIBLE PROFESSIONAL DEVELOPMENT FOR TEACHING AQUATIC SCIENCE INQUIRY: FINAL REPORT

EXECUTIVE SUMMARY

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This is the executive summary of the final report for a U.S. Department of Education Institute for Educational Sciences (IES) funded project (Grant No.R305A100091). The project was conducted by researchers and curriculum developers at the Curriculum Research & Development Group (CRDG), College of Education, University of Hawai'i at Mānoa. The project was an inquiry-based, year-long, modularized professional development (PD) for middle and high school teachers focused on aquatic science. The evaluation of the project was an eclectic, mixed-method study, which used instruments for collecting both formative-evaluation and summative-evaluation information. In this summary, we detail the purpose and goals of the TSI Aquatic PD; describe the intervention, setting, and population; and summarize key finding and outcomes.

Purpose & Goals

We developed and evaluated a series of four PD modules consisting of in-person trainings coupled with online learning support. The purpose of the module series was for teachers to become successful facilitators of scientific inquiry within the context of aquatic science, enabling them to create classrooms that function as a community of scientists—where students learn science by engaging in the practice of science. The PD modules were based on the unique Teaching Science as Inquiry (TSI) pedagogical framework. TSI, developed at the University of Hawai'i's Curriculum Research & Development Group (CRDG), emphasizes multiple modes of inquiry learning and teaching. Our PD modules were grounded in TSI and focused on aquatic science content. The goals of our project were to (a) increase teachers' content knowledge in aquatic science, (b) improve teachers' science process and pedagogical knowledge, and (c) improve student content knowledge and nature-of-science (NOS) understanding.

Intervention

Our PD focused on inquiry instruction in the practices of science. The TSI Aquatic PD material was organized into four thematic modules, including (a) physical, (b) biological, (c) chemical, and (d) ecological aquatic science. The four TSI Aquatic modules were spaced throughout the school year, resulting in a temporally accessible PD format that allowed teachers to work together in a learning cohort with sustained interaction. The modular structure of our TSI Aquatic PD project also allowed us to scaffold inquiry pedagogy and strategies over the span of a school year. In addition, the modular structure allowed us to assess teachers' inquiry understanding over time.

The course began with an introductory meeting (3 hours) followed by four modules. Each of the modules consisted of a two-day workshop (16 hours), an in-person follow-up training (3 hours), and a synchronous online follow-up (2 hours). The modules were united by our unique, asynchronous online learning community (OLC) that was built into our partner curriculum website, *Exploring Our Fluid Earth* (EOFE), which comprises updated materials from the CRDG

Living Ocean and *Fluid Earth* texts. The EOFE curriculum website was funded by a separate National Oceanic and Atmospheric Administration (NOAA) grant (exploringourfluidearth.org), and its addition to the OLC represented an additional component of the PD intervention to the project we initially proposed.

The workshop portion constituted the bulk of the TSI Aquatic PD in-person instruction. The in-person follow-up provided additional instruction and peer-mentoring time for teachers. The content portion of the EOFE site provided aquatic science curriculum (including activities and associated worksheets). The OLC component of the EOFE site (the teacher community and PD section) was designed to enhance collaboration. Together, these aspects of the website allowed teachers to utilize additional interactive competence and technological skills while enhancing locally sourced aquatic science knowledge. The online follow-up meeting was the culminating activity of each module; it also promoted collaboration as well as discussion and teachers' sharing of artifacts from their TSI Aquatic PD activity implementation. The four modules totaled 84 contact hours per teacher. We developed and implemented all four of our TSI Aquatic PD modules with each of five cohorts: Cohort 1 (Oʻahu), Cohort 2 (Maui County), Cohort 3 (Hawaiʻi Island), Cohort 4 (Oʻahu II), and Cohort 5 (Kauaʻi).

Setting & Population

Our PD targeted teachers of heterogeneous groups of students in middle and high schools throughout the state of Hawaiʻi. Our teachers represented public, private and public charter schools from urban and rural settings in general and special education classrooms. We had 75 teachers begin the TSI Aquatic PD. Of these, 69 finished the PD, and 63 completed all the PD, as well as all evaluation components of all four modules. In Cohort 1, 2010–2012, 8 of 13 starting Oʻahu teacher participants completed all the PD elements, along with four teacher leaders. Teacher leaders had TSI experience prior to the TSI Aquatic PD. They participated in Cohort 1 on Oʻahu and then served as assistant facilitators in later PD Cohorts 2 and 3. We had 2 teacher leaders from Hawaiʻi Island, 1 teacher leader from Maui, and 1 from Kauaʻi. In Cohort 2, 2011–2012, all of the 13 starting teachers from Maui and two teachers from Lanai (both of these islands are within Maui County) completed the PD portion, and only 12 of the 13 teachers completed all of the evaluation requirements. In Cohort 3, 11 out of 12 teachers from the island of Hawaiʻi completed all PD and evaluation components of all four modules. In Cohort 4, 15 of 16 teachers from Oʻahu completed all PD and evaluation components. In Cohort 5, 13 of 15 teachers from Kauaʻi completed all Oʻahu completed all PD and evaluation components.

Therefore, 51 teachers completed the TSI modules and evaluation instruments in the one-year form of the TSI Aquatic PD course. As the course was held over a single school year, these teachers had the same students in their classes throughout the PD. The number of teacher participants is three more teachers than the 48 we planned for in our project proposal. In our final iteration (Cohorts 4 and 5), 28 teachers completed the TSI PD and all evaluation components.

Key Measures & Outcomes

We successfully conducted five rounds of implementation with all four modules in our PD series as we iteratively developed, tested, evaluated, and refined our PD series. We measured the effects of the TSI Aquatic PD on the participating teachers' aquatic science content knowledge, understanding of the nature of inquiry-based science teaching, perceptions of their pedagogical practice, and implementation of the pedagogy and content of the TSI Aquatic PD. We also measured the effects on the teachers' students' understanding of the NOS and on knowledge of aquatic science content.

We developed and pilot-tested a total of 15 formal project evaluation instruments, including protocols for informally observing PD activities; a teacher background questionnaire; a post-workshop teacher questionnaire; a post-follow-up teacher questionnaire; four teacher science content assessments; an inquiry-teaching assessment; three teacher scale questionnaires (addressing pedagogical content knowledge, self-efficacy in teaching science, and metacognition

in teaching); a post-cohort teacher questionnaire; a teacher interview; a student nature-of-science assessment; and a student content assessment. Of the 15 instruments, three were used to collect data for immediate formative-evaluation feedback to the project development team, 10 were used for collecting both formative-evaluation and summative-evaluation data, and two were used for collecting summative data only.

Structurally, the amount of face-to-face time with teachers, the distribution of the PD activities throughout the year, the modular structure of the PD, and the content that was delivered in the PD were documented and observed to be implemented in the manner that the project team intended. The evaluation findings showed that the teachers perceived the PD to be valuable and relevant to their teaching practice—particularly the science content and the community building features of the PD. There were diverging opinions among the teachers about the value of the TSI pedagogical features. In terms of the EOFE curriculum and OLC website, teachers reported that they would continue to use the EOFE site after the PD for course activities and curriculum content and that they would continue to use the OLC aspect of the website to interact with each other. About half of the teachers (16 out of 28 in the final two cohorts) have continued to use the EOFE site, but only one has posted to the OLC.

With the caveat that we assume growth would not have occurred due to maturation in non-PD conditions, the teachers' self-reports on the three teacher scales suggested that the PD helped them improve on all three measures: pedagogical content knowledge for teaching science (effect size = 0.24, $p = .21$), self-efficacy in teaching science through the process of inquiry (effect size = 1.50, $p < .01$), and metacognition in teaching (effect size = 0.18, $p = .38$). Among these three, the strongest gain was in teachers' self-efficacy; gains in the other two were meaningful but not statistically significant. For the most part, there was a consistent perception among the teachers that the PD was helpful in improving their ability to teach the science content, but some teachers explained in the interview that they found parts of the pedagogy to be difficult to implement in their classrooms.

These findings suggested several possible conditions that might need to be considered in future TSI Aquatic PD if the objective is to make the pedagogy aspect of the PD accessible to all teachers: (a) participating teachers may need more time with the pedagogy before being expected to fully implement it in their classes; (b) teachers may need more scaffolding with the pedagogy in the early stages of the PD (which some teachers suggested in the interviews); (c) the pedagogy might need to be adjusted to better suit some grade levels; and (d) some features of the pedagogy, such as the call for explicit teaching of the TSI phases of inquiry to students, may need to be refined or altered.

The teachers' gains in the aquatic science content knowledge assessments were unambiguously positive. Their four module-level assessments were consistently significantly higher in the post-test than in the pre-test (effect sizes ranged from 0.66 to 1.01; all $p < .01$). Although we could not be certain that the teachers did not consult their materials when taking the posttest, the significant improvements provide a testament to the PD's success in delivering content that was accessible to the teachers. Consistent with other findings, the teachers reported having success implementing the content aspects of the target activities in their classrooms, and the evaluation results suggested that teachers improved in the quality of their implementation of the TSI phases of inquiry as the project progressed.

Teachers also improved in their understanding of the nature of inquiry-based science teaching, as measured by the Inquiry Teaching Assessment (effect size = 1.24, $p < .01$). The substantial gains on this instrument suggested that teachers matured in their breadth and depth of knowledge about teaching science through the process of inquiry.

The findings of the student level assessments suggested that students gained in their understanding of the NOS while participating in the project (in typical classrooms, effect size = 0.13, $p < .05$). Teachers with a low baseline in pedagogical content knowledge tended to have students with stronger than average pre-to-post gains (effect size = 0.20, $p < .01$). It is

notable that the students of teachers who reported adhering more closely to the PD gained significantly more than the students in classes taught by teachers with lower adherence ratings (effect size = 0.21, $p < .01$). This supports the tentative conclusion that the PD had an effect on students' NOS understanding.

The results of the student content assessment were similar to those observed with the NOS assessment. In typical classrooms, the effect size = 0.45, $p < .01$; in classrooms with teachers adhering more to the PD, there was an added effect size of 0.25, $p < .01$. In addition, we found that high-school students did not gain as strongly in content as middle-school students (effect size = -0.34, $p < .01$). We also found that students of teachers with little prior science PD experience showed significant gains in content knowledge (effect size = 0.18, $p < .01$), suggesting that the project benefited students in contexts with teachers that had less science PD exposure. However, because of the low reliability on this component of the student assessment, more research should be conducted before making decisions about this aspect of the PD.

Summary and Future Directions

Overall, the TSI Aquatic PD project was a success. The students improved in their NOS understanding and in their content knowledge. The teachers improved in their content knowledge, their self-efficacy in teaching science, and in their understanding of teaching science through the process of inquiry. The positive accounts in the interviews and in teachers' responses on multiple instruments also suggested they perceived the PD to be valuable, relevant, and to be an overall worthwhile experience.

For future studies, we are particularly interested in further examining the finding that teacher adherence to the PD resulted in higher student gains, this has implications for determining which components of the PD were most instrumental in effecting student gains in content and NOS knowledge. We are also interested in the implications of the results that the teachers who had the lowest starting pedagogical content knowledge improved the most. This finding suggests that perhaps (a) the PD should be targeted at lower level teachers, (b) teachers should be grouped in cohorts by starting level (PD facilitators felt that content level in the PD was decreased to accommodate lower level teachers), and/or (c) the PD should be modified to more equally benefit a range of teachers' starting levels.

In addition, we are aware that there is some need for improvement in our TSI Aquatic PD. In further studies we are interested in (a) ways to improve the TSI pedagogical aspects so that they are applicable to more teachers and so that they are easier to teach to students, (b) in ways to provide better feedback to teachers over the course of the PD, (c) in ways to improve our OLC, and (d) in ways to improve and streamline our evaluation instruments. Lastly, with the new release of the Next Generation Science Standards (NGSS), we would like to better align both our content and our pedagogy with the NGSS and the context in which they will be implemented across the country as states develop their policies.

CHAPTER I
INTRODUCTION TO THE PEDAGOGY AND PROFESSIONAL DEVELOPMENT STRUCTURE

Kanesa Duncan Seraphin, Joanna Philippoff,
Lauren Kaupp, and Lisa M. Vallin

In this chapter we (the project team) describe the need for professional development (PD) in science, the importance of aquatic science, the modular structure of our PD project, and the Teachings Science as Inquiry (TSI) pedagogy. This chapter also includes project team descriptions of the TSI Aquatic Project.

Introduction

The value of inquiry science teaching and learning in K-12 education is supported by a compelling body of research that demonstrates the positive impacts of inquiry on a variety of student outcomes, including student achievement, attitudes, conceptual understanding, critical thinking, process skills, problem solving, creativity, and vocabulary (e.g., Cohen & Spillane, 1993; National Research Council, 2012; Wu & Hseih, 2006; Aulls & Shore, 2008). The results of studies by our colleagues at the University of Hawai‘i at Mānoa’s (UHM) Curriculum Research & Development Group (CRDG), for example, indicated that students participating in an inquiry-based science curriculum had higher-level cognition and science process skills when compared to students learning with non-inquiry based curriculum (see review by CRDG, 2000). The studies included in this review were conducted with the CRDG-developed middle school program in *Foundational Approaches in Science Teaching* (FAST), an award-winning curriculum, deemed exemplary for its inquiry foundation by the U.S. Department of Education Mathematics and Science Education Expert Panel (2001).

In the science education community, the movement away from “didactic lectures, extensive coverage of content, and mindless drill” (Paul, 1990, p.1) is an attempt to engender a more scientifically literate populace able to utilize scientific knowledge to successfully face life’s daily challenges (American Academy for the Advancement of Science (AAAS), 1990; National Research Council, 2012; NGSS Lead States 2013a; NGSS Lead States 2013b). While scientific knowledge is in some cases nurtured at home, overall it falls to science teachers to provide opportunities for students to participate in the full and total practice of science. As mentors of science, teachers are encouraged to “support and engage active learners in the process of doing scientific inquiry” (Barab & Leuhmann, 2003, p. 445). Although there is merit to memorization and direct instruction, the scientific inquiry promotes in-depth understanding, critical thinking and problem solving skills.

A challenge to effective science instruction through inquiry arises when teachers who lack experience with or understanding of the scientific process are expected to facilitate scientific research with their students (Wee, Shephardson, Fast, & Harbor, 2007). This

dilemma is a major challenge to effective science instruction through inquiry. A study of pre-service teachers found that even those with strong conceptual science backgrounds often lacked many of the scientific habits of mind considered necessary by science experts to effectively teach science (Zembal-Saul, Munford, Crawford, Friedrichsen, & Land, 2002). Scientific habits of mind, such as critical analysis, curiosity, openness to new ideas, and inventiveness, represent many practices we expect of scientifically literate students. However, the incorporation of these scientific habits as part of teachers' inquiry-based teaching practice is a complex endeavor that requires significant effort, practice, and attention, especially for teachers not familiar with the real-world practice of science (see Hammer, 1999).

To help science teachers implement and practice scientific inquiry, we turn mainly toward PD as a means of improving instruction in science, particularly among veteran teachers, because it can help teachers learn to teach science through the process of inquiry (Smith, Desimone, Zeidner, Dunn, Bhatt, & Rumventseva, 2007). In order to be effective, however, PD must model inquiry teaching (Supovitz & Turner, 2000; Bybee, 1993) and be connected to teachers' current classroom duties, while improving content knowledge (Cohen & Hill, 1998). Providing inquiry-based science PD helps teachers better understand and teach the process of science by building their scientific process skills (Lederman, 1992). This understanding among teachers is extremely important because, in order to affect students' understanding of the nature-of-science, teachers need to explicitly address how scientific knowledge arises from scientific practice (Sandoval & Morrison, 2003).

The need for accessible professional development

The amount of time spent on PD is positively correlated with increased use of inquiry-driven teaching, particularly among teachers without a strong science background (Smith et al., 2007). However, there is a limit to the amount of time that teachers are able to spend in PD. Furthermore, there is also a limit to the effectiveness of PD that is offered as one continuous workshop, even if that PD lasts for an extended period of time. In other words, without follow-up, even lengthy amounts of time spent in PD may not yield the desired results. Indeed, PD research indicates that sustained follow-up generates greater change in teaching practices as well as improved teacher self-efficacy (Darling-Hammond & McLaughlin, 1995).

In the current climate of year-round school calendars (with shorter summer breaks during which to participate in PD) and decreased funding for teachers to attend PD during instructional days, it is difficult for teachers to attend continuous, long-term PD training (i.e., anything longer than one week). For example, the public school system in Hawai‘i (which consists of only one district) recently adopted a modified, year-round schedule (2008). Rather than the former twelve-week summer, teachers in Hawai‘i public schools currently have a nine-week summer break (during which many teach summer school), a one-week fall break, a two-week winter break and a one-week spring break. Since the

public school system in Hawai‘i adopted this schedule, teachers have found it more difficult to dedicate consecutive blocks of time to PD. The results of a 2008 survey of approximately 1/3 of Hawai‘i Science Teachers Association (HaSTA) members (85 out of 252 members) indicated that, “assuming longer-term, intensive professional development training allows you to gain deeper understanding of new knowledge and skills but that you must balance professional development with your other duties,” respondents’ inclination to take the course was inversely proportionate to course length: 4.4%, 8.5%, 18.3%, 40.2%, and 70.0% would definitely take a consecutive two-week, one-week, three-day, two-day, and one-day course, respectively. Similarly, 55.0% and 28.7% were unlikely to take a consecutive two-week or one-week course (Duncan, 2008). Although the sample size of this survey was relatively small, the respondents were likely to come from of a group of highly motivated teachers, suggesting that even the most engaged teachers are reluctant to devote extended, consecutive blocks of time for PD experiences.

Creating a synergy between accessibility, depth and sustained interaction

In response to the disjunction between the research-based effectiveness of long-term PD and teachers’ lack of time to participate in PD, we developed a year-long, place-based aquatic science TSI PD that enables teachers to teach aquatic science concepts through the disciplines of physics, chemistry, biology, and ecology. We worked to refine the structure of the PD over the course of implementation across five cohorts. Our initial PD program consisted of four modules, with each module consisting of an intensive two-day training workshop, extended online activities and support, and a three-hour in-person follow-up training session (Year 1 Cohort 1, Figure I-1).

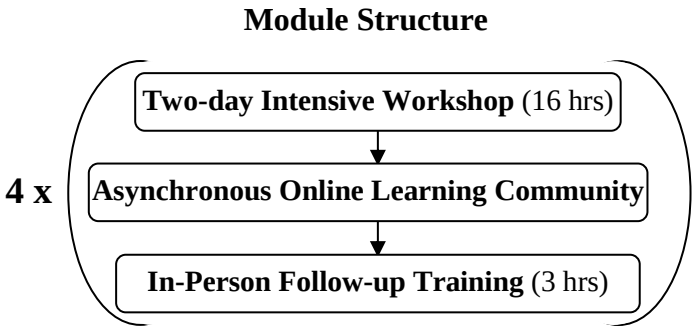

Figure I-1. Structure of modules in PD series during the first half of Cohort 1, Year 1.

However, the three-hour time limit (5–8pm) of the in-person follow-up did not allow enough time for us to both extend the theme of the module, with additional content and activities, while also providing teachers with the time to interact and share their implementation. As a result, we modified the PD structure during Year 2 to include both an in-person follow-up training (where teachers could interact, peer-share and learn content) as well as an online face-to-face, synchronous follow-up (where teachers could

formally share their classroom experiences. This was implemented for the second half of Cohort 1 and Cohorts 2 and 3, Figure I-2). For Cohorts 2 and 3, the in-person follow-up training was held in teachers' classrooms (For Cohort 2, Maui, one teacher per module would volunteer to host the follow-up. For Cohort 3, Hawai'i Island, two teachers per module volunteered to host follow-ups as we held two follow-ups per module due to the large geographic spread of the teachers.)

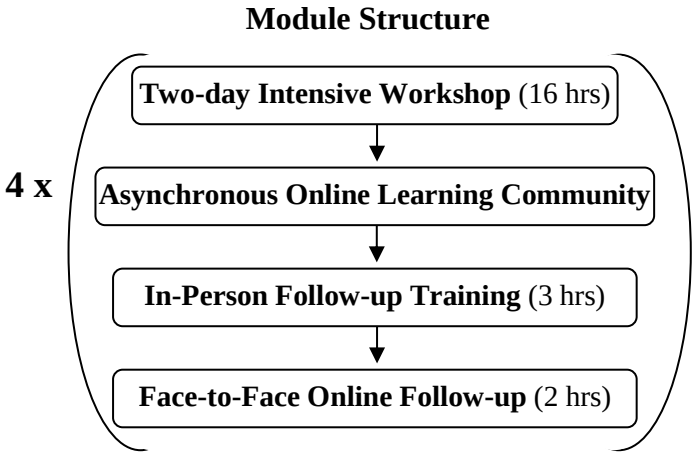

Figure I-2. Year 2 structure of modules in PD series, revised to include a two-hour synchronous, online follow-up, Cohorts 1 (the second half), 2 and 3.

Based on the need for complete teacher and student data sets, we added an introductory meeting to the PD series in August 2012 (Year 3, Cohorts 4 and 5; see Figure I-3). The introductory meeting served to outline the course and evaluation research components to the teachers. It allowed teachers to ask questions about the curriculum and pedagogy and give teachers time to adjust their classroom schedules to accommodate PD implementation. At the introductory meeting, teachers were given a course syllabus and a course honor code, indicating their agreement to attend and enthusiastically participate in all aspects of the PD course as well to be honest and accurate in all of the surveys. Teachers also met representatives from the evaluation team and learned about the purpose of the project. We believe that the addition of the introductory meeting allowed us to begin the first workshop of Module 1 with teachers prepared for the course expectations and ready to fully engage in all aspects of the PD. In addition, the introductory meeting provided teachers with approximately one month to collect student and parent consent forms as well as complete their own pre-program surveys. Thus the final PD model began with an introductory meeting (3 hours) followed by four modules. Each of the modules consisted of a two-day workshop (16 hours), an in-person follow-up training (3 hours), and a face-to-face synchronous online follow-up (2 hours). The modules were united by our unique, asynchronous online learning community (OLC). This hybrid approach, with in-person training combined with face-to-face synchronous and asynchronous online support and extension, is supported by the

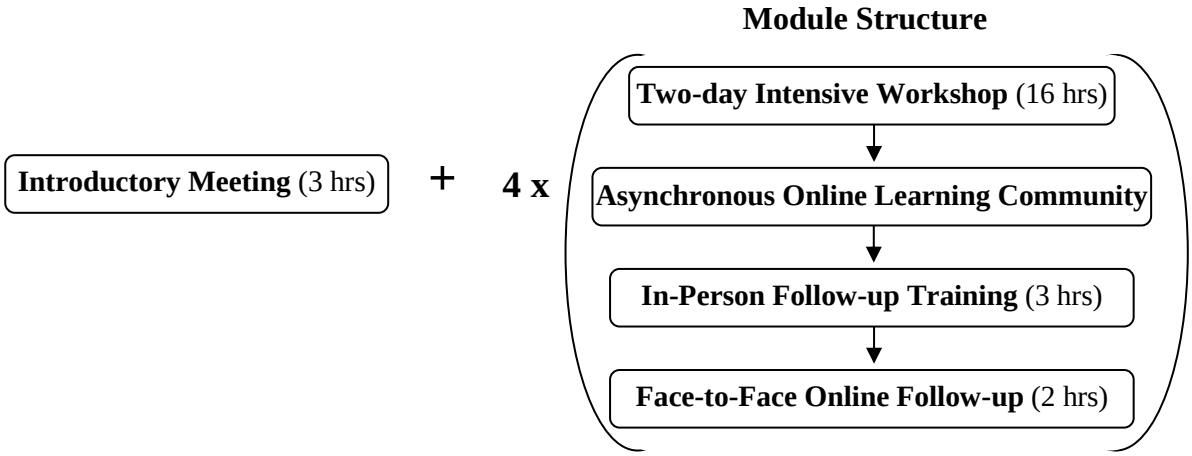

Figure I-3. Year 3 (Cohorts 4 and 5) structure of modules in PD series, revised to include a pre-PD introductory meeting.

recent shift in online PD from computer-based feedback towards collaborative interaction and reflection (Vrasidas & Glass, 2004), where the best approach is a combination of in-person, face-to-face, and online PD.

This shift bodes well for teachers who prefer in-person learning as well as those who prefer the communication and collaboration that Web technologies provide (Leach & Scott, 1995; Leach, Ahmed, Makalima, & Power, 2005). Furthermore, the use of online PD allows program developers to provide follow-up assistance to teachers in remote rural sites where frequent, in-person assistance and coaching is not feasible. It also allows continual connection between PD participants through, an interactive online learning community (see Figure I-4). Data from HaSTA member teachers further suggests that our approach to modularization is appreciated. Respondents to our survey (N=85) indicated that "chunking of a one or two-week course into a series of modularized workshops would somewhat (27.5%), more (33%), and very (13.2%) likely improve their desire to attend a course; 20.9% said that modularization would not affect their attendance, and only 5.5% said they would be unwilling to attend a modularized course (Duncan, 2008).

The need for professional development in scientific inquiry

The U.S. Bureau of Labor Statistics (2013) reported that nineteen of the 30 occupations projected to grow fastest from 2012 to 2022 typically require some form of postsecondary education. These occupations also have higher median wages and are projected to grow faster than occupations requiring a high school diploma or less. Specifically in the sciences, employment in occupations related to STEM—science, technology, engineering, and mathematics—are projected to grow faster than the average occupation, and wages in STEM occupations are projected to be higher than the median occupation (Vilorio, 2014). According to Public Agenda (Johnson, Rochkind, & Ott, 2010), most Americans see STEM education as a doorway to future opportunities, want their kids to take more science and math, and support investing in STEM education.

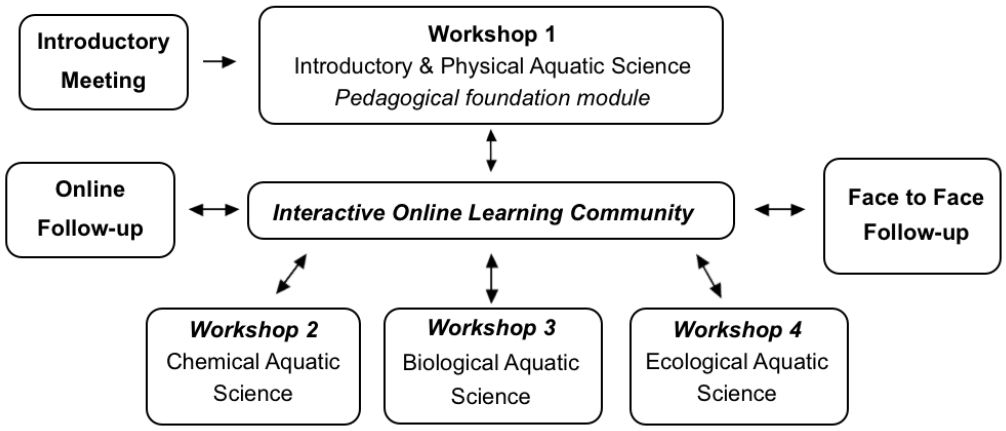

Figure I-4. TSI professional development structure illustrating the sequence of, and links between, PD components in the final iteration of the PD.

However, Johnson et al. (2012) also report that there is an urgency gap; most parents are confident that schools are doing a good job. Yet as a nation, U.S. citizens do not show evidence of strong retention of scientific principles. In a competence test of 15 year-olds students from 64 different nations, U.S. students ranked lower than 29 other nations in mathematics and lower than 22 other nations in science. In math, 26% of U.S. students are performing lower than level 2 (on a 6-point scale), and 18% are performing lower than level 2 in science (Program for International Student Assessment, 2012). As U.S. students continue to underperform in math and science, addressing the lack of American students pursuing careers in STEM fields has become critically important nationally (Kadlec & Friedman, 2008).

Thus, there is increased need to focus on reaching out to K–12 students to enhance the educational pipeline for post-secondary degrees in general and STEM disciplines specifically. A challenge arises, however, when we expect teachers, whose scientific experience is often limited to basic college science classes and education methods courses, to effectively facilitate scientific research with their students (Moscovici & Nelson, 1998; Wee, Shephardson, Fast, & Harbor, 2007). Well-designed PD can help teachers learn the scientific inquiry process and become better communicators, facilitators, and teachers of science.

Professional Development: teaching and learning science the way it is practiced

CRDG has developed a PD framework for TSI where we, as facilitators of the PD, use the same model of inquiry teaching with teachers that we expect them to use in their classrooms with students—a model that reflects authentic scientific practice. Contrary to the opening chapters of many science textbooks, true scientific investigation rarely proceeds linearly through the scientific method. Linn & Songer (1993) found that students could more effectively gain conceptual knowledge about their everyday experiences when they had formulated a more dynamic view of science. The TSI learning model mimics the non-linear progression of true scientific endeavors. For example,

during a TSI investigation new questions may be initiated, and interpretation of data may lead to the invention of new hypotheses or study designs. Instruction is ongoing, multi-directional and embedded throughout the process, meaning that participants take part in instructing one another.

We recognize that while teachers are learners, they are also pedagogical experts and professionals (Loucks-Horsley, Hewson, Love, & Stiles, 2003; Park Rogers et al., 2007). The TSI instructional model accommodates multi-directional instruction and collegial exchange during workshops, a feature essential to effective professional development (Guskey, 2003; Park Rogers et al., 2007). In the TSI program, teachers reflect together on their professional practice in a supportive environment. Teachers are encouraged to make adjustments in their instruction by incorporating more extensive inquiry experiences for their students. Such embedded modification to ongoing practice is much more likely to be maintained than externally mandated, large-scale change. By taking part in the series of TSI aquatic science modules, teachers become members of our aquatic science education network. In this way, the PD builds a network of practitioners engaged in applying new pedagogical knowledge to improve inquiry and aquatic science teaching practice.

We developed our series of four TSI PD modules using instructional inquiry, which is learning about a discipline by engaging in the practice of that discipline. The CRDG model of instruction, exemplified by our inquiry-based products like FAST, engages students in teaching and learning practices that mirror the professional practice of that discipline (Pottenger & Berg, 2006; Pottenger, Baumgartner, & Brennan, 2007). TSI is a supportive, skills- and content-based PD experience that builds inquiry into teachers' existing professional practice through gradual and sustained implementation of skills within the classroom (Pottenger & Berg, 2006).

One of the primary features of meaningful PD is that it be research-based (Guskey, 2003; Park Rogers, Abell, Lannin, Wang, Musikul, & Dingman, 2007). The TSI model applies evidence-based practices refined from CRDG's long-term study of inquiry science learning, teaching, and PD (e.g., see CRDG, 2000; Brandon, , Taum, Young, Pottenger, & Speitel, 2008; Brandon, Young, Taum, & Pottenger, 2009). By grounding the teacher training in learning research, TSI provides meaningful PD through a well-defined, research-supported image of learning and teaching (see Loucks-Horsley et al., 2003). The TSI model also promotes deep understanding of science content and process. This deep understanding allows teachers to successfully conduct authentic science within their classrooms, helping students build their own scientific habits of mind (Handler & Duncan, 2006; Pottenger et al., 2007). The goal of our project was to (a) increase teachers' content knowledge in aquatic science, (b) improve teachers' science process and pedagogical knowledge, and (c) improve student content knowledge and nature of science understanding.

TSI Pedagogy

The central premise of TSI is that learning, including that done at the professional level through PD, is best accomplished through authentic application of knowledge and skills. When scientific learning resembles the actual process of science, it enables students to better apply what they have learned in real-word situations (Edelson, 1998). Through the TSI PD, teachers learn to help students understand not only basic scientific concepts, but also the process used to gain and refine those concepts over time. Teachers learn to help students evaluate and decide which tools and techniques to use and are encouraged to provide students with opportunities for social interaction, within the context of science, both inside the classroom and beyond. When teachers teach science through TSI-based inquiry, they effectively guide students' thinking and reasoning through the judicious use of discussion, insight, and assistance—thereby teaching science *as* and *through* inquiry rather than *by* inquiry (see van Zee et al., 2005). Moreover, as teachers help students engage in authentic scientific practice within the classroom, they build students' integrity, diligence, fairness, curiosity, openness to new ideas, skepticism, and imagination (see Baumgartner, Duncan, & Handler, 2006; Duncan & Daly-Engel, 2006). These demeanors reflect the scientific "habits of mind" identified by the Project 2061 report, Science For All Americans (AAAS, 1990, p. 185), as essential to scientifically literate individuals.

The TSI instructional model reflects the flexible and collaborative nature of scientific inquiry and supports the development of scientifically literate students who recognize the dynamic nature-of-science. The TSI philosophy is grounded in the ideas of disciplines of knowledge (King & Brownell, 1966) and disciplinary inquiry (Pottenger, 2007). Within the discipline of science, a community of scientists shares a common set of practices and demeanors when participating in scientific inquiry. In a TSI classroom, teachers and students are linked as part of a disciplinary community of knowledge generation (Pottenger, 2007; Duncan Seraphin & Baumgartner, 2010). Students are expected to act as scientists (Duncan Seraphin & Baumgartner, 2010), engaging in scientific practices such as asking questions, collecting, analyzing, and interpreting data, communicating, contributing to the community, and exhibiting the demeanors of professional scientists, such as honesty, responsibility, and open-mindedness. Because TSI emphasizes the nature of science, importance is placed on learning about scientific processes (e.g., what scientists do) in the context of scientific findings (e.g., what scientists know).

TSI encompasses cycles of both learning and instruction. These cycles are reflected in phases, which represent different aspects of the inquiry process. The five phases of the TSI model are *initiation, invention, investigation, interpretation,* and *instruction*. Initiation is a phase of originating interest or developing a focus for inquiry. This may come in the form of a student asking a question or a teacher posing a problem. The invention phase entails problem solving and information gathering, including creating a testable hypothesis, designing an experiment, or troubleshooting a procedural step.

Students engage in investigation as they gather new knowledge through carrying out tests or analyzing data. Information gathered during investigation requires interpretation, evaluating results and conclusions through both a reflective, internal process and an objective, external process. Instruction is integral to each phase. Instruction is broadly defined in the TSI model and includes communication from teacher-to-student, student-to-student, and student-to-teacher. 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—with its many nuances—surrounds and 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 I-5).

The square-in-circle diagram of the TSI phases reflects our understanding of the nature of the process of science. The arrangement of the phases, which are connected but not sequential, places an emphasis on the possibility of multiple logical progressions rather than rigid, linear, procedural steps. For example, initiation can occur at the beginning of a lesson, but it can also occur throughout the course of investigation as students re-initiate by experiencing anomalies, asking questions, or considering new information. An encountered difficulty in interpretation can redirect the learning cycle, leading to the need for invention of new processes or ideas to be investigated. Alternatively, investigation may spark an entirely new learning cycle, composed of new questions, materials, and investigations. The encompassing instruction phase can occur throughout the other phases, as a teacher prompts students to consider alternate conceptions or methods, as students communicate and share information with each other, or when students present their findings outside the classroom. Students may move fluidly through the phases as individuals, pairs, or groups, while the whole class community progresses through a larger cycle of learning, moving toward clearer understandings of scientific concepts. The flexibility of the TSI cycle thus reflects not only what happens in an authentic scientific process, but also what happens in a classroom setting (Duncan Seraphin & Baumgartner, 2010).

In addition to the phases of inquiry, TSI emphasizes the flexibility of science by exploring a variety of different modes of inquiry (Pottenger & Son, 2005; Pottenger et al., 2007). This is an important aspect of scientific inquiry and a unique feature of TSI. Science is practiced in many ways (Windschitl, Dvornich, Ryken, Tudor, & Koehler, 2007), but the many modes are routinely ignored in most models of inquiry-based science. Most approaches to teaching inquiry in K–12 science focus on experiments, which is only one of the ten modes in the TSI model. According to Tytler (2002), one of the key features of education supporting student learning through conceptual change is that the nature of science is presented in all of its different aspects. The unique modes of the TSI framework are summarized in Table I-1.

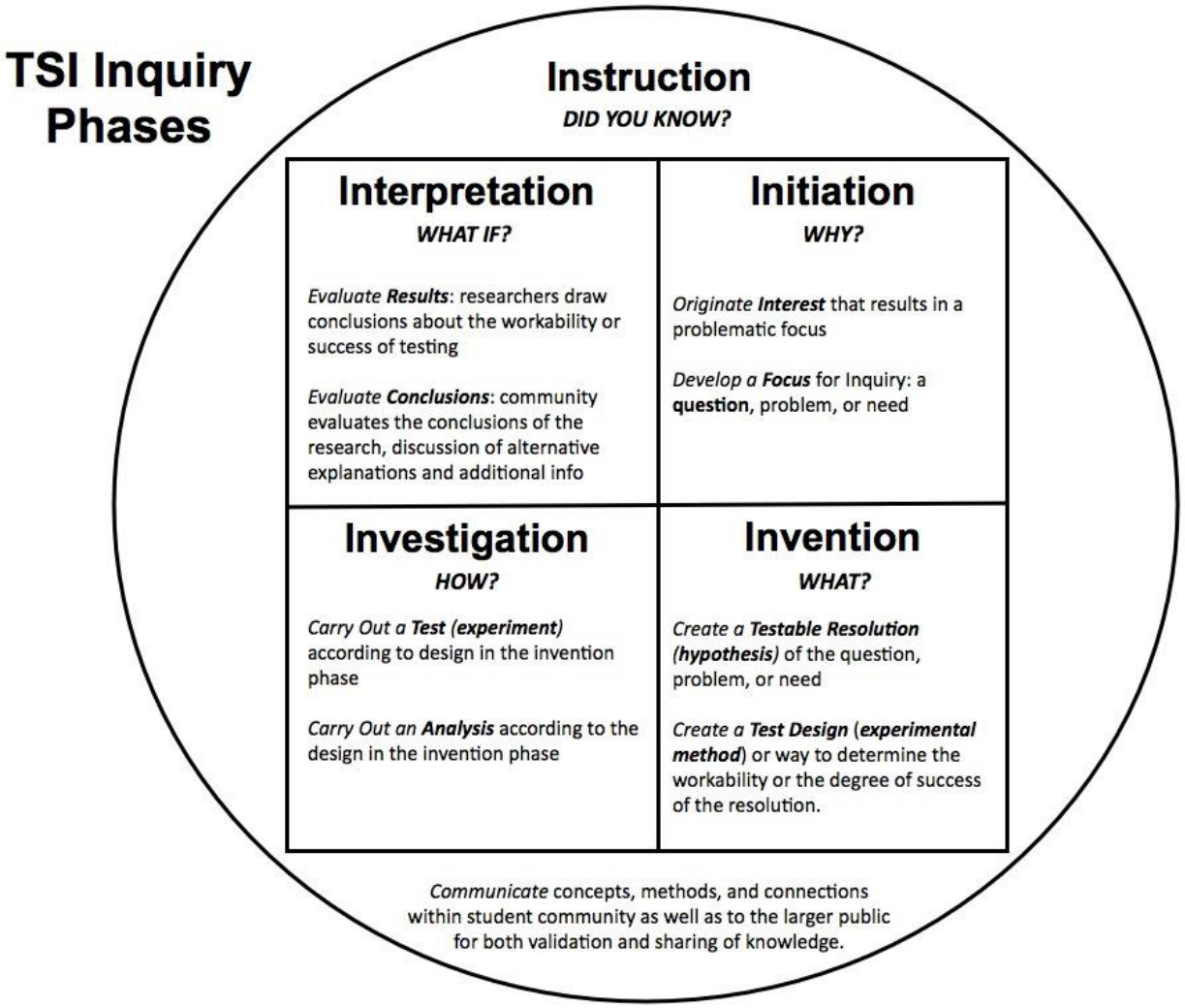

Figure I-5. The TSI square-in-circle phase diagram, which lacks arrows, allows each of the five phases to connect with each other, illustrating the interconnected nature of scientific inquiry. The instruction phase encircles the other phases, emphasizing the role of communication in teaching and learning through inquiry.

Modes are used in the TSI framework to reflect the variety of ways to do scientific inquiry. Whereas phases define the stages of the inquiry cycle, modes describe the multiple approaches to knowledge generation and acquisition, an important aspect of disciplinary inquiry (see Windschitl, Dvornich, Ryken, Tudor & Koehler, 2007). Investigating various aspects of the nature of science and using evidence from a variety of sources can lead to conceptual change in science understanding (Tytler, 2002; Zembel-Saul, Munford, Crawford, Friedrichsen, & Land, 2002). Research on the process of knowledge development, therefore, supports the use of multiples modes of inquiry. We have found that inquiry instruction is less intimidating to teachers when they realize that there are many ways in which they and their students can legitimately do scientific inquiry.

Table I-1
The Modes of Inquiry Addressed in TSI *(modified from Duncan Seraphin, Philippoff, Parisky, Degnan, & Papini Waren, 2012)*

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

TSI uses the concept of the modes of inquiry to emphasize the many different ways of participating in the scientific process, challenging the widely held misconception that all inquiry is hands-on and all hands-on activities are inquiry (see Rankin, 2000). The TSI framework argues that each of the other modes, including authoritative knowledge, are an important means by which to access information in scientific inquiry. In addition, although some modes and phases are well suited to each other, such as instruction and authoritative knowledge, or initiation and curiosity, any mode can be employed in any phase. For example, description, induction, deduction, and transitive knowledge are often important modes in the instruction phase.

TSI and Metacognition

Although not explicitly addressed in the theoretical framework of TSI (Pottenger, 2007), we have found metacognition to play a key role in teaching and learning science through inquiry. Inquiry-based learning has been associated with improving student self-

regulation (Schraw, Crippen, & Hartley, K, 2006), which is linked to metacognitive abilities (Dinsmore, Alexander, & Loughlin, 2008; Schraw et al., 2006). The TSI framework balances content, context, inquiry, and pedagogy, and creates a classroom setting that fosters self-regulation and intentional learning, a crucial element of effective learners. Intentional learners are able to actively integrate new information with their own awareness of how they learn. Intentional learners are fueled by motivation and eagerness to learn; they understand and expect that knowledge about a topic continues to evolve and that mastery takes significant time, considerable effort, and perseverance (Ormrod, 2011). Self-regulated, intentional learners are in charge of, and responsible for, much of their learning, using elements of inquiry and metacognition to help guide their thinking.

The TSI pedagogical framework focuses on learning through the authentic application of knowledge and skills. The framework is designed to help teachers teach both the processes and content of science, which, according to Edelson, Gordin, & Pea (1999), enables students to better apply what they have learned in real-word situations. When teachers effectively teach science through TSI-based inquiry, they guide students' reasoning through the judicious use of discussion, insight, and assistance. Teachers help students evaluate and decide which inquiry techniques to use during their investigations through a process of self-regulation. Using this inquiry- and process-based approach to science teaching, teachers help students develop the two main components of metacognition, awareness and control of their thought processes.

Our understanding of the role that metacognition plays in creating self-directed, intentional learners, and the connection between inquiry and metacognition, has led us to incorporate explicit discussion, activities, examples, and modeling of metacognition into the TSI pedagogy. A number of studies have examined ways to improve metacognition through classroom instruction and have suggested that metacognition can be improved by direct instruction and modeling of metacognitive strategies (e.g. Gunstone & Mitchell, 1998; Mason, 1994). Working under this premise, and the idea that students can be taught to monitor their understanding in order to improve learning gains (see Baird, 1986; Bielaczyc, Pirolli, & Brown, 1995; Chi DeLeeuw, Chiu, & LaVancher, 1994; Paliscar & Brown, 1984), we have included metacognitive activities in the PD that teachers subsequently implement in their classrooms. Thus, integrated into the TSI PD experience, teachers follow the instruction and modeling exemplified in the workshops as they teach their students to be metacognitive in their science studies.

The need for professional development in aquatic science education

On the national level, ocean and aquatic sciences have been among the most underrepresented disciplines in K–12 curricula (College of Exploration, 2013). This neglect is remarkable considering that the ocean is the dominant feature on Earth, whose surface is covered by more than 70% water. The ocean affects every aspect of human life. The ocean regulates our weather and climate. It supplies foods, medicines, minerals, and energy resources. Our environmental sustainability, which ultimately leads to economic

and social stability, depends on understanding the processes of the ocean. Current world issues, such as global climate change and collapsing world fisheries, are tied to ocean processes and have local and global implications. As such, it is critical that all people receive access to the resources and materials needed for aquatic and ocean literacy; understanding the mutual influence of the ocean on humankind and humankind on the ocean is a critical component of broader efforts to build scientific and global literacy for all citizens. Because of this, the new NGSS have taken steps to address aquatic and ocean science (National Research Council, 2012; NGSS Lead States 2013a; NGSS Lead States 2013b).

Furthermore, as the choice of content for PD development, the wide range of scientific endeavors and concepts related to aquatic and ocean science fit well into any general science course, across the scientific disciplines and grade levels (i.e., the TSI Aquatic PD was relevant to teachers of courses other than "marine science"). Indeed, learning general science through the focus of aquatic science can help students to form a more complete understanding of the scientific process, as outlined in the National Research Council's (2012) A Framework for K-12 Science Education and the Next Generation Science Standards (NGSS, NGSS Lead States 2013a; NGSS Lead States 2013b). As a reference tool, hundreds of ocean scientists, science educators (K–12 and informal) and learning researchers developed a set of seven over-arching concepts that guide the K–12 teaching and learning of ocean sciences. These Ocean Literacy Principles (OLP) constitute the knowledge needed by someone considered to be "ocean literate." According to the OLP, every ocean literate person should understand these concepts:

1. Earth has one big ocean with many features.
2. The ocean and life in the ocean shape the features of Earth.
3. The ocean is a major influence on weather and climate.
4. The ocean makes Earth habitable.
5. The ocean supports a great diversity of life and ecosystems.
6. The ocean and humans are inextricably interconnected.
7. The ocean is largely unexplored.

Exploring Our Fluid Earth Curriculum

The series of TSI Aquatic PD modules is tailored to the seven OLP and draws content from the *Exploring Our Fluid Earth* (EOFE) curriculum, which is being produced through a National Oceanic and Atmospheric Administration (NOAA) funded project through the University of Hawai'i Sea Grant Center for Marine Science Education. The EOFE curriculum is based on the CRDG created, nationally recognized *Fluid Earth/Living Ocean* (FELO) aquatic science curriculum (Klemm, Pottenger, Speitel, Reed, & Coopersmith, 1990; Klemm, Reed, Pottenger, Porter, & Speitel, 1995). FELO was written for a 9th grade audience and is used by public and private schools across the U. S. (including a 2013–2017 state-wide adoption of the program in Texas), the Pacific region, and in Department of Defense schools. A multi-state FELO implementation study

(Higa, Smithers, & Brandon, 2002) provided data on teacher use of the program. The study showed that, across all units of the program, an average of 95% of the responding teachers said the difficulty and concept content of the units was at the appropriate level, and 77% said that students showed moderate to high levels of interest in the program. Lambert (2005) also reported students' positive comments about the accessibility of the curriculum and the manner in which FELO teaches scientific vocabulary.

The new EOFE curriculum is online and updated for the digital age (exploringourfluidearth.org), but it is also grounded in FELO and the TSI approach to learning. EOFE includes media resources, activities, questions, special features, and teacher resources. The EOFE curriculum website also includes an area just for teachers participating in PD courses and an interactive teacher community that together serve as the online learning community (OLC) for the TSI PD (see TSI Summative Final Report Chapter Three).

Providing content and skills support across aquatic science disciplines

We developed and implemented an aquatic systems PD consisting of four modules. Each TSI module focused on an aspect of aquatic science: (1) physical, (2) chemical, (3) biological, and (4) ecological. Together, the four aquatic science TSI modules included a series of activities that provide a cohesive set of content gained through inquiry. The integration of disciplines in this way provided a mechanism for students to the learn science concepts outlined in A Framework for K-12 Science Education (National Research Council, 2012). The integrated content also provided multiple entry points to the course materials, which teachers could approach from the perspective of their respective disciplines. In addition, we highlighted the influence of water on terrestrial systems to increase the applicability of our program beyond coastal locations.

The modular structure of our TSI Aquatic PD program allowed us to scaffold inquiry pedagogy and strategies throughout the course of the modules. The modular structure also allowed us to assess teachers' inquiry understanding over time. We compiled an outline of TSI inquiry pedagogy, themes, and overarching content, for each module, which includes modeling science, observation and inference, and scientific language. We shared this outline with our external project consultants and used this outline to structure the development and iterative revisions of the modules. The TSI foci, themes, and content are outlined by module in Table I-2.

We completed the PD with five cohorts over the course of the project. Following feedback from the evaluation team, teacher participants, and external project consultants, we modified the PD content and delivery as we implemented each of the modules in the PD. Modifications primarily entailed the amount of time focused specifically on content and pedagogy as well as our attention to use of TSI language in discussions with the teachers. We moved toward more time spent on content that teachers in our first few cohorts found difficult. We also moved toward more express discussion of TSI pedagogy, including goals, before and after each activity.

Table I-2
Outline of TSI *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 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 TSI phases and modes using TSI inquiry questioning strategies	Scientific Language Questioning Strategies	Explore aquatic diversity, focusing on structure, function, and 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

In addition, we modified the TSI PD so that teachers were required to teach both pedagogical lessons as well as content lessons to their students.

As a continuation of our modification from Year 2, in Year 3 we identified not only target content activities, but also target pedagogical activities (see Appendix A) within the sequence of the modules. Teacher participants were required to implement target activities in their classrooms. Teachers were provided all of the supplies needed to implement target activities. In the workshop, target activities served as exemplars that we spent additional instructional time on compared to other activities. We found that the target activities were helpful organizers for dialogue between teachers and for evaluation purposes. Provision of supplies helped to ensure further implementation of activities. Teachers had to implement a minimum of eight aquatic science activities and four pedagogical activities over the course of the PD in their classrooms. Overall, our evaluator reports and teacher responses to evaluation instruments indicate that our structure, delivery, and overall TSI program has improved over successive iterations. (See Appendix A for module agenda descriptions and activities.)

Module 1. Physical Aquatic Science was delivered to Cohort 1 (Oahu) in fall 2010, to Cohorts 2 and 3 (Maui and Hawaii Island) in fall 2011, and to Cohorts 4 and 5 (Oahu II and Kauai) in fall 2012. Module 1 concentrated heavily on the TSI framework and building a strong contextual foundation. The pedagogical focus of Module 1 was on teachers building an understanding of disciplinary inquiry and becoming more

metacognitive about their teaching and learning. We also introduced the concept of ocean literacy. The themes of Module 1 were *science as a human endeavor* and *community* to reflect our building of a community of aquatic science teachers engaged in the PD. The content focus for Module 1 was on the physical processes necessary to understand ocean circulation, including the physical content of density, especially as it relates to temperature and salinity, waves, tides, and the ocean floor. Our fifth iteration of the Module 1 agenda is attached as Appendix A.

Module 2. Chemical Aquatic Science was delivered to Cohort 1 (Oahu) in spring 2011, to Cohorts 2 and 3 (Maui and Hawaii Island) in fall 2011, and to Cohorts 4 and 5 (Oahu II and Kauai) in fall 2012. The pedagogical focus of Module 2 was on furthering teachers' understanding of TSI and learning to guide their students through the TSI phases (learning cycle). The themes of Module 2 were *observation and inference* and *modeling science*. The chemistry module used modeling and demonstrations to focus on types of matter, bonding and the breaking for bonds, for example through electrolysis, concentration, the periodic table, water properties, solubility, conductivity, phase changes especially as they relate to the water cycle, pH, and ocean acidification. Our fifth iteration of the Module 2 agenda is attached as Appendix A.

Module 3. Biological Aquatic Science was delivered to Cohort 1 (Oahu) in fall of 2011, to Cohorts 2 and 3 (Maui and Hawaii Island) in spring 2012, and to Cohorts 4 and 5 (Oahu II and Kauai) in spring 2013. The pedagogical focus of Module 3 was on furthering teachers' use of TSI as a tool to guide students through both the phases and modes of inquiry through their use of questioning strategies. The theme of Module 3 was *scientific language* because of its importance as a tool in the effective communication of science. The biological module's content focus was on the exploration of aquatic diversity, including structure, function, and the evolutionary connections between organisms. During Year 4, we drafted and completed the last two iterations of Module 3. Our fifth iteration of the Module 3 agenda is attached as Appendix A.

Module 4. Ecological Aquatic Science was delivered to Cohort 1, 2 and 3 (Oahu, Maui and Hawaii Island) in spring 2012 and to Cohorts 4 and 5 (Oahu II and Kauai) in spring 2013. The pedagogical focus of Module 4 was on furthering teachers' understanding of disciplinary inquiry by becoming familiar with the TSI practices of inquiry and transferring TSI pedagogy to their own lessons. At the end of this module teachers had learned and been asked to implement the full suite of TSI pedagogical tools in their classroom. The ecological module focused on the application of the content teachers learned in the first three modules as they related physical, chemical, and biological principles to the investigation of an aquatic environment. During Year 4, we drafted and completed the last two iterations of Module 4. Our fifth iteration of the Module 4 agenda is attached as Appendix A.

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CHAPTER II
DESCRIPTION OF THE IMPLEMENTATION AND PROJECT TEAM REFLECTIONS

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This chapter describes the implementation of the TSI PD modules, TSI lessons by the participating teachers, and the TSI consultant meeting. This chapter also includes project team reflections about the PD implementation. Additional data concerning lessons and teacher implementation is detailed in the formal Ch. IV Evaluation Plan and Methods and Ch. V Summary of Evaluation Findings.

Implementation of TSI PD

Overall, the PD facilitators felt TSI Aquatic PD's hybrid structure allowed for participant interaction with the material in a variety of ways and offered many avenues for community engagement. The module structure (described in Ch. I) made efficient use of facilitators' time, and we will use (and recommend that others also use) the hybrid structure, with in-person workshops and face-to-face online follow-ups. The in-person follow-up in teachers' classrooms was also beneficial. In fact, it was one of the highlights for facilitators and teachers. However, it was also the most time-intensive in terms of travel for facilitators and also hard for teachers to schedule. Thus, this is an element we would like to experiment with in future research.

Cohort 1 (O'ahu) 2010-2012

The first cohort spanned two years because it was our initial testing cohort. Teachers were recruited in partnership with the HI DOE, the Hawai'i Science Teachers Association (HaSTA), the local chapter of the National Marine Educators Association (OCEANIA), the Charter School Network and the Hawai'i Association of Independent Schools. We also emailed the teachers on our contact lists and recruited teachers from University of Hawai'i at Mānoa (UHM) College of Education courses. We had higher attrition than expected, in part we believe due to the two-year long implementation of the course. Eight teachers (out of our original twelve) began in September 2010 and completed Cohort 1 in June 2012 of Year 3. The data from this first O'ahu cohort were used as formative evaluation information for development and refinement of the TSI Aquatic PD modules.

Cohorts 2 & 3 (Maui and Hawai'I Island) 2011-2012

Cohorts 2 & 3 began late in project Year 2. We accepted fifteen teachers for the Maui cohort (12 from Maui, 2 from Lana'i, and 1 from Moloka'i) and twelve teachers for the Hawai'i Island cohort. All of the teachers completed 100% of the pre-evaluation instruments and the PD components of the project, but only thirteen Maui teachers and eleven Hawai'i Island teachers completed all of the post-evaluation data requests in June 2012 of Year 3.

Cohorts 4 & 5 (O‘ahu II and Kaua‘i Island) 2012-2013

We modified our promotional flyer and application to fit the O‘ahu and Kaua‘i Island Cohorts. In addition to the recruitment means mentioned above, we went on the radio to advertise the PD. We also faxed and called every public and private middle and high school in Hawai‘i directly targeting science teachers as well as targeting school leaders (principals, secretaries, and science department heads).

For the final two cohorts, we added orientation-recruitment meetings, two on O‘ahu and one on Kaua‘i, to explain the PD course and research project. These meetings were held in the spring prior to the start of the PD—approximately four months in advance of the course. In the orientation meetings, we highlighted PD curriculum components, activities, the pedagogical framework, and shared the experiences of past cohort members. We chose teachers from a variety of school settings and, as much as possible, selected teachers without prior experience using TSI.

We recruited 16 teachers for the O‘ahu II cohort and 15 teachers for the Kaua‘i cohort. Each of the teachers agreed to participate in the full series of four modules comprising our PD program, implement PD activities in their classroom, and complete all evaluation instruments required of them. Fifteen of the sixteen O‘ahu teachers completed these requirements, thirteen of the fifteen Kaua‘i teachers completed these requirements.

Teacher Leaders

Four teacher leaders, two from the island of Hawai‘i, one from the island of Maui, and one from the island of Kaua‘i participated from 2010-2012. (Note that after Module 2, one of our Maui teacher leaders withdrew as a teacher leader due to illness in her family, so although we began with two, by the end of our project Year 3 we only had one teacher leader from Maui.) Teacher leaders attended the O‘ahu I Cohort training as participants and then attended the subsequent training on their island, where they were asked to contribute to the PD as peer leaders.

The use of teacher leaders was one of the innovative aspects of our implementation. We felt that the teacher leaders were a valuable asset to the PD. Each traveled to O‘ahu and actively participated in the series of four modules, including the evaluation components. They also provided additional feedback on the PD design and implementation. In addition, the teacher leaders helped recruit for and attended the PD modules on their respective islands, acting as mentors for their fellow teachers and assistant facilitators to the PD. However, the level of engagement and participation of the teacher leaders varied tremendously, and we decided recruitment and training of excellent quality teacher leaders was unsustainable. Thus, we chose to implement our final two cohorts without teacher leaders’.

Summary

In summary, 75 teachers began the TSI Aquatic PD. Of these, 69 finished the PD, and 63 completed all PD as well as all evaluation components of all four modules. Of the 63 teachers that completed all elements, 12 (8 teachers and 4 teacher leaders) were part of

our Cohort 1 trial implementation, a two-year development phase of the TSI modules. Therefore, 51 teachers completed the TSI modules and evaluation instruments in the one-year form of the TSI Aquatic PD course. As the course was held over a single school year, these teachers had the same students in their classes throughout the PD.

The teachers in the TSI PD comprised a range of experience, subjects, and grade levels. The focus of our summative evaluation was for the results obtained from Cohorts 4 and 5 (the final two cohorts), which encompassed a range of experience typical of previous cohorts. See Table II-1 for a description of the teachers in Cohorts 1-3 and Table II-2 for a description of the teachers in Cohorts 4 and 5.

The number of teacher participants is 3 more teachers than the 48 we planned for in our project proposal (see Table II-3 for a breakdown of project participants by cohort). In our final iteration (Cohorts 4 and 5), 31 teachers completed the TSI PD, and 28 completed all evaluation components.

Table II-1
Teachers' Background Characteristics for Cohorts 1-3 (N=44)

Characteristic	Number of teachers
Grade level taught:	
Elementary school (Grade 5)	0
Middle school[a] (Grades 6-8)	29
High school (Grades 9-12)	18
Undergraduate Major:	
Science	28
Education	3
Other	13

[a]*Three teachers taught both middle and high school levels and are counted twice.*

Course Dates

The PD course meetings were conducted at the times shown in Table II-4. Note that, for Cohort 3 (Hawai‘i Island), we chose to do two follow-up meetings (one on each side of Hawai‘i Island) due to geographic and traveling issues except for the Module 4 Follow-up session, then the full cohort met in one central location. In addition, we offered the follow-up Elluminate/Blackboard sessions on two to three days for the final two cohorts to minimize the length of time the teachers needed to be online continuously (the teachers each were required to attend only one of the Elluminate/Blackboard sessions per module). Note that the proprietary name of the virtual software used for the online follow-up changed from Elluminate to Blackboard in 2012.

Professional Development Credits

We collaborated with the Hawai‘i Department of Education (HI DOE) personnel in charge of the accreditation of PD courses to establish three units of HI DOE credit in the department's units of PD Experiences that Educate and Empower (PDE^3) for each of the Modules. Thus, the teachers could earn a maximum of twelve units of credit over the course of our PD. Teachers enrolled in PDE^3 completed portfolios in addition to all TSI PD requirements.

Table II-2

Teachers' Background Characteristics for Cohorts 4 and 5 (N=28)

Characteristic	Number of teachers
Grade level taught:	3
Elementary school (Grades 5 and 6)	(2 Grade 5 and 1 Grade 6)
Middle school (Grades 6-8)	14
High school (Grades 9-12)	11
Undergraduate Major:	
Science	14
Education	9
Other	5
No. of years teaching science[a]*:*	
1-2	6
3-4	2
5-6	3
7-8	3
9-10	4
>10	10
No. of DOE highly qualified teachers (HQT) in science	
Yes	15
No	13
No. of undergraduate science courses taken:	
0	1
1-3	5
4-6	6
7-0	4
>10	12
No. of graduate science courses taken:	
0	14
1-3	6
4-6	2
7-0	2
>10	4
Familiarity with ocean literacy principles[b]*:*	
1 (not at all familiar)	15
2	4
3	6
4	2
5 (very familiar)	1
Experience conducting research:	
Yes	16
No	12
No. of science PD courses taken in past five years:	
0	10
1-2	5
3-4	6
>5	7
Science subjects taught during the study year: Aquaponics, Biology, Chemistry, Clinical Health, CAD, Earth and Space Science, ELL Science, Health Science, Human Anatomy, Life Science, Marine Science, Marine Tech, Physical Science, Physics, General Science	

[a] *This question was only asked of Cohorts 4 and 5.*

[b] *Teachers were asked to respond to this item using a 1-5 scale, where 1= not at all familiar and 5 = very familiar.*

Table II-3

Number of Teachers Completing TSI Aquatic PD and Post-project Research Tasks

Cohort	*N* teachers at pre	Pre-CIQ and Background Questionnaire	TSI PD	Post SSQ[a]	Inquiry Teaching Assessment	Post-CIQ Questionnaire[b]	Post-Cohort Questionnaire	Post-Cohort Interview[c]	Completed all components[d]
1 Oʻahu	13	13	8	NA	8	8	8	8 (4BB, 4SM)	8
2 Maui	15	15	15	14	14	14	14	13 (5BB, 8SM)	12
3 Hawaiʻi Island	12	12	11	10	11	11	11	11 (6BB, 5SM)	11
Teacher leaders	4	4	4	NA	4	4	4	4 (2BB, 2SM)	4
4 Oʻahu II	16	16	16	15	15	15	15	15 (15BB)	15
5 Kauaʻi	15	15	15	13	13	13	13	13 (7BB, 5SM)	13
Total	75	75	69	52	65	65	65	64 (17BB, 21SM)	63[e]

[a]Cohort 1 and teacher leaders were not asked to administer the Student Science Questionnaire (SSQ) to their students. The SSQ comprised the Student Nature of Science Assessment and, in Cohorts 4 and 5, the Student Aquatic Science Content Assessment. [b]The Classroom Instruction Questionnaire (CIQ) included measures of pedagogical content knowledge, science teaching self efficacy, and metacognition in teaching science. [c]Was either synchronous online via conferencing software (Blackboard) or asynchronous online via survey software (SurveyMonkey); BB = Blackboard, SM = SurveyMonkey. [d]Overall, 63 teachers completed all the end of project paperwork (excluding the SSQs). [e]This number includes the four teacher leaders.

Table II-4

PD Course Meetings by Cohort, Module, and Component

Cohort	Module	PD meeting	Date
1 O‘ahu Oct. 2010 – Jun. 2012	1	Workshop	Oct. 29 and 30
		Follow-up	Jan. 19
	2	Workshop	Apr. 15 and 16
		Follow-up	May 25
		Elluminate	Jun. 21 or 23
	3	Workshop	Sept. 16 and 17
		Follow-up	Oct. 19
		Elluminate	Nov. 29 or Dec. 1
	4	Workshop	Feb. 10 and 11
		Elluminate	April 10 or 11
		Follow-up	April 25
2 Maui Aug. 2011 – Jun. 2012	1	Workshop	Aug. 12 and 13
		Follow-up	Sept. 7
		Elluminate	Oct. 4, 5, and 6
	2	Workshop	Oct. 14 and 15:
		Follow-up	Nov. 30
		Elluminate	Jan. 3, 4 or 5
	3	Workshop	Jan. 13 and 14
		Follow-up	Feb. 1
		Elluminate	Feb. 28, 29 or Mar. 1
	4	Workshop	March 9 and 10
		Elluminate	May 1, 2, or 3
		Follow-up	May 5
3 Hawai‘i Island Aug. 2011 – Jun. 2012	1	Workshop	Aug. 26 and 27
		Follow-up	Sep. 21 or 22
		Elluminate	Oct. 11, 12, or 13
	2	Workshop	Nov. 4 and 5
		Follow-up	Dec. 7 or 8
		Elluminate	Jan. 10, 11, or 12
	3	Workshop	Jan. 27 and 28
		Follow-up	Feb. 22 or 23
		Elluminate	April 3, 4, or 5

Table II-4

PD Course Meetings by Cohort, Module, and Component (continued)

Cohort	Module	PD meeting	Date
3 Hawai‘i Island Aug. 2011 – Jun. 2012	4	Workshop	Apr. 20 and 21
		Elluminate	May. 15, 16 or 17
		Follow-up	Jun. 2
4 O‘ahu II Aug. 2012 – May 2013	Introductory Session	Introduction	Aug. 8
	1	Workshop	Sep. 7 and 8
		Follow-up	Sep. 26
		Elluminate	Oct. 16, 17, or 18
	2	Workshop	Nov. 2 and 3
		Follow-up	Nov. 28
		Elluminate	Jan. 8, 9, or 10
	3	Workshop	Jan. 18 and 19
		Follow-up	Feb. 6
		Elluminate	Feb 26, 27, or 28
	4	Workshop	Mar. 8 and 9
		Elluminate	Apr. 23, 24, or 25
		Follow-up	May. 8
5 Kaua‘i Aug. 2012 – May 2013	Introductory Session	Introduction	Aug. 15
	1	Workshop	Sep. 21 and 22
		Follow-up	Oct 24
		Elluminate	Nov. 6, 7, or 8
	2	Workshop	Nov. 16 and 17
		Follow-up	Dec. 5
		Elluminate	Jan. 22, 23, or 24
	3	Workshop	Feb. 1 and 2
		Elluminate	Mar. 12, 13, or 14
		Follow-up	Mar. 8
	4	Workshop	Apr. 5 and 6
		Elluminate	Apr. 30, May 1, or 2
		Follow-up	May. 15

Forty-four out of the 69 (64%) teachers who completed the PD also completed at least one module for PDE^3 credit. The number of teachers who completed PDE^3 by cohort and by module is shown in Table II-5 (note that many teachers completed PDE^3 credit requirements for multiple modules).

Table II-5
Number of TSI Aquatic PD Teachers Completing HI DOE PDE^3 Credits by Cohort

Module	Date	*N* teachers completed PDE^3
	Cohort 1 (O'ahu), Project Years 1-2	
1	October 29, 2010 - March 08, 2012	8
2	April 15, 2011 - August 02, 2011	6
3	January 14, 2012 - April 16, 2012	5
4	March 10, 2012 - July 30, 2012	4
	Cohort 2 (Maui), Project Years 2-3	
1	August 13, 2011 - November 29, 2011	9
2	October 15, 2011 - February 27, 2012	11
3	January 14, 2012 - April 16, 2012	9
4	March 10, 2012 - July 30, 2012	9
	Cohort 3 (Hawai'i Island), Project Years 2-3	
1	August 27, 2011 - November 29, 2011	6
2	November 05, 2011 - March 05, 2012	10
3	January 28, 2012 - May 14, 2012	9
4	April 21, 2012 - August 13, 2012	4
	Cohort 4 (O'ahu II), Project Years 3-4	
1	August 08, 2012 - December 10, 2012	9
2	November 03, 2012 - March 04, 2013	10
3	January 18, 2013 - April 29, 2013	11
4	March 23, 2013 - July 08, 2013	11

We were also accredited with 15 High Objective Uniform State Standard of Evaluation (HOUSSE) points per Module. HOUSSE points count toward a teacher's highly qualified status and are based on content specific to the discipline in which they teach. Teachers need to earn 100 HOUSSE points in the HI DOE in order to become highly qualified if they do not have a primary degree in the subject that they teach. Our establishment of HOUSSE points is a credit to the quantity of content being provided to the teachers through our Modules.

TSI Lesson Implementation

As detailed in Ch. I of this report, we completed five iterations of each Module. Modifications made to the PD through the iterations primarily entailed spending more time modifying and fine-tuning the content that the teachers in our first few cohorts found difficult. We also moved toward more express discussion of TSI pedagogy, including goals, before and after each activity. In addition, we modified the TSI PD so that the teachers were required to teach both pedagogical lessons as well as content lessons to their students. The teachers in our final two cohorts (4 and 5) had to teach two target content activities and one target pedagogical activity per module. The teachers had to implement a minimum of eight aquatic science activities and four pedagogical activities over the course of the PD in their classrooms. (See Appendix A for Module Agenda descriptions and activities.)

Modifications

As the teachers implemented lessons, they kept track of any modifications that they made to the TSI lessons and the reasons for their modifications. The teachers reported on these modifications in their activity lesson reflections; the modifications are summarized below in Table II-6, which show the modifications by all the teachers in Cohorts 4 and 5 (N = 28; elementary teachers = 3, middle school teachers = 14, and high school teachers = 11). The options that the teachers could select for modifications that they made on the activity reflections were: age of students, number of students, classroom constraints, class time, student characteristics (SPED, etc.), management issues, supplies, and other.

Note that because teachers selected two content lessons, from a choice of three, in Modules 1-3, there are fewer "N = number of teachers who completed reflection" for some lessons. Also, in Module 4, teachers were required to complete the two content lessons because the pedagogical lesson involved the development of their own TSI-based lesson. Thus, there were only two lessons from which modifications were made in Module 4.

As shown in Table II-6, across all teachers (N = 28) there were a total of 14 lessons with an average of 11 lesson per teacher. Across all teachers and all lessons, 30.4% of the time no modifications were made to the TSI lessons. When modifications were made (an average of about 70% of the time) the highest percentage of modifications were made because of class time (48.4%), followed by age of students (17.8%), student characteristics (13.8%), management issues (12.7%), number of students (10.8%), supplies (10.7%), and classroom constraints and other reasons both 8.6%.

The high school teachers (n = 11) made the fewest modifications across all lessons—perhaps this is explained by the TSI Aquatic curriculum being geared towards 9th grade. And when modifications were made, class time was again the most often reported reason for the modification, followed by supplies and management issues (Table II-7).

Table II-6

Percentage of Modifications Made by All Teachers to Activities by Module in Cohorts 4 and 5

Module	*N*[a]	Activity	Zero modifications made	Age of students	No. of students	Classroom constraints	Class time	Student characteristics[b]	Management issues	Supplies	Other
	28	Practices of Scientists[c]	21.4%	28.6%	7.1%	10.7%	53.6%	17.9%	3.6%	0.0%	17.9%
	28	Density Bag[c]	21.4%	21.4%	10.7%	28.6%	53.6%	14.3%	25.0%	28.6%	14.3%
1	23	Soda and Scientific Reasoning[d]	17.4%	17.4%	4.3%	17.4%	47.8%	26.1%	13.0%	30.4%	8.7%
	5	Kinesthetic Moon Model[d]	40.0%	0.0%	20.0%	0.0%	60.0%	0.0%	20.0%	0.0%	0.0%
		Module 1 average:	25.1%	16.8%	10.6%	14.2%	53.7%	14.6%	15.4%	14.8%	10.2%
	28	PM of Scientific Practice[c]	32.1%	14.3%	7.1%	3.6%	42.9%	21.4%	3.6%	0.0%	21.4%
	28	Water Properties[c]	21.4%	17.9%	7.1%	7.1%	53.6%	14.3%	14.3%	21.4%	14.3%
2	17	Electrolysis[d]	35.3%	17.6%	0.0%	0.0%	41.2%	11.8%	5.9%	5.9%	17.6%
	13	Conductivity[d]	30.8%	23.1%	7.7%	7.7%	46.2%	15.4%	23.1%	23.1%	0.0%
		Module 2 average:	33.0%	20.4%	3.8%	3.8%	43.7%	13.6%	14.5%	14.5%	8.8%
	28	Scientific Language[c]	10.7%	28.6%	3.6%	3.6%	53.6%	17.9%	3.6%	0.0%	17.9%
	20	Microevolution[d]	45.0%	25.0%	5.0%	5.0%	35.0%	20.0%	0.0%	0.0%	5.0%
3	18	Phases and Modes (PM)[e]	27.8%	11.1%	0.0%	0.0%	22.2%	16.7%	16.7%	5.6%	11.1%
	16	Fish Form and Function	37.5%	12.5%	6.3%	12.5%	43.8%	12.5%	18.8%	25.0%	18.8%
		Module 3 average:	36.8%	16.2%	3.8%	5.8%	33.7%	16.4%	11.8%	10.2%	11.6%
	28	Sampling for Abundance[c]	25.0%	21.4%	28.6%	14.3%	64.3%	10.7%	0.0%	3.6%	3.6%
4	28	Sampling Design[c]	28.6%	14.3%	21.4%	7.1%	60.7%	10.7%	17.9%	3.6%	3.6%
		Module 4 average:	26.8%	17.9%	25.0%	10.7%	62.5%	10.7%	8.9%	3.6%	3.6%
		Average % of modifications made	30.4%	17.8%	10.8%	8.6%	48.4%	13.8%	12.7%	10.7%	8.6%

Note. [a]The *N* reflects the number of teachers who completed each reflection. [b]Student characteristics such as SPED. [c]This was a mandatory TSI activity (content or pedagogy, depending on the activity) that all teachers implemented. [d]This was a choice activity. Teachers implemented at least one choice TSI activity in each module. [e]This was a choice TSI pedagogy activity provided at teachers' request to give teachers a second opportunity to teach the TSI Phases and the Modes to their students. [f]In Module 4, the pedagogical lesson required the teachers to create their own lesson based on TSI pedagogy rather than modifying a mandatory TSI lesson, therefore, no modifications were made to this lesson.

The middle school teachers (n = 14) made the highest percentage of modifications. As with the high school teachers, class time was the most frequent reason for making a modification. Followed by age of students and number of students (See Table II-8).

Lastly, the elementary school teachers (n = 3) made no modifications to TSI lessons 27.5% of the time. When modifications were made, teachers reported it was due to age of students and amount of class time available (Table II-9.)

To get a better understanding about how the activities were implemented in the classroom, we provided an item on the activity reflection that had teachers indicate how the activity was implemented. The options were: (a) Used this TSI activity instead of a different lesson or activity that covered similar concepts (e.g. you swapped in this TSI activity for a different activity in your curriculum), (b) Implemented this TSI activity as a "fun" activity (e.g. before a holiday or weekend), (c) Built a new lesson progression around this TSI activity, (d) Used this activity in the same lesson progression presented in the workshop, and (e) Other. In Table II-10, we present the percentages of how the teachers incorporated their activities into their curriculum across each of the four Modules. The results in Table II-10 show that the teachers built a new lesson progression around the activity at the highest rate (32.1%), followed by using the activity instead of a different lesson to cover a similar concept.

We found the dominance of modifications due to time constraints somewhat expected as we recognize that our TSI lessons take more than a single (average 45 minute) class period to implement. The teachers with the flexibility to extend the TSI lessons over several class periods made fewer modifications; however, it was generally the elementary school teachers who had the most flexibility but had the highest percentage of modifications made because of the age of the students. In future PD implementation, we therefore plan to explain time requirements more fully so a higher percentage of teachers are prepared and able to dedicate sufficient time to each TSI lesson implementation. Modification for age was expected from the elementary and middle school teachers, because the curriculum used in the PD is written for high school students. Surprisingly, middle school teachers made more overall modifications than elementary school teachers. These results must be viewed with caution, however, as the sample was small (n = 3) compared to both middle (n = 14) and high (n = 11) school teachers. The reason for elementary school teachers' fewer modifications (as compared to middle school teachers) appeared to be their greater flexibility in content and time. In future cohorts we would like to have a more uniform distribution by grade level so as to provide lessons with more appropriate content for the target student groups. Modifications because of supplies were somewhat surprising because we provided all necessary supplies to the teachers. Furthermore, comments gathered during the end-of-year interviews with Cohort 4 and 5 teachers suggest that they were thankful for, and found it very helpful with being able to implement the activities, as a result of the supplies provided.

Table II-7

Percentage of Modifications Made by High School Teachers to Activities by Module in Cohorts 4 and 5

Module	*N*[a]	Activity	Zero modifications made	Age of students	No. of students	Classroom constraints	Class time	Student characteristics[b]	Management issues	Supplies	Other
	11	Practices of Scientists[c]	36.4%	18.2%	0.0%	0.0%	36.4%	18.2%	0.0%	0.0%	9.1%
	9	Density Bag[c]	33.3%	0.0%	0.0%	0.0%	33.3%	22.2%	11.1%	0.0%	11.1%
1	11	Soda and Scientific Reasoning[d]	36.4%	9.1%	0.0%	27.3%	36.4%	9.1%	0.0%	36.4%	18.2%
	2	Kinesthetic Moon Model[d]	0.0%	0.0%	50.0%	0.0%	100.0%	0.0%	50.0%	0.0%	0.0%
		Module 1 average:	26.5%	6.8%	12.5%	6.8%	51.5%	12.4%	15.3%	9.1%	9.6%
	11	PM of Scientific Practice[c]	273%	0.0%	0.0%	0.0%	45.5%	27.3%	0.0%	0.0%	0.0%
	11	Water Properties[c]	36.4%	0.0%	0.0%	0.0%	27.3%	18.2%	9.1%	36.4%	18.2%
2	6	Electrolysis[d]	66.7%	0.0%	0.0%	0.0%	0.0%	16.7%	0.0%	0.0%	16.7%
	6	Conductivity[d]	33.3%	0.0%	0.0%	0.0%	50.0%	0.0%	16.7%	16.7%	0.0%
		Module 2 average:	40.9%	0.0%	0.0%	0.0%	30.7%	15.5%	6.4%	13.3%	8.7%
	11	Scientific Language[c]	9.1%	9.1%	0.0%	0.0%	54.5%	18.2%	0.0%	0.0%	18.2%
	8	Microevolution[d]	62.5%	0.0%	0.0%	0.0%	37.5%	12.5%	0.0%	0.0%	12.5%
3	7	Phases and Modes (PM)[e]	42.9%	14.3%	0.0%	0.0%	14.3%	28.6%	14.3%	14.3%	0.0%
	7	Fish Form and Function	57.1%	0.0%	0.0%	0.0%	28.6%	14.3%	0.0%	28.6%	0.0%
		Module 3 average:	42.9%	5.8%	0.0%	0.0%	33.7%	18.4%	3.6%	10.7%	7.7%
	11	Sampling for Abundance[c]	36.4%	0.0%	9.1%	9.1%	54.5%	18.2%	0.0%	0.0%	0.0%
4	11	Sampling Design[c]	54.5%	0.0%	9.1%	27.3%	9.1%	0.0%	0.0%	0.0%	0.0%
		Module 4 average:	45.5%	0.0%	9.1%	18.2%	31.8%	9.1%	0.0%	0.0%	0.0%
		Average % of modifications made	38.9%	3.2%	5.4%	6.3%	36.9%	13.8%	22.6%	25.1%	20.2%

Note. [a]The *N* reflects the number of teachers who completed each reflection. [b]Student characteristics such as SPED. [c]This was a mandatory TSI activity (content or pedagogy, depending on the activity) that all teachers implemented. [d]This was a choice activity. Teachers implemented at least one choice TSI activity in each module. [e]This was a choice TSI pedagogy activity provided at teachers' request to give teachers a second opportunity to teach the TSI Phases and the Modes to their students. [f]In Module 4, the pedagogical lesson required the teachers to create their own lesson based on TSI pedagogy rather than modifying a mandatory TSI lesson, therefore, no modifications were made to this lesson.

Table II-8

Percentage of Modifications Made by Middle School Teachers to Activities by Module in Cohorts 4 and 5

Module	*N*[a]	Activity	Zero modifications made	Age of students	No. of students	Classroom constraints	Class time	Student characteristics[b]	Management issues	Supplies	Other
	14	Practices of Scientists[c]	14.3%	28.6%	14.3%	21.4%	57.1%	21.4%	0.0%	0.0%	21.4%
	14	Density Bag[c]	7.1%	21.4%	21.4%	35.7%	78.6%	21.4%	50.0%	28.6%	14.3%
1	11	Soda and Scientific Reasoning[d]	0.0%	27.3%	9.1%	36.4%	63.6%	36.4%	18.2%	54.5%	9.1%
	3	Kinesthetic Moon Model[d]	66.7%	0.0%	0.0%	0.0%	33.3%	0.0%	0.0%	0.0%	0.0%
		Module 1 average:	22.0%	19.3%	11.2%	23.4%	58.2%	19.8%	17.0%	20.8%	11.2%
	14	PM of Scientific Practice[c]	28.6%	21.4%	14.3%	7.1%	50.0%	21.4%	7.1%	0.0%	42.9%
	14	Water Properties[c]	14.3%	21.4%	14.3%	14.3%	71.4%	14.3%	21.4%	7.1%	14.3%
2	9	Electrolysis[d]	11.1%	22.2%	0.0%	0.0%	77.8%	11.1%	11.1%	11.1%	22.2%
	5	Conductivity[d]	40.0%	40.0%	20.0%	20.0%	40.0%	40.0%	40.0%	40.0%	0.0%
		Module 2 average:	23.5%	26.3%	12.1%	10.4%	59.8%	21.7%	19.9%	14.6%	19.8%
	14	Scientific Language[c]	7.1%	35.7%	7.1%	7.1%	57.1%	21.4%	7.1%	0.0%	21.4%
	10	Microevolution[d]	30.0%	40.0%	10.0%	10.0%	40.0%	30.0%	0.0%	0.0%	30.0%
3	9	Phases and Modes (PM)[e]	11.1%	0.0%	0.0%	0.0%	33.3%	11.1%	22.2%	0.0%	22.2%
	7	Fish Form and Function	14.3%	28.6%	14.3%	28.6%	71.4%	14.3%	42.9%	28.6%	28.6%
		Module 3 average:	15.6%	26.1%	7.9%	11.4%	50.5%	19.2%	18.1%	7.1%	25.6%
	14	Sampling for Abundance[c]	14.3%	28.6%	50.0%	21.4%	71.4%	7.1%	0.0%	7.1%	7.1%
4	14	Sampling Design[c]	7.1%	21.4%	35.7%	14.3%	92.9%	14.3%	35.7%	7.1%	7.1%
		Module 4 average:	10.7%	25.0%	42.9%	17.9%	82.1%	10.7%	17.9%	7.1%	7.1%
		Average % of modifications made	18.0%	24.2%	18.5%	15.8%	62.6%	17.9%	18.2%	12.4%	15.9%

Note. [a]The *N* reflects the number of teachers who completed each reflection. [b]Student characteristics such as SPED. [c]This was a mandatory TSI activity (content or pedagogy, depending on the activity) that all teachers implemented. [d]This was a choice activity. Teachers implemented at least one choice TSI activity in each module. [e]This was a choice TSI pedagogy activity provided at teachers' request to give teachers a second opportunity to teach the TSI Phases and the Modes to their students. [f]In Module 4, the pedagogical lesson required the teachers to create their own lesson based on TSI pedagogy rather than modifying a mandatory TSI lesson, therefore, no modifications were made to this lesson.

Table II-9

Percentage of Modifications Made by Elementary School Teachers to Activities by Module in Cohorts 4 and 5

Module	*N*[a]	Activity	Zero modifications made	Age of students	No. of students	Classroom constraints	Class time	Student characteristics[b]	Management issues	Supplies	Other
	3	Practices of Scientists[c]	0.0%	66.7%	0.0%	0.0%	100.0%	0.0%	33.3%	0.0%	33.3%
	3	Density Bag[c]	3.6%	66.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1	3	Soda and Scientific Reasoning[d]	3.7%	33.3%	0.0%	0.0%	33.3%	0.0%	0.0%	33.3%	0.0%
	0	Kinesthetic Moon Model[d]	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Module 1 average:	1.8%	41.7%	0.0%	0.0%	33.3%	0.0%	8.3%	8.3%	8.3%
	3	PM of Scientific Practice[c]	66.7%	33.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	Water Properties[c]	0.0%	66.7%	0.0%	0.0%	66.7%	0.0%	0.0%	33.3%	0.0%
2	2	Electrolysis[d]	50.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	Conductivity[d]	0.0%	50.0%	0.0%	0.0%	50.0%	0.0%	0.0%	0.0%	0.0%
		Module 2 average:	29.2%	50.0%	0.0%	0.0%	29.2%	0.0%	0.0%	8.3%	0.0%
	3	Scientific Language[c]	33.3%	66.7%	0.0%	0.0%	33.3%	0.0%	0.0%	0.0%	0.0%
	2	Microevolution[d]	50.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3	2	Phases and Modes (PM)[e]	50.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	Fish Form and Function	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	50.0%
		Module 3 average:	45.8%	41.7%	0.0%	0.0%	8.3%	0.0%	0.0%	0.0%	12.5%
	3	Sampling for Abundance[c]	33.3%	66.7%	0.0%	0.0%	66.7%	0.0%	0.0%	0.0%	0.0%
4	3	Sampling Design[c]	33.3%	33.3%	0.0%	0.0%	33.3%	0.0%	0.0%	0.0%	0.0%
		Module 4 average:	33.3%	50.0%	0.0%	0.0%	50.0%	0.0%	0.0%	0.0%	0.0%
		Average % of modifications made	27.5%	45.8%	0.0%	0.0%	30.2%	0.0%	2.1%	4.2%	5.2%

Note. [a]The *N* reflects the number of teachers who completed each reflection. [b]Student characteristics such as SPED. [c]This was a mandatory TSI activity (content or pedagogy, depending on the activity) that all teachers implemented. [d]This was a choice activity. Teachers implemented at least one choice TSI activity in each module. [e]This was a choice TSI pedagogy activity provided at teachers' request to give teachers a second opportunity to teach the TSI Phases and the Modes to their students. [f]In Module 4, the pedagogical lesson required the teachers to create their own lesson based on TSI pedagogy rather than modifying a mandatory TSI lesson, therefore, no modifications were made to this lesson.

Table II-10
Percentage of Cohort 4 and 5 Teachers' Incorporation of Activity Into Their Curriculum by Module (N=28)

How teacher incorporated the activity into their curriculum	Mod 1	Mod 2	Mod 3	Mod 4	All Mods
Used this TSI activity instead of a different lesson or activity that covered similar concepts (e.g. you swapped in this TSI activity for a different activity in your curriculum)	15.5%	26.7%	21.7%	25.3%	22.3%
Implemented this TSI activity as a "fun" activity (e.g. before a holiday or weekend)	28.6%	11.6%	20.5%	18.1%	19.7%
Built a new lesson progression around this TSI activity	32.1%	34.9%	30.1%	31.3%	32.1%
Used this activity in the same lesson progression presented in the workshop	16.7%	17.4%	14.5%	21.7%	17.6%
Other	7.1%	9.3%	13.3%	3.6%	8.3%

Other modifications (e.g. number of students, classroom constraints, student characteristics, and management issues) seem appropriate to the implementation of lessons in any given environment and/or subject, especially considering the range of courses taught by teachers in our PD.

Aquatic Science Content

Feedback from our teachers indicated that aquatic science provided a cohesive content umbrella that made the PD accessible to a wide variety of educators. Educators, who taught a range of subjects, from earth and space science to chemistry, applied to participate in and completed the PD. For each aquatic science activity, over 85% of the teachers from all of these disciplines reported they would do the activity again. There was also a high positive correlation between the teachers' self-report of the extent to which they connected the activities to the ocean and their perceptions of how much connecting the activity to the ocean engaged their students (Cronbach coefficient $\alpha = .87$). Although we believe that understanding aquatic science is essential to developing scientifically literate global citizens connected by the world ocean, we also believe that similar overarching content, like climate change, would also attract a diverse group of participants. In the future, we will look to connect content explicitly with the Next Generation Science Standards (which were not released until the conclusion of this project).

Implementation of TSI Pedagogy

The disciplinary form of inquiry-based teaching espoused by the TSI philosophy advocates students learning science concepts through the process of doing science. We followed this principle by teaching metacognition through aquatic science content, using context to generate the thought processes needed for metacognitive reflection. The TSI Aquatic format of a year-long, modular PD permitted the scaffolding of metacognitive strategies and TSI pedagogy, including the use of the language of the TSI phases and modes, along with implementation and reflection components.

Although the capability to use metacognitive strategies generally develops with age and increasing prior knowledge (Brown & DeLoache, 1978), students and teachers vary in metacognitive ability. Prior to the TSI Aquatic PD, use of metacognitive strategies was not a familiar component of our participant teachers' practice. At the start of Module 1, it was common for both new and seasoned teachers to be unfamiliar with the concept of metacognition. Before our teachers could help their students become more metacognitive, they needed to understand the significant role that awareness and control of one's thought processes plays in understanding the scientific process and acquiring scientific knowledge. We began this process by acknowledging that students at all levels, including teachers, have room to improve in their assessment of their skills and knowledge and manage their learning abilities (Brown, Bransford, Campione, & Ferrara, 1983; Hacker et al., 2000; Kruger & Dunning, 1999; Pascarella & Terenzini, 2005). Using this perspective, we were able to create a community of teachers, from various backgrounds, content knowledge levels, and pedagogical experience, focused on using metacognition to better their teaching practice in order to more effectively teach science as a discipline.

Previous research has indicated that metacognitive skills are difficult to report and assess because they often develop in the absence of conscious reflection (Schraw, Crippen, & Hartley, 2006). The TSI Aquatic PD gave teachers, and their students, a common language to communicate the process of science. The TSI terminology, together with the unique reflective TSI phase diagram, generated an awareness, through critical observation and reflection, of the multi-directional process of knowledge acquisition that occurs during a classroom inquiry. This awareness of thought processes is a crucial component in becoming more metacognitive (see Schraw et al., 2006), and is a factor in the development of self-regulation skills as students with better self-regulation skills are able to learn more efficiently and report higher levels of academic satisfaction (Pintrich, 2000; Zimmerman, 2000).

TSI Lesson Plans and Reflection

The TSI phase diagram, as introduced in Ch. I of this report, was used to both plan and reflect on learning trajectories. Teachers used the TSI phase diagram to diagram how their students progressed through activities. By carefully observing and documenting a group of students, teachers showed new awareness of the nuances of the scientific process in their classroom. This understanding of the fluid cognitive movement between phases was described by one teacher as "students moved into the investigation stage when they worked on [the] worksheet…This activity had a lot of discussion which moved them into the instructional phase…They moved into interpretation as they decided on a final answer, as they were doing this they moved into instruction as well, with much discussion…". By the end of the program, teachers seemed to have a better understanding of the fluid and multidirectional nature of scientific inquiry, describing how students engaged in learning "move in and out of the phases and just keep going."

Over the course of the project, we found that teachers needed more time working with phases, so we moved the planning with phases from Module 4 to Module 2, so that

teachers practiced planning with the phases for three modules (Modules 2-4). The lesson planning was scaffolded to build increasing use of TSI pedagogy, but plans always included general objectives, goals, logistics, etc. (see scaffolding in Table II-12 and lesson plans in Appendix A). Interestingly, the results from the activity reflection (see chapters IV and V) provide good evidence that teachers' self-efficacy with guiding their students through the phases steadily increased between Module 1 and 4, suggesting that our decision to introduce the phases earlier in the PD had a positive effect on teachers' perceived ability to implement the phases successfully. Along with the shift in planning, we stopped asking teachers to reflect using TSI phase diagrams after Module 1. Teachers did continue to reflect on their activities online, with activity-specific reflections that scaffolded over the course of the modules.

Table II-12
TSI pedagogy as metacognitive tool in teacher lesson planning, reflections, and classroom implementation

Module	Cohorts 2-3			Cohorts 4-5		
	Planning[a]	Reflection[a]	Classroom Implementation	Planning[a]	Reflection[a]	Classroom Implementation
1	Planned with TSI modes mind	Used TSI phase diagram as to infer students' metacognitive processes + Completed online reflection focused on TSI pedagogy		Planned with TSI modes in mind	Use TSI phase diagram to infer students' metacognitive processes + Completed online reflection focused on TSI pedagogy	
2	*Same as Module 1*	*Module 1* + Narrative description of diagram using TSI language		Planned using TSI phases and modes, described how would lead students through phases	Completed online reflection focused on TSI pedagogy	Taught students TSI phases using metacognitive activity. (*Optional*) Teacher students TSI modes
3	*Module 1* + Planned TSI questioning strategies	*Same as Module 2*	Taught TSI phases to students using metacognitive activity	*Module 2* + Planned TSI questioning strategies	*Same as Module 2*	Options: *If had not already*, teach students TSI modes, re-teach both phases and modes to students if desired, or teach 3rd content activity
4	Planned using TSI phases, modes and questioning strategies.	*Same as Module 2*	Taught TSI modes to students using metacognitive activity	*Module 3* + TSI practices of inquiry teaching strategies	*Same as Module 2*	Cover TSI phases and modes in own lesson created following TSI pedagogy

[a]For each of the TSI activities implemented: twelve total (three activities per module).

In addition, preparing and presenting a PowerPoint on one of their lessons (once per module) was also an important reflection (and sharing) tool. PowerPoint prompts were also scaffolded by modules, and facilitators took extensive notes (As side note, we found that three facilitators were needed at the initial blackboard session – one running, one to take notes, and one for tech help. In the later two modules, we were able to transition to two facilitators).

The reflective TSI phase diagram gave teachers the opportunity to utilize their metacognitive skills and critically observe their students process of knowledge acquisition. Categorizing classroom events into TSI phases through the use of diagrams and reflections provided a format for teachers to communicate how their students acquired knowledge during an activity. Teachers recognized the value of the TSI phase diagram as a pedagogical tool to monitor student learning. One teacher commented that she "noticed that most students spent the majority of their time in the investigation/interpretation phases because they were continually trying new tests and evaluating their work." She went on to say, "I would have encouraged this [alternation between investigation and interpretation] if I had not seen it," indicating that her observation of students' thought processes allowed her to not only observe, but also to assess and modify her role as instructor by documenting her students' progression through the TSI phases of inquiry, ultimately helping her achieve her teaching goals.

In addition, there was evidence that teachers with lower science content knowledge developed a deeper, richer understanding of scientific inquiry through thoughtful lesson planning and reflections. For example, teachers tended to begin the PD with the assumption that instruction requires the teacher, and they moved toward categorizing instruction as "students completing lab questions together" and "(planned) student to student discussion."

TSI With Students

Teachers used the TSI metacognition pedagogy activity to teacher TSI to their students. Initially, many teachers and students had trouble with the TSI metacognition activity. One teacher described this struggle; "The most difficult part of this lesson was getting students to think about their thinking. It was difficult to explain as there is SO much to it–just like it was for us when we learned it…so I felt their pain, but I also know that as they get familiar with it, it will become easier." Some teachers dealt with this difficulty by circumventing the intent of the activity; they described and assigned TSI phases to specific portions of an activity rather than allowing their students to recognize and categorize their own actions and thoughts. Other teachers supported student understanding by teaching the TSI phases as science vocabulary words, sharing examples of their own reflective TSI phase diagrams with their students, and allowing students to

work together in preparing student-generated phase diagrams. These teachers noted that once students "got the hang of it (they) started talk[ing] about how interesting it was that they spent a lot of time in one or the other phases."

For the final two modules, we moved TSI instruction to students from beginning in Module 3 to beginning in Module 2, and had teachers repeat the TSI metacognition activity. When teachers repeated the activity, students were more familiar with the language of TSI and the process of the activity. One teacher noted that this time "following the procedures for the metacognition activity made guiding students through the TSI phases much simpler. Students wrote their thoughts and actions down. They are improving their written communication, but they still have room to improve on details. I handed out the worksheet identifying the different phases of instruction, initiation, invention, investigation, and interpretation. At this point, matching up the TSI phases [with their thoughts and actions] was much more obvious for most students."

In summary, our experience with the teachers and the results obtained suggest that science education should strive to teach science as inquiry, promote metacognition, and be mindful of the development of epistemic beliefs consistent with effective learning strategies. To that end, we advocate both the explicit scaffolding of metacognitive strategies in PD with teachers and the extension of these strategies from teachers to their students. We believe that scientific literacy is enhanced when students use their metacognitive skills to think critically about, while engaging in, the scientific process.

Consultant Meeting Implementation

Our three external consultants traveled to Hawai‘i to meet with our project team personnel for three days (June 18, 19, and 20, 2012). The timing of our consultant meeting coincided with the end of implementation of all four modules in Cohorts 1, 2, and 3, providing us the opportunity to revise our program (both PD content and delivery in person and via the OLC) as well as our evaluation program prior to our final implementation of the PD, which began in August 2012.

During the consultant meeting, we began with an overview of the project, curriculum and evaluation plan on our first day. On our second day, we covered the OLC and pedagogical aspects of the PD. On our third and final day (Wednesday), we returned to the evaluation plan, instruments, and teacher interviews. We concluded Wednesday afternoon with discussion and feedback. Throughout the process, we also solicited feedback informally through discussion and formally through comment forms.

Overall, the consultant meeting was very successful and something we would like to implement in future projects. We incorporated consultant suggestions when implementing and evaluating our final two cohorts. The in-person consultant meeting of has also fostered increased communication and feedback between project personnel and consultants. The agenda for the meeting is outlined on the next page.

TSIA Consultant Meeting Agenda (Honolulu, HI, June 18th - 20th 2012):

June 18th Content Progression

AM

- Introductions
- Project and Consultant Meeting Overview
- Curriculum Overview
- Curriculum Activity

PM

- Evaluation Plan Overview
- Teacher Content Knowledge Assessments

June 19th Inquiry Progression

AM

- Online Learning Community - Development
- Online Learning Community - Current

PM

- Pedagogical Scaffolding - PD
- Pedagogical Scaffolding - Implementation/Inquiry Knowledge Growth

June 20th Evaluation Synthesis

AM

- Inquiry Instruments
- Global Perspective - Teacher Interviews

PM

- Additional Discussion, Feedback, Wrap-Up

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CHAPTER III
ONLINE LEARNING COMMUNITY

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In this chapter, we (the learning technology—LT—and project teams) discuss the development and assessment of the online learning community (OLC). The goal of this aspect of the project was to develop a useful, relevant OLC that provided a platform where teachers could communicate and share resources online. During the first two years of this project, we focused on the development of the OLC. In the third year, we collected data to assess how people were using the OLC and if they would continue to use it after the project. These efforts have resulted in a curriculum website and OLC that will provide a format for future professional development (PD). We also hope these online tools will foster further teacher communication and collaboration and increase the teaching of aquatic science.

OLC Version 1

Software development

The development of the OLC began in June of 2010. After reviewing several software packages, vBulletin was chosen to serve as the platform for the TSI Aquatic PD OLC. The decision to use vBulletin 4.0 was based on our knowledge of its capabilities and because it provided a content management system. The vBulletin platform satisfied two requirements essential to implementation. The first requirement was that the OLC be accessible in the Hawaii Department of Education (HIDOE) network. HIDOE has significant firewalls in place and blocks many sites that have social networks. vBulletin had been used successfully in past HIDOE projects with teachers and administrators and can be accessed from school classrooms as well as from home. The second requirement was the need for a reliable forum (also known as a discussion board or thread) which was easy to use. vBulletin met the ease-of-use requirement; furthermore, the version we utilized incorporated a new and promising content management system (CMS).

We purchased the license and installed vBulletin on a dedicated Mac server. We spent approximately six weeks learning the intricacies of vBulletin through online guides and community forums. The base URL was http://programs.crdg.hawaii.edu/tsi/.

We needed the TSI Aquatic PD OLC to allow teachers to (a) comment on target activities highlighted in the PD workshops and (b) reply to comments made by their peers. We configured vBulletin to suit the needs of our online community, including making decisions on the website layout, navigational menus, and user permissions. Some programming was used to enable certain functions that we believed would enhance the site's usability. For example, we wanted to embed videos from outside sources such as National Geographic and the Smithsonian Institution, which was not possible without coding.

Characterization of Cohort 1

To better understand our participants' online usage, we administered an introductory computer use questionnaire and a motivation questionnaire to the Cohort 1 teachers. We adapted our motivation questionnaire from Ying Hu's (2008) dissertation study, in which the author developed or adapted instruments addressing motivation, usability, and their interrelationships in a self-paced online learning environment. From this questionnaire we learned that while our Cohort 1 (O'ahu, $N = 14$) teachers all read science articles online and searched for information for use in their teaching online; they had a wide variety of experiences with online environments and Internet tools. Some teachers were very comfortable online. Eight teachers reported being part of a professional online group that was not required by their schools, five teachers watched videos online for work purposes on a regular basis, and three teachers ran their own blog. However, some teachers did not have any experience posting discussions or completing online tutorials, three teachers were not members of any online group, one teacher did not have a personal email address, and none of the teachers listened to web feeds (also known as really simple syndication (RSS) feeds). Less than half of the teachers had participated in a semester-long online course (Table III-1). Because teacher's had such a wide variety of experiences with the Internet, we focused on developing a user-friendly OLC interface that would draw in teachers with less online experience while simultaneously having advanced features that would attract and engage experienced Internet users.

Implementation with Cohort 1

In the OLC, we tracked the number of times a participant posted to the site or participated in a discussion. We found an average of about seven posts per person ($N = 16$, $M = 7.4$, $SD = 2.8$) over ten months, a span that included Modules 1 and 2 of the TSI Aquatic PD, for Cohort 1. During this time, the teachers were required to post in the OLC ten times as part of their participation in the PD. These required posts were in response to prompted questions. Although we agree that the number of posts is not the best metric to use for determining the success of an OLC (Fung, 2004), we expected engagement at least equal to the requirements. One possible reason for the lack of engagement by Cohort 1 in the first year of their PD in the OLC was that these teachers were supplied the full *Exploring Our Fluid Earth* (EOFE) aquatic science curriculum in a full color, paper binder, which may have negatively influenced the need to rely on the OLC. We continued our efforts to increase interaction and instill a sense of community online using the vBulletin OLC with Cohorts 2 and 3.

Implementation with Cohorts 2 and 3

The first version of the OLC using vBulletin was implemented with Cohorts 2 and 3. To increase teacher interaction on the OLC and enhance teacher ownership of their comments, we moved from requiring teachers to respond to structured posts on the OLC to requiring a certain number of posts and peer responses but with no formal prompts. We found that less-structured posting requirements, allowing for more teacher choice, was

Table III-1
Teacher experience with online environments in Cohort 1

Prompt	$N_{teachers}$	Number of teachers with the experience (percent)
Read research article or book online	14	14 (100%)
Searched courses or research-related information online	14	14 (100%)
Accessed course-related information or documents from course management system	14	13 (92.9%)
Posted messages to online course-related discussion groups	14	11 (78.8%)
Had live/synchronous online class session	14	11 (78.8%)
Completed asynchronous online tutorial	14	9 (64.3%)
Completed semester-long online asynchronous course	14	6 (42.8%)
Completed semester-long online synchronous course	14	5 (35.7%)
Completed semester-long online blended course containing both synchronous and asynchronous sessions	14	5 (35.7%)
Completed an online academic program consisting of a number of courses and earned a degree or certificate	14	4 (28.8%)

Note. The results reported here are for the 14 teachers in Cohort 1 on O‘ahu who completed an introductory computer use questionnaire.

important for enhancing OLC use and usability. The teachers in Cohorts 2 and 3 indicated that they would continue to use the OLC beyond the scope of the PD series and that the website was valuable to their teaching. However, at this point the LT and project teams had determined that vBulletin was not as user-friendly as desired and was inappropriate for scaling the project in terms of content and teachers. For example, the teachers reported that commenting on activities, a PD requirement, was very confusing in vBulletin. With a long list of comments associated with each activity, the teacher participants found it challenging to not only locate but also reply to a specific comment made by a peer. In addition, to enhance our ability to do research on the OLC, we needed a powerful and versatile analytics program. Because vBulletin did not allow us to access certain information we needed to analyze OLC usage, we decided to transition the OLC to a more robust CMS.

OLC Version 2

Exploring Our Fluid Earth Curriculum Website

During Fall 2012, the LT and project teams began working collaboratively with the University of Hawai‘i’s College of Education Distance Course Design and Consulting

Group (DCDC). DCDC was tasked with developing a website based on the EOFE curriculum. The content and activities in this aquatic science curriculum were utilized in the TSI Aquatic PD. The EOFE website development was a separate endeavor, originating from Dr. Duncan Seraphin's work in the Curriculum Research & Development Group (CRDG) in partnership with the National Oceanic and Atmospheric Administration (NOAA) and the University of Hawai'i Sea Grant College Program. The EOFE curriculum is based on updated materials from CRDG's *Living Ocean* and *Fluid Earth* texts (Klemm, Pottenger, Speitel, Reed, & Coopersmith, 1990; Klemm, Reed, Pottenger, Porter, & Speitel, 1995). The purpose of the website is to provide teachers, students, and the general public access to science information and activities. Though the EOFE website development, per se, was not a part of this U.S. DOE grant, we saw great potential in leveraging technologies available through the website for the TSI Aquatic PD OLC and began to research how to integrate the OLC into the website.

Transition from vBulletin to Drupal

The vBulletin platform was not as robust as needed to scale the project to include the full EOFE curriculum and a larger teacher community. In addition, we envisioned an online resource that included mechanisms with which to provide more sophisticated OLC features for easier communication and collaboration, more varied types of content to teachers, and advanced search capabilities.

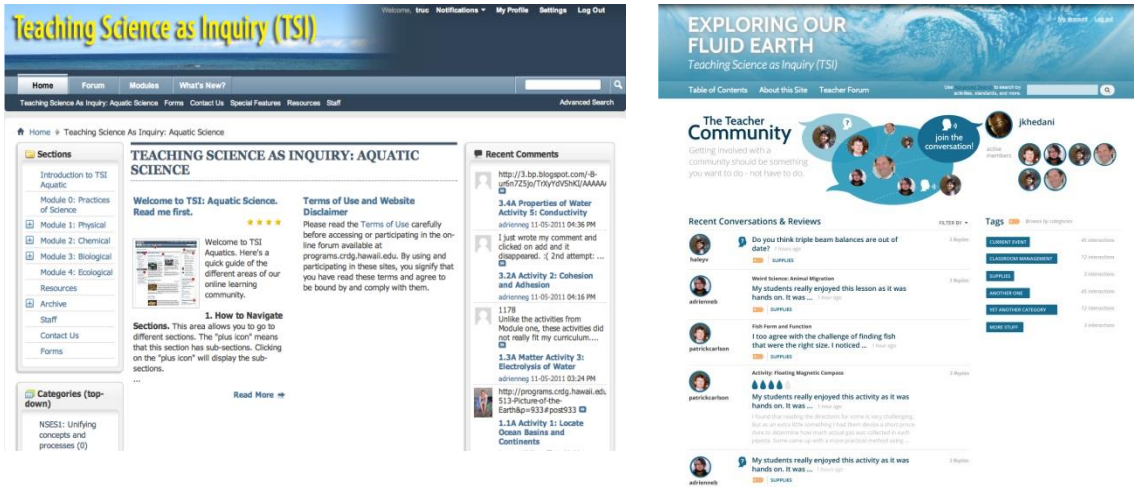
DCDC and the TSI Aquatic PD LT team spent a few months researching a suitable platform for EOFE and eventually decided on Drupal. Drupal had a CMS that would allow us to customize the design of the user interface. We tested Drupal to make sure it met the first requirement of a site—that it functioned in HIDOE schools and would not be blocked by the HIDOE firewall. A few of the TSI Aquatic PD teacher participants tested the EOFE site at their schools; all features were accessible. Drupal also met our second implementation requirement; it was a reliable forum framework (see Table III-2).

In addition to a having a powerful CMS and versatile customization, Drupal offered features for the OLC that the vBulletin platform was missing. Since the CMS feature was new to vBulletin, it did not offer the flexibility to create an easy-to-use and visually pleasing interface. In addition, compared to vBulletin, Drupal content was and is easier to manipulate and organize. Drupal also has a library of add-on features that allow us to customize the look and feel of the EOFE website and OLC (see the comparison of the two platforms in Figure III-1.)

In Drupal, we were able to use the add-on features and programs to incorporate a commenting system with analytics that made it possible to obtain data for OLC research. The Drupal OLC includes both a private PD section in which only the teacher participants in a TSI Aquatic PD can interact, and a public section in which teachers are connected to the larger EOFE site. The private PD section has PD logistic and implementation information as well as the capability for teachers to turn in lesson plans or post questions to their cohort or PD facilitators. The public section of the EOFE site

Table III-2
Online learning community feature comparison in vBulletin and Drupal

Features	vBulletin	Drupal
Customizable user analytics	No	Yes
Customizable search	No	Yes
Organized CMS	Limited	Yes
Customizable CMS user interface and layout	Limited with themes	Yes
Customizable user status and permissions	No	Yes
Forum content and interface manipulation	No	Yes
User checklist/progress list	No	Yes
Organize and search content and comments through tags	No	Yes
Customizable through add-ons/plugins	Limited	Yes



(A) (B)

Figure III-1. OLC Version 1 vBulletin interface (A) compared to OLC Version 2 Drupal interface (B)

has the aquatic science curriculum and public teacher community, through which TSI Aquatic PD teachers could interact with other PD cohorts (Figure III-2 shows the public teacher community). This dedicated public OLC allows teachers to communicate with one another about their use of the online resources.

The EOFE website (exploringourfluidearth.org), including content and the public teacher community, will be open to the public in August 2014. The EOFE website will ultimately have four access levels: (a) the general public, including students; (b) registered teachers allowed access to the online learning community; (c) paid users

allowed access to tutorials and teacher materials; and (d) teachers who are enrolled in TSI PD allowed access to their cohort's private OLC in the PD section of the website.

For the Drupal iteration of the OLC, layout was a key design-driving force. We worked closely with DCDC to address issues of usability and design. For example, the project team suggested that the private OLC PD section needed a different color or shading to distinguish it from the public EOFE website and OLC. This was implemented to allow the participants to visually know which part of the site they were in—the public section or the private PD section.

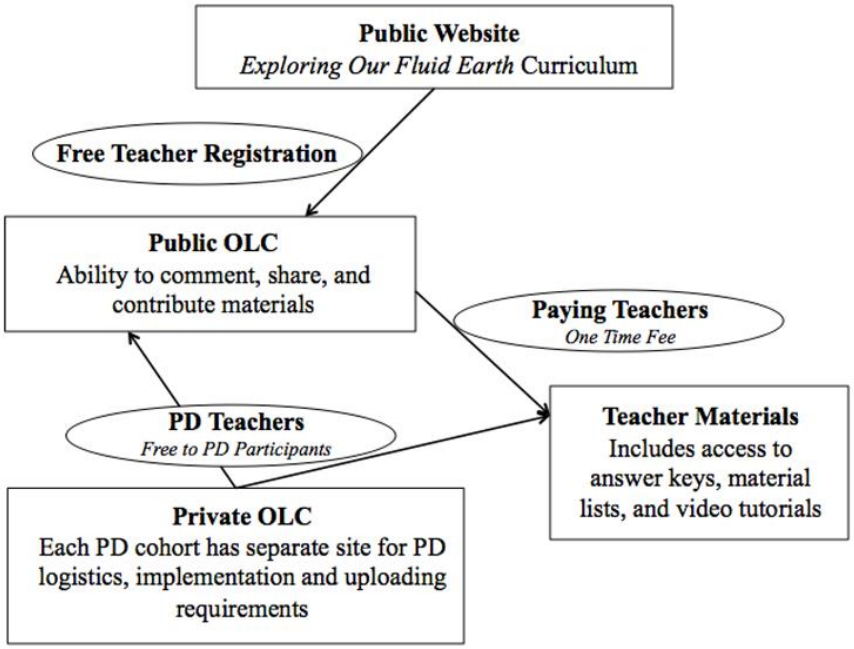


Figure III-2. Diagram of EOFE website and OLCs by access level

Cohorts 4 and 5

Characterization of Cohorts 4 and 5

To understand the teacher participants' online usage, the teachers in Cohorts 4 and 5 (O'ahu and Kaua'i, $N = 28$) were administered an introductory computer use questionnaire and an online motivation questionnaire. The teacher participants reported they were very comfortable using the Internet ($M = 8.39$, $SD = 2.25$, on 1–10 Likert scale where *1* = not comfortable and *10* = very comfortable). Only one teacher did not use Internet resources during classroom instruction or for classroom planning purposes. Eight teachers used the Internet in their classroom once a week or less, 14 used it two-to-three times a week, and 5 teachers used the Internet in their classroom teaching daily. Seven teachers used the Internet for classroom planning purposes once a week or less, 9 used it two-to-three times a week, and 11 used the Internet for classroom planning every day (Table III-3).

The teachers' experience with Internet tools varied. While all of them had read blogs and watched online videos, most read science articles online and searched for information

for use in their teaching online, and seven (25.0%) ran their own blogs, some had no experience with online forums and six (21.4%) did not have a social networking account. More of the teachers had participated in a synchronous online class session than in an asynchronous online tutorial, although only nine had completed a semester-long online blended course and only five had completed an asynchronous course. Five teachers (17.5% of participants) had completed an online academic program consisting of a number of courses and earned a degree or certificate; four of these teachers had completed their master's degrees online (Table III-4.)

Table III-3
Frequency of Internet Use Among Cohort 4 and 5 Participants

Prompt	$N_{responses}$	*M*	*SD*	Min	Max
How frequently do you use resources from the Internet just for your own classroom planning purposes?	28	3.96	1.11	1	5
How frequently do you use resources from the Internet during classroom instruction?	28	3.68	1.02	1	5

Note. These results are for the 28 teachers in Cohorts 4 and 5 on (15 on O'ahu and 13 on Kaua'i) who completed an introductory computer use questionnaire. Response categories ranged from *1* (never) to *5* (daily).

Analysis of the OLC

The analysis of the OLC was based on three core frameworks in educational technology: John Keller's (1987) ARCS Model, Ruth Small's (1997a, 1997b) Website Motivational Analysis, and Taylor & Voigt's (1986) Value-Added Model. In particular, in instructional design research, the ARCS model refers to attention, relevance, confidence, and satisfaction of a learner in regards to the instruction or the material. The analysis focused on (a) understanding how the teachers were communicating and interacting on the OLC, (b) the teachers' use and perceived usefulness of the EOFE website and OLC, and (c) the teachers' continued use of the website after the conclusion of the PD. Data for this analysis were collected from the teacher interactions on the OLC, a mid-PD OLC questionnaire at the end of Module 2, a post-PD OLC questionnaire, and analytics of website use. The two questionnaires were pilot-tested with Cohorts 1–3. For Cohorts 4 and 5, the questions posed in the post-PD OLC questionnaire reflected both components of the EOFE website—the EOFE content and activity information and both the public and private OLC sections, where the teacher interactions occurred.

Cohort 4 and 5 Teacher Interactions on the OLC

Communication among participants is considered an indicator of the ability of a website to sustain a community in the absence of face-to-face interaction. Social network analysis was used to analyze the teacher interactions on the OLC. We focused on how the teachers interacted with each other in the 2,307 page views they made to the EOFE public OLC teacher community (out of 45,991 overall page views to the EOFE site, including visits to the private PD section of the OLC and content areas of the website).

Table III-4
Teacher experience with online environments in Cohorts 4 and 5

Prompt	$N_{teachers}$	Number of teachers with the experience (percent)
Searched for supplemental course content online	28	24 (85.7%)
Read research articles or books online	28	23 (82.1%)
Posted messages to online course-related discussion groups	28	20 (71.4%)
Had live/synchronous online class session	28	17 (60.7%)
Accessed course related information or documents from a course management system	28	16 (57.1%)
Completed asynchronous online tutorial	28	16 (57.1%)
Completed semester-long online asynchronous course	28	12 (42.9%)
Completed semester-long online blended course containing both synchronous and asynchronous sessions	28	9 (32.1%)
Completed an online academic program consisting of a number of courses and earned a degree or certificate	28	8 (28.6%)
Completed semester-long online synchronous course	28	5 (17.9%)

Note. Results are for the 28 teachers in Cohorts 4 and 5 on (15 on Oʻahu and 13 on Kauaʻi) who completed an introductory computer use questionnaire.

We focused our analysis on understanding how information flowed to and from each person using participant activity comments from Cohorts 4 and 5 (Oʻahu II, $N = 15$ and Kauaʻi, $N = 16$) and the project team facilitators ($N = 5$). Thus, in our analysis, we included the comments of the three teachers who started the project but did not complete it. The teachers in these two cohorts were required to post to the OLC 12 times (three times per module). It was a requirement that four of the posts (one of the three required posts per module) be responses to a peer's comment.

We looked at visual depictions of interactions among participants using UCINET analytical software and applying the NetDraw feature to derive Freeman's degree centrality measures. As shown in Figure III-3, engagement with the OLC varied widely. Two central teachers emerged from each Cohort—a teacher from Cohort 4 (Oʻahu II), named teacher O2, and a teacher from Cohort 5 (Kauaʻi), named teacher K11 (see Figure III-3). Figure III-4 is a visual depiction of two ego analyses on each of these central teachers in our OLC. In social network analysis, an ego is an individual focal node. In our analysis, egos are individual teacher participants, but egos can also be groups, organizations, or whole societies (Hanneman & Riddle, 2005).

In social network analysis, actors (in our case individual teacher participants) differ from each other in the number of connections they have and if they received or sent information (Hanneman & Riddle, 2005). Teachers who have a high "in" comment degree value are on the receiving end of comments and are considered to be prominent, or have high prestige, in the social network. Teachers who have a high "out" comment degree value send more information to others than those with lower values.

Teacher O2 had an "in" comment degree value of 15 and an "out" comment degree value of 14. Teacher K11 had an "in" degree value of 20 and an "out" degree value of 6. Teacher O2 had an almost equal number of comments directed "in" to them from other teachers in the social network and posts "out" to teachers. On the other hand, teachers commented "in" to Teacher K11 more than this teacher sent more information "out" to others. In other words, information flow was almost even for one central teacher but more lopsided for the other central teacher. Teacher K11 would be considered the most prominent teacher in our social network.

Over-moderating a site where teachers are encouraged to take control and share expertise may hinder the process of community building. In our PD, the project team acted as website facilitators, but they maintained a peripheral role in the OLC, with one person mostly answering technical questions (Figure III-3). The teachers appeared to interact more with peers from their cohort, and thus from a similar geographic area, than with other cohorts (propinquity). This may indicate the PD was more successful at developing an in-person community than an online community, and the in-person interactions were perpetuated online, rather than the OLC representing a separate robust community that transcended PD cohorts.

The teachers' use of the curriculum and OLC components of the EOFE website. Overall, the teachers found the EOFE site engaging [$N = 28$, $M = 7.04$, $SD = 2.16$ on a Likert-scale, response categories ranged from *1* (strongly disagree) to *10* (strongly agree)]. The teachers also found the website and OLC useful, but the scores on ease of use were lower than we would have liked (Table III-5). The teachers' navigation struggles may have been due to the large scope of content on the site and because of the beta nature of the site during PD participant's use. Based on the teachers' comments, features have been added and improved for the EOFE public release in August 2014.

In terms of usefulness, the teachers felt most strongly that the EOFE curriculum website helped them to refresh their memory about content and activities learned in the TSI Aquatic PD workshops, helped them to incorporate aquatic science concepts into their curriculum, helped them to teach general science concepts to their students, and was relevant to their teaching practice (see Table III-5). When asked to indicate how they used the EOFE curriculum content in their teaching (by checking all that apply), almost all the teachers (96.4%) reported they read content for teaching purposes. To a lesser extent, the teachers reported both printing content directly and reading content for their own interest (that they did not teach about).

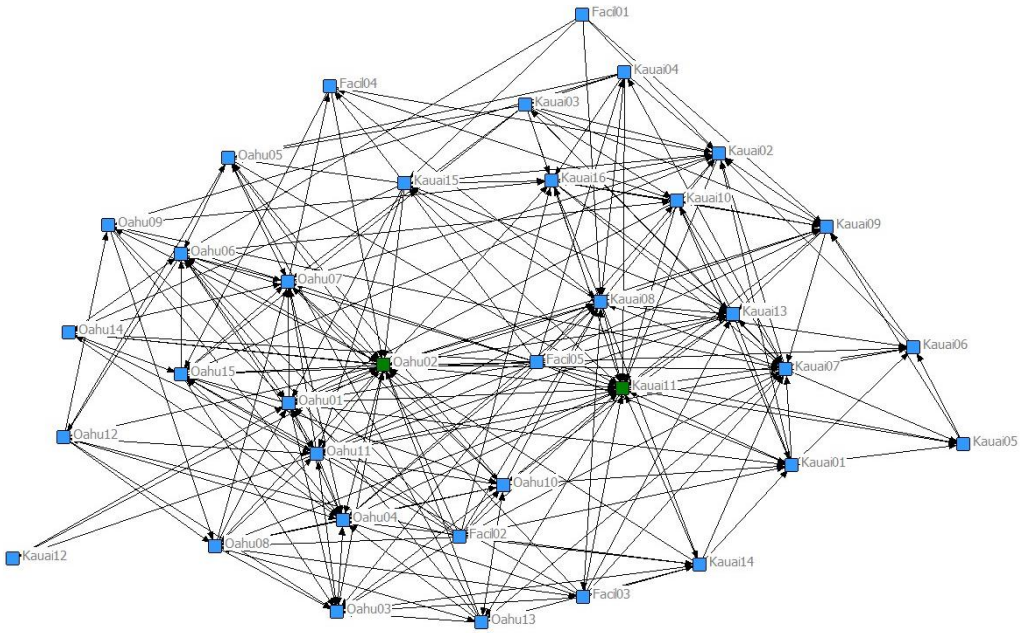
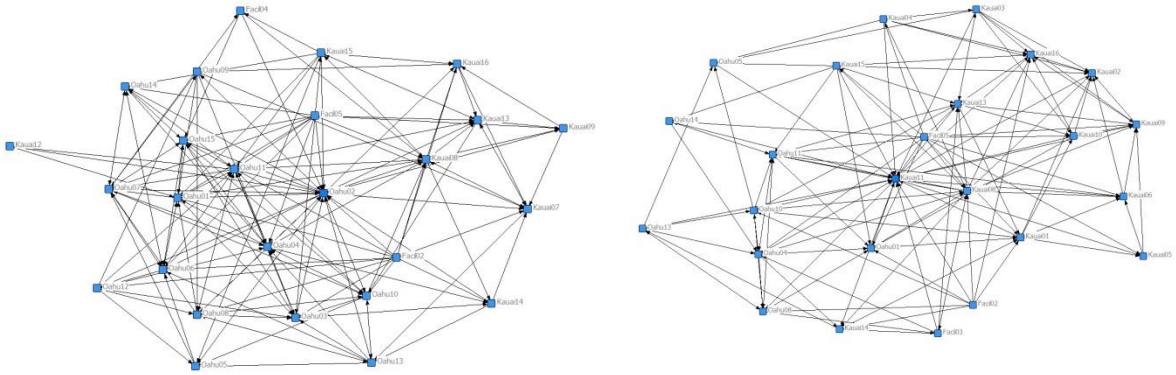


Figure III-3. Social network of the TSI Aquatic PD OLC. Arrows are directional and represent posts from one person to another. The central teachers are in green.



(A) (B)

Figure III-4. Ego networks for Teacher O2 (A) and Teacher K11 (B).

Interestingly, the number of teachers who projected the website in their classroom for students to see increased from 28.6% to 50.0% from mid- to post-PD questionnaires (see Table III-6), suggesting increased use of the EOFE site with students as the PD progressed. On the post-PD OLC questionnaire, eight of the 28 teachers (28.8%) said they used the EOFE curriculum directly with their students. On a Likert-scale of 1–10 (*1* = never, *10* = daily), the average of the eight teachers who used the EOFE with their students was 5.5 (*SD* = 2.27). Although the teachers were required to use the website, they were not required to use it with their students, so we consider over 25% of the teachers using the curriculum in the classrooms to be a promising finding.

Table. III-5

Item-Level Descriptive Statistics of Ease of Use and Usefulness Constructs of the post-PD OLC questionnaire for Cohorts 4 and 5

Construct	Prompt	$N_{responses}$	*M*	*SD*
Ease of Use	I find it easy to upload my work to the EOFE curriculum website.	28	7.39	2.73
	I find it easy to post comments on the EOFE curriculum website.	28	7.04	2.34
	I find it easy to communicate with other teachers on the EOFE curriculum website.	28	6.75	2.17
	The EOFE curriculum website is well organized.	27	6.48	2.69
	I find it easy to navigate the EOFE curriculum website.	28	6.04	2.41
Perception of Usefulness	The EOFE curriculum website helps to refresh my memory about content and activities I learned in the TSI workshops.	28	8.64	1.34
	The topics covered on the EOFE curriculum website help me to incorporate aquatic science concepts into my teaching.	28	8.29	1.67
	The topics covered on the EOFE curriculum website help me to teach general science concepts I need to cover with my students.	28	8.21	1.54
	The EOFE curriculum website is relevant to my teaching practice.	28	8.21	1.74
	The EOFE curriculum website is valuable to my teaching practice.	28	7.96	1.68
	The special features sections of the EOFE curriculum are valuable to me as a learner.	28	7.82	2.02
	The special features sections of the EOFE curriculum are valuable for use in my classroom to capture student interest or extend student learning.	28	7.61	2.04

Note. The results reported here are for the 28 teachers in Cohorts 4 and 5 on (15 on Oʻahu and 13 on Kauaʻi) who completed a post-PD OLC questionnaire. Likert-scale response categories ranged from *1* (strongly disagree) to *10* (strongly agree). Cronbach's α for Ease of Use construct was .90; for Perception of Usefulness it was .95.

In terms of the OLC component of the EOFE website, the teachers reported that they did not always read their peers' comments about activities before implementation, nor did they always read peer comments before posting their own comments (see Table III-7). However, the teachers' ratings of the time they spent interacting with the other teachers online was positive, as was their indication that questions and comments from the other teachers prompted them to reflect on their own teaching strategies (see Table III-7).

Table III-6
Cohort 4 and 5 teachers' reported use of the EOFE website on mid- and post-PD questionnaires

Prompt	$N_{teachers}$	MID-PD Questionnaire	POST-PD Questionnaire
		Number of teachers using EOFE (percent)	Number of teachers using EOFE (percent)
Read content for your teaching	28	27 (96.4%)	27 (96.4%)
Print content or activities directly from the website	28	21 (75.0%)	18 (64.3%)
Read content for your own learning that you do not teach about	28	16 (57.1%)	12 (42.9%)
Copy and paste content from the website	28	12 (42.9%)	13 (46.4%)
Project the website in your classroom	28	8 (28.6%)	14 (50.0%)

Note. Results are for the 28 teachers (15 on Oahʻu and 13 on Kauaʻi) in Cohorts 4 and 5 who completed the post-PD OLC questionnaire.

Most Useful Aspects of OLC and Areas for Improvement

In four open-ended questions from the post-PD OLC questionnaire, we asked the teacher participants about improvements and usefulness of the website. The questions asking about usefulness of the website were, (a) what is your favorite part of the EOFE curriculum website?, and (b) what is the most useful part of the EOFE curriculum website? The questions asking about feedback on improvement were, (a) what modifications would you like to see made to the content part of the EOFE curriculum website?, and (b) what modifications would you like to see made to the sharing, commenting, and interactive part of the EOFE curriculum website?

We analyzed the open-ended responses to the questions using a grounded theory approach (Corbin & Strauss, 2008). A member of the LT team read through the data and coded for emerging themes. A second LT team member verified the code system and evaluated coded segments for agreement. Six themes emerged from the questions through this process (Table III-8).

Of the 28 Cohort 4 and 5 teachers, the majority mentioned that the quality of the content on the EOFE website was both their favorite aspect (18 out of 28 teachers, or 64.3%) as well as the most useful part of the site (21 out of 28 teachers, or 75.0%). The teachers commented on both the quality of the content and the quality of the activities. The teachers also valued the community aspect of the EOFE website, found the feedback from their fellow teachers helpful, and liked the ability to upload their own work.

Table III-7

Item-Level Descriptive Statistics of Peer Interaction and Perception of Usefulness of Peer Interaction Constructs of the post-PD OLC questionnaire for Cohorts 4 and 5

Construct	Prompt	$N_{responses}$	*M*	*SD*
Peer Interaction	I reply to people who respond to my comments.	27	6.56	2.45
	Before implementing an activity in my classroom, I read my peers' comments about the activity online.	28	5.46	2.73
	After I implement an activity in my classroom, I read my peers' comments before I comment on the activity myself.	28	5.29	2.84
Usefulness of Peer Interaction	The interactions I have on the EOFE curriculum website reinforce the TSI teaching and learning pedagogy we are covering in the TSI course.	27	7.44	2.35
	Questions and comments from other participants on the EOFE curriculum website prompt me to reflect on my teaching strategies.	28	7.36	2.29
	The interactions I have on the EOFE curriculum website encourage the integration of aquatic science content into my classes.	28	7.32	2.49
	The time I spend reading and responding to other participants' comments and materials on the EOFE curriculum website is valuable.	28	7.18	2.19
	The responses I receive from other participants on the EOFE curriculum website are valuable.	28	7.00	2.49
	The time I spend commenting and sharing my materials on EOFE curriculum content is valuable.	28	6.71	2.39

Note. Results are for the 28 teachers in Cohorts 4 and 5 on (15 on Oʻahu and 13 on Kauaʻi) who completed a post-PD OLC questionnaire. Likert-scale response categories ranged from *1* (strongly disagree) to *10* (strongly agree). Cronbach's α for Peer Interaction construct was .90; for Usefulness of Peer Interaction it was .95.

The teachers also provided suggestions on how the EOFE website can improve. Regarding content, improvement to the usability of the website was a major theme. Examples of improvements that the teachers suggested to address usability issues included better organizing the website and improving navigation ability, as well as addressing technical maintenance like fixing links and posting bugs (see Table III-8). In response to teacher feedback, for our August 2014 public release of the EOFE website, we have added an advanced search engine to the site, made user posts searchable, and added a search element that allows teachers to search the content by standard.

Table III-8
Major Categories of Themes Identified in the Content Analysis of the Open-Ended Questions in the Post-PD OLC Questionnaire

Categories	$N_{teachers}$	What is your favorite part…?		What is the most useful part…?	
		$N_{comments}$	Percent of comments in a category	$N_{comments}$	Percent of comments in a category
Quality Content	28	18	64.3%	21	75.0%
Community	28	12	42.9%	13	46.4%
Printing	28	5	17.9%	2	7.1%
Ease of access	28	5	17.9%	5	17.9%
Visually pleasing	28	5	17.9%	2	7.1%
Other	28	3	10.7%	1	3.6%

Note. Results are for the 28 teachers (15 on Oahʻu and 13 on Kauaʻi) in Cohorts 4 and 5 who completed the post-PD OLC questionnaire.

Context and frequency of EOFE and OLC site use

For the items about how often and where the teachers use the EOFE website, we found a relatively even split between home and school use on the post-PD OLC questionnaire. The teachers reported using the site regularly, but not daily. In Cohorts 4 and 5, the teachers (N = 27) reported that they used the EOFE site at school an average of 5.93 (SD = 2.57) verses an at home average of 6.97 (SD = 2.50) on a Likert scale of 1–10, where 1 = rarely and 10 = daily.

Community Building Online and In-Person

In two questions from the post-PD OLC questionnaire, we asked the 28 teachers in Cohorts 4 and 5 about their thoughts on the community aspect of the TSI Aquatic PD project in general and in relation to the website and OLC. When asked to what extent the teachers thought a community was effectively built through program (*1* = not effective, *10* = very effective), they indicated that the in-person community (M = 8.29, SD = 2.00) was more successfully built than the online community (M = 6.04, SD = 1.91).

Continued use of the EOFE curriculum and OLC website post-PD

From August 2012 until almost a year post-PD (May 2014), web page views varied dramatically by teacher in Cohorts 4 and 5, from 8,486, which was twice as many page views as the next teacher (3,390), to 499 (N = 28, M = 1594.4, SD = 1518.9). However, there was no correlation between the number of page views and the teacher's perceptions of the value or relevance of the EOFE site to their teaching practice, or if the teachers found the website engaging.

Cohort 4 and 5 teachers' ratings of their intent to use the website at the conclusion of the PD were relatively high on a 1–10 Likert-scale (see Table III-9). We compared the teachers' self-reports in the middle of the program to their self-reports at the end of the program. From mid-way through the project, the teachers indicated they would continue to use the EOFE website after the PD for curriculum content and activities.

Table III-9
Teachers' beliefs on their continued use of the OLC

		Mid Program		Post Program					
I will continue using this OLC …	$N_{teachers}$	*M*	*SD*	*M*	*SD*	*t*-value	*df*	*p*	*Cohen's d*
To interact [a]	28	6.57	2.40	7.78	1.69	3.58	27	.001	1.37
For course activities	28	8.32	2.16	8.61	1.69	1.14	27	.265	0.44
For curriculum content	28	8.21	2.21	8.46	1.60	1.02	27	.316	0.39

Note. Results are for the 28 teachers (15 on Oahʻu and 13 on Kauaʻi) in Cohorts 4 and 5 who completed the mid-PD and post-PD OLC questionnaires. Response categories ranged from *1* (strongly disagree) to *10* (strongly agree). Cronbach's alpha was 0.89. Comparison of mid- to post-program is based on a paired t-test. [a]Paired t-test was statistically significant ($p < 0.05$).

The teachers expressed significantly higher levels of intent to continue to use the website to interact with each other at the end of the program (as compared to mid-PD), indicating that the community aspect of the EOFE site became more important over time (see Table III-3). In addition, at the end of the PD, the teachers reported being highly likely to recommend to EOFE website to others ($N = 28$, $M = 8.43$, $SD = 2.72$ on Likert-scale 1–10 in response to statement "I will recommend the EOFE curriculum website to my colleagues", *1* = strongly disagree, *10* = strongly agree).

In practice, 16 of the 28 teachers in Cohorts 4 and 5, in PDs that ended in June 2013, have continued to use the EOFE website, although not the OLC, in the 2013–2014 school year. As the EOFE site has been under construction and development this past year, and because we know, anecdotally, that at least 5 of the 28 teachers in these cohorts are no longer teaching in traditional K–12 classrooms, we consider the continued use of the site by 16 teachers (57.14%) in our final two cohorts promising.

Conclusions About the OLC

The goal of the TSI Aquatic PD OLC was to develop a useful, relevant OLC that provided a platform where teachers could communicate and share resources online. During the first two years of this project, we focused on OLC development. We developed an OLC that is accessible in the Hawaii Department of Education (HIDOE) network and has a reliable forum framework. The Drupal platform of our OLC provides many avenues for customization, including sophisticated features for ease of communication and collaboration, inclusion of varied types of content, and advanced search capabilities. The OLC is embedded in our EOFE aquatic science curriculum website.

In the third year of the project, we collected data to assess how people were using the OLC and if they would continue to use it after the project. The analysis focused on (a) understanding how the teachers were communicating and interacting on the OLC (b) the teachers' use and perceived usefulness of the EOFE website and OLC, and (c) the teachers' continued use of the website after the conclusion of the PD.

Overall, the teachers found the EOFE site engaging, useful, and relevant to their teaching practice, but the scores on ease-of-use were lower than we would have liked. Some teachers expressed dissatisfaction with the website's organization and navigation. The teachers' navigation struggles may have been due to the large scope of content on the site and because of the beta nature of the site during PD participant's use. Both perceived usefulness and perceived ease of use beliefs impact attitudes towards using a website.

Based on the teachers' comments and feedback, technical issues have been addressed and features have been added and improved for the EOFE public release in August 2014.

At the teacher level, engagement with the OLC varied widely. Some of the teachers interacted much more with their peers than others and emerged as central to the OLC social network. The teachers interacted more with peers from their cohort, and thus from a similar geographic area, than with other cohorts (propinquity). This may indicate the PD was more successful at developing an in-person community than an online community, and the in-person interactions were perpetuated online, rather than the OLC representing a separate robust community that transcended PD cohorts. Although teacher use of the OLC varied, those that spent time online interacting with their peers reported the experience was positive, that the peer feedback was helpful and the other teachers' questions and comments prompted them to reflect on their own teaching strategies.

Almost all of the teachers reported they read EOFE content for teaching purposes. To a lesser extent, the teachers reported printing content from the website and reading it for their own interest (that they did not teach about). Interestingly, the number of teachers who projected the website in their classroom for students to see increased from mid- to post-PD questionnaires, suggesting increased use of the EOFE site with students as the PD progressed. On the post-PD OLC questionnaire 28.8% of the teachers said they used the EOFE curriculum directly with their students. This finding is encouraging because although the teachers were required to use the website in the PD, they were not required to use it with their students, so we consider student use to be an unexpected extension of the PD.

Most of the teachers mentioned that the quality of the content on the EOFE website was both their favorite aspect (18 out of 28 teachers, or 64.3%) as well as the most useful part of the site (21 out of 28 teachers, or 75.0%). The teachers commented on both the quality of the content and the quality of the activities.

We found over the course of the project that longer exposure to the website and OLC significantly increased the likelihood of continued interaction, supporting Wenger et al.'s (2002) notion of mutual commitment. This may be because the teachers needed substantial support at the beginning of the program to use the website as intended. As PD

moves online, it is important for providers to allow time for explicit instruction in how to share experiences and support peers.

The teachers reported they were likely to continue to use the website at the conclusion of the PD. Interestingly, as opposed to their reports of their likelihood to continue to use the website for content and activities, which was already highly likely mid-project; the teachers expressed significantly higher levels of intent to continue to use the website to interact with each other at the end of the PD (as compared to mid-PD). This indicates that the community aspect of the EOFE site became more important over time.

One year after the PD has ended, 57.1% of the teachers are still using, although not commenting, on the website. This may be because the site is being updated and is still under construction. Overall, we conclude that the TSI Aquatic PD's hybrid structure allowed for participant interaction with the material in a variety of ways and offered many avenues for community engagement.

Future OLC Directions

In the future, we plan on improving our OLC by building a more effective online community and integrating and modeling the use of the program website and OLC as more than just a resource.

We are interested in comparing the PD facilitators' perceptions of teacher interactions in the in-person components of the PD and the teachers' use of and interactions on the OLC and curriculum website to see if different aspects of a hybrid PD engage different learners. For example, we hypothesize the teachers who prefer to learn at their own pace may be more engaged online than in the workshops.

As Shen et al. (2008) posited, because we also do not know about additional interactions that may have occurred outside of the OLC, such as communications through emails, other social networks, or even at our own in-person TSI Aquatic PD workshops, we do not know how representative our social network analysis is of participant relationships. Additional data would need to be collected to account for these outside elements. To capture this information, in the future we will consider asking if the participating teachers have taken courses or workshops together, if they teach at the same school, and if they consider another teacher in the workshop a friend.

We are also interested in looking at patterns between and triangulating data from the website and other PD instruments. For example, by comparing website analytic data with the findings from teacher content assessments we can determine if there is a relationship between the number of "hits" online and the mastery of content. We posit that the teachers who are weaker in content mastery may depend more on the availability of content on the site or feedback and advice from their peers.

Finally, we are interested in comparing navigation of the website between participant teachers who have taken the PD and those external to the project. We are delaying this further analysis until the EOFE site becomes available to the public in August 2014. These analyses will have implications for professional development facilitation as well as contributions to best practices in OLC development.

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CHAPTER IV
EVALUATION PLAN AND METHODS

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In this chapter, we (the evaluation team) discuss the evaluation of the TSI Aquatic project, including (a) its approach, purposes, and evaluation questions; (b) the overall evaluation plan; and (c) the evaluation methods and results. We briefly describe the instruments, referring the reader to Appendix B for a more detailed outline of their development and administration; Appendix C includes the instruments (these instruments may be freely reproduced and distributed for non-profit educational purposes). For efficiency and clarity, we present the methods and results together for each instrument; in Chapter V, we present a discussion of the findings organized by evaluation question.

Approach, Purposes, and Evaluation Questions

The evaluation of the TSI Aquatic project was an eclectic, mixed-method study.1 It used instruments for collecting both formative-evaluation and summative-evaluation information (some, such as observations of the various PD components, were for formative-evaluation information only). During the first two years, the primary task of the evaluation team was to identify existing and develop new data-collection methods, try them out with the first three cohorts (Years 1 and 2) of the study, and provide the project team with formative-evaluation feedback in regular formal meetings and through informal discussions. In the third year, the evaluation team collected data for long-term formative evaluation feedback (to inform future endeavors in implementing the TSI Aquatic program, after the completion of this project) and implemented the summative component of the study.

The study addressed the evaluation questions that were stated in the project proposal, revised to reflect the refinements in focus of key aspects of the PD. The questions addressed the project training, the project implementation, and the effects of the project on teacher and student learning. They were

1. To what extent was the PD structured in the intended manner?
2. To what extent did the teachers find the PD valuable and relevant to ongoing practice?
3. To what extent did the teachers improve in their pedagogical content knowledge, self-efficacy in teaching science, and metacognition in teaching?
4. To what extent did the teachers gain in their understanding of inquiry-based science teaching?
5. To what extent did the teachers gain knowledge about aquatic science content?
6. To what extent did the teachers implement the project activities in the intended manner with fidelity?
7. To what extent did the students gain in their nature-of-science understanding and in their aquatic-science-content knowledge?

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[1] We use the word *evaluation* instead of *research* throughout the report to highlight the formative-evaluation and summative-evaluation foci of the study and to distinguish the evaluative activities from the project team's research and development activities.

Evaluation Design and Methods

The types of data-collection instruments used during the study included a broad array scheduled throughout an entire year of the PD. These types were observations, questionnaires, interviews, content and inquiry-based science assessments for teachers and for students, and a teacher reflection (a kind of log). As is displayed in Table IV-1, for five of the seven evaluation questions, more than one kind of data-collection method was employed. By the final year of the project, we had developed and pilot-tested a total of 15 instruments: two protocols for informally observing PD activities, one during the workshops and one during the follow-ups; a teacher background questionnaire; a post-workshop teacher questionnaire; a post-follow-up teacher questionnaire; teacher science content assessments (one per module, counted here as one instrument); an inquiry-teaching assessment; a three-scale teacher questionnaire (addressing pedagogical content knowledge, self-efficacy in science teaching, and metacognition in teaching, counted here as three instruments); the teacher reflection (multiple per module, counted here as one instrument); a teacher interview; a teacher questionnaire at the conclusion of each cohort; a student content assessment; and a student nature-of-science assessment.

Of the 15 instruments, we used the two PD observation protocols and the post-follow-up teacher questionnaire for collecting formative-evaluation data. Data from each of these instruments were quickly summarized and immediately provided to the project team to help them improve the project as it progressed over the three years. The evaluation team also drew from these data to better understand the nuances of the program as it was developing, which prompted impromptu in-depth discussions with the PD project team, which in turn contributed to the project teams' development efforts. We did not formally analyze the results of the observations but drew upon the most salient findings when answering Evaluation Question 1.

In Table IV-2, we show each instrument's focus (including the evaluation question(s) addressed), the project components (implementation, outcomes, or context) each instrument addressed, and the intended uses (formative, summative, or both) of each instrument. [2] The data from these instruments addressed (a) how well aspects of the PD were implemented by the project team in the training of the teachers and by the teachers in their classrooms, (b) teachers' and students' understanding of the material covered in the PD, and (c) the teachers' perceptions about the strengths, weaknesses, and context of the project. As seen in the table, most of the instruments addressed and resulted in multiple types of use.

The evaluation plan was multi-faceted. The nature of the plan can be gleaned from Figures IV-1 and IV-2, in which we present our data collection schedule. The analyses consisted of (a) calculations of descriptive statistics, (b) effect sizes of pre-to-post changes in standard-deviation units (along with paired *t*-test significance levels) with some teacher-level data, and (c) multi-level modeling of the student-level data (nested within teachers' classes), with some of the instruments' results serving as cluster-level moderating variables of student results.[3]

[2] We did not include the PD observations or the post-follow-up questionnaire in this table because these were informal and were for formative-evaluation purposes.

[3] The results of additional analyses will be reported in dissertations stemming from the TSI Aquatic project, including one for which observation data, not planned or reported for the evaluation, were collected.

Table IV-1
Evaluation Questions and Instruments

Evaluation question	Teacher instruments							Student instruments	
	Classroom Instruction Questionnaire (three scales)	Inquiry Teaching Assessment	Teacher Science Content Assessments	Post-Workshop Question-naires	Teacher Reflections	Post-Cohort Question-naire	Post-Cohort Interview	Nature of Science Assessment	Aquatic Science Content Assessment
1. To what extent was the PD structured in the intended manner?				✔			✔		
2. To what extent did the teachers find PD valuable and relevant to ongoing practice?				✔		✔	✔		
3. To what extent did the teachers improve in their pedagogical content knowledge, self-efficacy in teaching science, and metacognition in teaching?	✔				✔		✔		
4. To what extent did the teachers gain in their understanding of inquiry-based science teaching?		✔			✔		✔		
5. To what extent did the teachers gain knowledge about aquatic science content?			✔						
6. To what extent did the teachers implement the project activities in the intended manner with fidelity?					✔	✔			
7. To what extent did the students gain in their nature-of-science understanding and in their aquatic-science-content knowledge?								✔	✔

Table IV-2

TSI Aquatic Instrument Foci, Evaluation Questions ("Q"), the Project Components That the Instruments Address, and the Intended Uses of the Evaluation Results

Instrument(s)	Focus	Component			Use	
		Implementation	Outcomes	Context	Formative	Summative
I. Teacher instruments						
Teacher Background Questionnaire	Teacher demographics (two items as moderator variables in Q. 7)			✔	✔	
Classroom Instruction Questionnaire (three scales)	The teachers' self-reports of their pedagogical content knowledge for teaching science, efficacy in teaching science, and perceptions of meta-cognitive skills in teaching (Q. 3)		✔		✔	✔
Inquiry Teaching Assessment	The teachers' understanding of what inquiry looks like in the science classroom (Q. 4)		✔		✔	✔
Aquatic science content assessment (one per module)	The teachers' knowledge of physical, chemical, biological, and ecological science content in the context of aquatic science (Q. 5)		✔		✔	✔
Post-Workshop Questionnaire (one per module)	How fully and well the PD workshops were implemented (Qs. 1–2)	✔			✔	✔
Teacher Reflection (one per target lesson activity)	How fully and how well the teachers implemented the TSI lessons (Qs. 3–4, Q. 6)	✔			✔	✔
Post-Cohort Questionnaire and Post-Cohort Interview	The teachers' perspectives about the implementation, strengths, weaknesses, and context of the project (Qs. 1–4, Q. 6)	✔	✔	✔		✔
II. Student instruments						
Nature of Science Assessment; Aquatic Science Content Assessment	The students' understanding of the nature of science; students' knowledge of aquatic science content (Q. 7)		✔		✔	✔

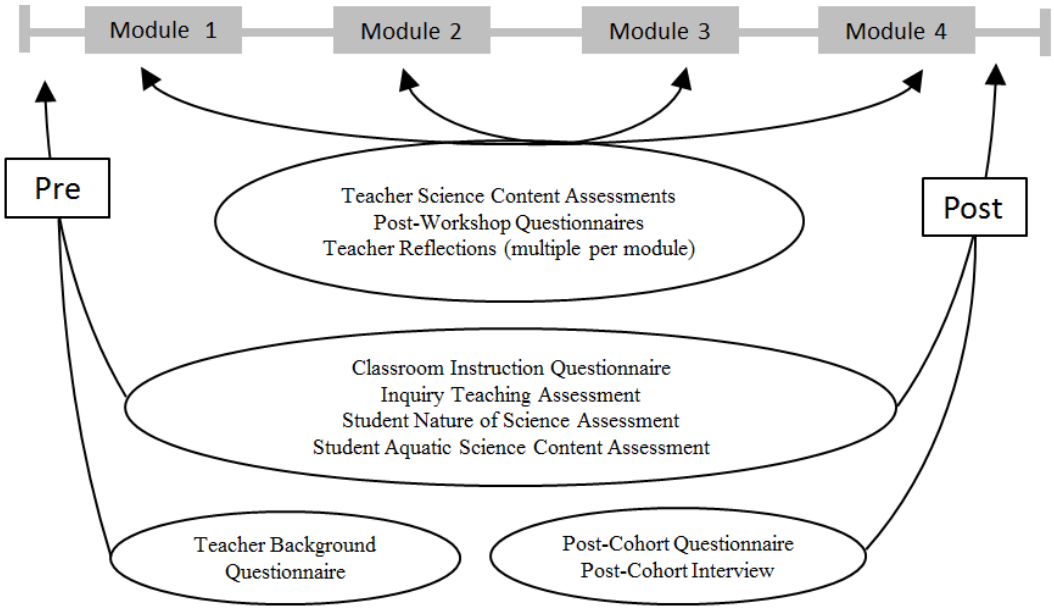

Figure IV-1. Schedule of data collection for the evaluation. The timeline spans the academic year, from August 2012 to June 2013.

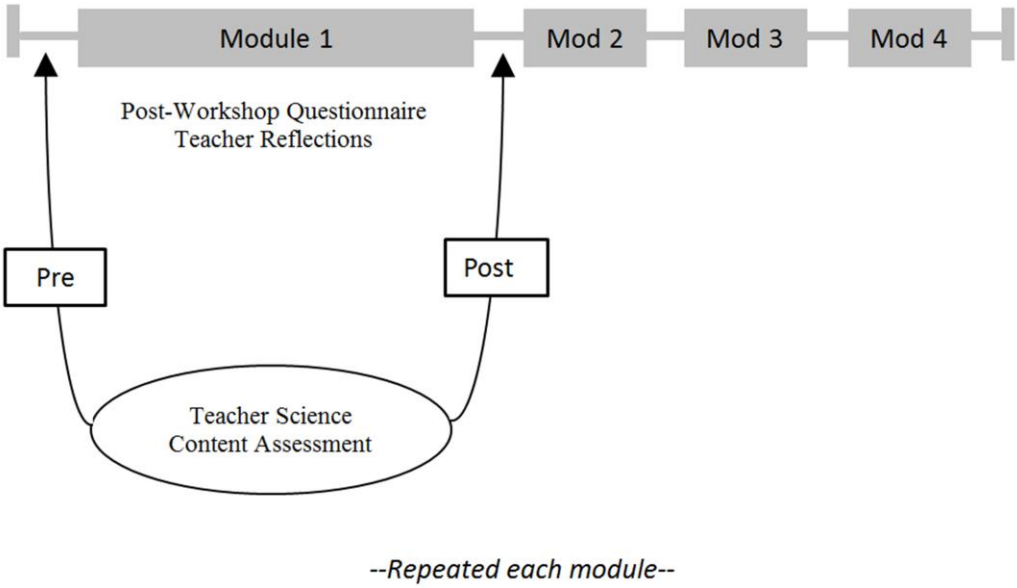

Figure IV-2. Data collection in each module. The post workshop questionnaire was administered at the end of the workshop. Teacher reflections were completed throughout the module as teachers implemented the activities.

Instrument Development, Validation, Administration, Analyses, and Results

A substantial portion of the evaluators' activities during the TSI Aquatic project involved instrument adaption and development to strengthen the validity of these measures. We present these activities for each instrument in this section. The instruments were selected because of their availability and feasibility in development, and because they addressed central aspects of teaching science as inquiry. We acknowledge that a complete unpacking of teaching science as inquiry would result in a larger battery of instruments, but in the interest of balancing available resources with the most important measurable outcomes, we elected to use those listed here. Additionally, because the evaluation developed alongside the program's development, we added instruments and adapted existing ones as the program became more refined and its goals became more clarified.

For ease of reading and understanding, our descriptions here are brief; we provide many more details about each instrument and the steps taken to address validity in Appendix B. In the narrative here, we describe each instrument and provide the main points of the results. An overview of the methods and the major results is also provided in Table IV-3.

Teacher Instruments

Teacher Background Questionnaire

The evaluation team borrowed a number of items addressing teachers' educational background and demographics that CRDG had previously developed and used (reported in Brandon et al., 2007) and prepared an online instrument for the TSI Aquatic teachers to complete at the beginning of their cohorts. Some items were added prior to the final year of the project to address information the project team sought; for example, a new item asked teachers how many science PDs they had participated in prior to participating in TSI Aquatic. We calculated descriptive statistics for the items and shared them with the project team at the start of each cohort's academic year. A report of the descriptive statistics of the most salient points, for the final year's cohorts (Cohorts 4 and 5), is included in the description of the program in Chapter II.

Classroom Instruction Questionnaire

We assembled an instrument that included the *Pedagogical Content Knowledge Scale*, the *Self-efficacy in Science Teaching Scale*, and the *Metacognition in Teaching Scale*. All three of the scales comprised self-report items. We prepared online versions and administered the questionnaires at the beginning and end of each cohort's academic year, with the exception of the self-efficacy scale, which was administered at the end as a retrospective pre-post questionnaire (described below). The purpose of the instrument was to estimate the degree to which teachers changed on these scales from the beginning to the end of the project, thereby providing a rough estimate of the effect of the project on these aspects of teachers' science teaching.

The *Pedagogical Content Knowledge Scale* was developed by Scarlett (2008) for measuring science teachers' changes while participating in professional development courses. Scarlett followed a transactional model of pedagogical content knowledge and included features deemed to be important in TSI such as the nature of science, use of inquiry, teacher-as-facilitator, student discussion and questioning, connections and relevance to the real world, and so forth. The items were on a five-point Likert scale of frequency; they prompted teachers to select a response indicating how often the teachers (or the students in their classes, for some prompts) engaged in the behavior in each prompt. The items were not specific to the TSI Aquatic pedagogy components (the "TSI toolbox"), but they were considered as representative of the overall intent of the PD.

The *Self-efficacy in Science Teaching Scale* was adapted from CRDG's earlier NSF grant (Brandon et al., 2007), where it was used to collect data on students' self-efficacy in science. The items, on a six-point scale, prompted the teachers to select a response indicating their degree of ability with specific teaching practices. New items were added to address components of the TSI pedagogy. This scale was administered as a retrospective pre-post questionnaire, at the end of the PD only; that is, the teachers were asked to think about their current self-efficacy after having completed the PD and then to reflect back to their previous self-efficacy before participating in the PD. The rationale for this retrospective component was to ensure that the teachers interpreted the prompts the same way for both the pre and the post; because information about the TSI Aquatic pedagogy and definitions of terms used in the pedagogy constituted the PD, the teachers would not likely have interpreted the prompts in the same manner at both time points.

The *Metacognition in Teaching Scale* comprised items drawn from Balcikanli (2011). The project team deemed metacognition in teaching to be important for the intended outcome of the PD. The items were on a five-point Likert scale and addressed metacognitive strategies for teaching in general; that is, the strategies were not specific to TSI or to instruction in a science classroom context.

For the final two cohorts (Cohorts 4 and 5), all three instruments had high reliability, with estimates (Cronbach's alpha) exceeding .85 on both the pre and post measures, calculated separately (Table IV-4 lists the estimates). Estimates of the descriptive statistics for the three scales are provided in Table IV-4. The gains in Pedagogical Content Knowledge Scale and Metacognition in Teaching Scale were about 25% and 20% of a standard deviation, respectively (neither gain was statistically significant at the .05 level, however). The teachers' responses to the Self-efficacy in Science Teaching Scale yielded a gain of about 150% of a standard deviation unit (statistically significant at the .01 level).

The project team also sought to investigate the teachers' metacognition in learning. For this, they requested that the Classroom Instruction Questionnaire include five items drawn from a longer survey from Schraw and Dennison (1994).

Table IV-3
Overview of the Evaluation Methods and Summative Evaluation Results

Instrument	Analyses	Summative results
	Teacher instruments	
Teacher Background Questionnaire	Descriptive statistics; some results included in multilevel model	Description of the teachers is provided in Chapter II.
Classroom Instruction Questionnaire		
Pedagogical Content Knowledge Scale	Descriptive statistics and pre-post analyses; pretest included in multilevel model	Mean scores improved by approximately 25% of a standard deviation (see Table IV-4.).
Self-Efficacy in Science Teaching Scale	Descriptive statistics and pre-post analyses; pretest included in multilevel model	Mean scores improved by approximately 150% of a standard deviation (see Table IV-4).
Metacognition in Teaching Scale	Descriptive statistics and pre-post analyses; pretest included in multilevel model	Mean scores improved by approximately 20% of a standard deviation (see Table IV-4).
Inquiry Teaching Assessment	Descriptive statistics and pre-post analyses; pretest included in multilevel model	Multi-facet Rasch modeled mean scores improved by 1.24 of a standard deviation (see Table IV-5).
Teacher Science Content Assessments (one each for physical science, chemistry, biology, and ecology)	Descriptive statistics pre/post for each module; aggregate pretest across modules included in multilevel model	Percent-correct scores improved an average of 12.5 across modules (see Table IV-6).

Table IV-3
Overview of the Evaluation Methods and Summative Evaluation Results (continued)

Instrument	Analyses	Summative results
Post-Workshop Questionnaires (one each for physical science, chemistry, biology, and ecology)	Descriptive statistics of each item across modules and cohorts; descriptive statistics across items for each module and each cohort	After showing gains across Cohorts 2–3 the previous year, the mean scores for Cohorts 4–5 were high (all but one > 5.50), with little variation between cohorts or modules with cohort (see Table IV-8).
Teacher Reflections	Informal review of results following each administration; post-project descriptive statistics of scales and of variables that also included Post-Cohort data; trend of use mode- and phases-implementation across modules; implementation variables were included in multilevel model	The teachers adhered to about 68% of the project activities; teachers adhered more to, were more responsive to, and thought they implemented with higher quality the science content features than some features of the pedagogy (see Table IV-9). As the project progressed, the experimentation mode was slightly deemphasized in teachers' classrooms, and the authoritative knowledge, product evaluation, and replication modes were given slightly greater emphasis; the phases were given greater emphasis (See Figures IV-3 and IV-4).
Post-Cohort Questionnaire	Descriptive statistics; implementation variables included in multilevel model	See Table IV-10.
Post-Cohort Interview	Content analyses	See Table IV-10 and Appendix B.

Table IV-3
Overview of the Evaluation Methods and Summative Evaluation Results (continued)

Instrument	Analyses	Summative results
	Student instruments	
Nature of Science Assessment	Descriptive statistics; outcome in multilevel model	Rasch-modeled scores improved from pre- to post (see Tables IV-13 and IV-16); multilevel model results showed student gains were significantly predicted by teachers' adherence to the program and that teachers with low incoming pedagogical content knowledge had students with significantly stronger gains than teachers arriving with a high degree of pedagogical content knowledge.
Aquatic Science Content Assessment	Descriptive statistics; outcome in multilevel model	Rasch-modeled scores improved from pre- to post (see Tables IV-13 and IV-16); multilevel model results showed gains were significantly predicted by teachers' adherence to the program and that in classes with teachers having less prior experience in science PDs, students were estimated to gain significantly more than students in classes with teachers have taken more science PDs. Grades 6–8 students had significantly higher gains compared to Grades 9–12 students.

Because the items were administered as a pilot-test rather than as an intended outcome measure for summative evaluation purposes, the evaluation team did not include these data in the findings, but we did conduct a pre-post analysis: The teachers' mean responses decreased by more than half a point on the one-to-five scale (M_{pre} = 4.22, M_{post} = 3.68, $p < .01$, Hedge's g = .69), suggesting that the teachers' metacognition skills in learning worsened as they participated in the project. We speculate that this worsening was due to the teachers' improvements in their understanding of what metacognition is and that this had an effect on their understanding of the prompts. That is, even though the prompts include commonly known vocabulary, the teachers may have become more sensitive to the meaning of the prompts, thereby realizing that components of metacognition, such as learning strategies, involved more than they had considered when responding to the prompt on the pre, before participating in the PD. This speculation is aligned with the change in reliability from the pre to the post: On the pre, Cronbach's alpha was .74; on the post, it was .93, suggesting that the items—or rather, teachers' interpretations of the items' prompts—were more stable on the post than on the pre as a measure of teachers' self-reports of metacognition in learning.

Table IV-4
Descriptive Statistics of the Three Teacher-Outcome Scales in the Classroom Instruction Questionnaire

Instrument	Time	*N* items	*M*	*SD*	*s.e.*$_M$	Cronbach's α
Pedagogical Content Knowledge Scale[a]	Pre	36	3.84	0.36	0.07	.87
	Post	36	3.93	0.36	0.07	.92
Self-Efficacy in Science Teaching Scale[b]	Pre	15	3.52	0.99	0.19	.97
	Post	15	4.79	0.67	0.13	.96
Metacognition in Teaching Scale[c]	Pre	10	4.37	0.42	0.08	.86
	Post	10	4.48	0.65	0.12	.89

Note. Results are for 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] The questionnaire was administered with a retrospective pre-post design. Response categories ranged from *1* (low ability) to *6* (high ability). The pre-post mean difference was statistically 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).

Inquiry Teaching Assessment

Toward the goal of measuring the teachers' understanding of the nature of inquiry-based science teaching in the classroom, we considered two methods and, in the end, adopted a third, the *Inquiry Teaching Assessment*. The first two methods were concept maps and long vignettes. We rejected the former because it was difficult to score reliably and, after a considerable development and trial period, rejected the latter because it was

too unwieldy, as we describe in detail in Appendix B. We then tried out the *Pedagogy of Science Inquiry Teaching Test* (Schuster et al., 2007), which seemed more logistically and psychometrically manageable. The instrument included both selected-response (multiple-choice) and constructed-response (short essay) prompts following several short science-teaching vignettes. After item review by experts, subsequent revision of some of the items, pilot-testing with three project personnel, and additional revisions, we prepared an abbreviated version that required no more than one hour to complete. The revisions also aligned the prompts more explicitly with the inquiry-science approach taught in the TSI Aquatic project; for example, the multiple-choice responses were treated as part of the prompt rather than part of the score because inquiry, as presented in TSI Aquatic, can take many appearances (the multiple-choice prompts were various actions the teacher could take in any given scenario), and what was intended to be measured was teachers' rationales for selecting each response rather than their actual choice (captured in the short essay in their constructed response). Because we made multiple revisions to the instrument, we named it the *Inquiry Teaching Assessment*.

We administered the *Inquiry Teaching Assessment* online at the beginning and end of each cohort's academic year. The teachers' responses on both the pre- and post-cohort assessments were compiled into a single response dataset to be scored after the post-cohort assessment was completed; this was to reduce possible rater bias that could have occurred if the raters knew which time point the responses came from; it also removed variability that would have occurred if ratings were given on two separate occasions (to reduce rater drift). To rate the responses, two trained raters used a nine-point scale on a rubric, available in Appendix C. Ratings were Rasch analyzed to estimate teachers' scores. The two raters did not differ in their degree of severity, and internal consistency was high, with a Rasch-reliability estimate of .95.

Estimates of the descriptive statistics for pre- and post-cohort scores are provided in Table IV-5. The teachers' scores yielded a gain of 1.24 standard deviation units (statistically significant at the .01 level).

Table IV-5
Descriptive Statistics of the Inquiry Teaching Assessment

	Teachers					Raters	
Time	*N*	*M*	*SD*	Min	Max	*N*	*M*
Pre	28	-1.01	1.24	-2.85	2.50	2	0.00
Post	28	0.53	1.22	-1.82	2.65	2	0.00

Note. Results are in logits based on scores from the multi-facet rating-scale model (Andrich, 1978; Linacre, 2010) under a Rasch analysis framework, with both the pre- and post-cohort scores modeled together to ensure scores at the two time points were on the same scale. Ratings were on a nine-point performance-assessment scale. The variability of the rater facet was approximately zero. The Rasch reliability of the person separation was .95. All seven items fit the model (within ±2.0 standardized units), with point-biserial correlations ranging from .72 to .84. The effect of the pre-to-post gain was strong (Hedges' $g = 1.24$, $p < .01$).

Teacher Science Content Assessments

In collaboration with the project team, the evaluators developed an assessment for each subject matter taught in the four PD modules. Through an iterative process described in detail in Appendix B, the members of the project team and evaluators agreed on a number of topics, developed a number of multiple-choice items, tried them out in the first cohort of teachers, conducted item analyses, prepared final versions of the assessments, and administered them to Cohorts 2–5 (in Years 2 and 3 of the project) at the beginning and end of each module.

The descriptive statistics and reliability estimates (KR-20) for Cohorts 4 and 5 (in the final year of the project) are shown in Table IV-6. As seen in the table, the instruments ranged from between 29 items to 38 items in length. The reliability estimates ranged from .66 to .87 across the eight administrations of the instruments (two per module), with six of the assessments showing estimates greater than .80. The percentage correct for the assessments ranged from 45% to 79% (M_{pre} = 58.25%; M_{post} = 70.75%, for a mean gain of 12.5 percentage points; *SD* = 10.3 and 9.5, respectively). The estimated gains in the teachers' scores on each of the four modules ranged from two-thirds of a standard-deviation unit (Module 1) to three-fourths of a standard deviation (Modules 2 and 3) to

Table IV-6
Teacher Content Assessment Results

Instrument	*N* teachers	*N* items	*M*[a]	*SD*	*s.e.*$_M$	Min, Max	KR-20
Module 1 Pre	31	29	19.39 (67%)	5.33	0.96	9, 29 (31%, 100%)	.83
Module 1 Post	31	29	22.68 (78%)	4.58	0.82	14, 29 (48%, 100%)	.82
Module 2 Pre	29	38	25.14 (66%)	7.15	1.33	10, 37 (26%, 97%)	.87
Module 2 Post	29	38	30.10 (79%)	5.88	1.09	18, 37 (47%, 97%)	.86
Module 3 Pre	28	36	19.71 (55%)	5.62	1.06	9, 29 (25%, 81%)	.80
Module 3 Post	28	36	24.00 (67%)	5.58	1.05	9, 34 (25%, 94%)	.81
Module 4 Pre	28	32	15.25 (45%)	4.39	0.83	9, 25 (26%, 74%)	.66
Module 4 Post	28	32	19.96 (59%)	4.90	0.93	13, 28 (38%, 82%)	.75

Note. All pre-post differences were significant ($p < .0001$), with effect sizes ranging from about .65 of a standard-deviation unit to 1.00 standard-deviation unit (for Module 1, Hedges' g = 0.66; for Module 2, Hedges' g = 0.76; for Module 3, Hedges' g = 0.76; and for Module 4, Hedges' g = 1.01). KR-20 = reliability estimate.
[a]Percents are percent-correct scores

one whole standard-deviation improvement (Module 4). The significance tests (*t*-tests) showed statistically significant differences ($p<.01$) between pre- and post- for each of the four modules.

Post-Workshop Questionnaire

The evaluators collected teachers' feedback about the training conducted in each of the four PD workshops (one per module and administered at the completion of the workshop) with an instrument that CRDG routinely uses for evaluating the training that we provide in various subjects and in various settings. The instrument addresses the features of PD that have been found to be effective across a number of studies (Guskey, 2003). The teachers' responses on this instrument were anonymous (within the cohort), ameliorating the social-desirability threat to validity but making it impossible for us to examine these results in other analyses (as a predictor, for example, in the Student-Science-Questionnaire analysis). We summarize the results of the instrument in Tables IV-7 and IV-8. The average reliability (Cronbach's alpha) across the eight administrations of the instrument (one for each of the four modules in each of the two cohorts) ranged from .64 to .90; the mean was .81. The mean scores on the instrument averaged 5.59 for Cohort 4 and 5.54 for Cohort 5. The standard errors of the mean ranged from 0.13 to 0.17, with one exception (0.23).

Teacher Reflection

The Teacher Reflection was developed over multiple iterations based on collaboration between the evaluation and project team members. The reflection was designed to collect data about the teachers' fidelity of implementation (FOI)—a construct addressing the degree to which a program is implemented in the intended manner (Dusenbury, Brannigan, Falco, & Hansen, 2003)—for each of the four module's target activities. The reflection addressed three primary constructs of FOI commonly discussed in the FOI literature (Dane & Schneider, 1998; Dusenbury, Brannigan, Falco, & Hansen, 2003; O'Donnell, 2008): (a) the extent to which the steps of activities of a program are implemented, or adherence; (b) how well the program is implemented, or quality; and (c) the enthusiasm for and degree of participation in the program activities, or participant responsiveness. Additionally, the reflection collected information on the teachers' perceptions about the extent to which the professional development affected their content knowledge and confidence; the context in which the teachers implemented the activities, including the extent to which the teachers made modifications to the activity being implemented and any unexpected events that they believed may have affected how the activity was implemented; and options for open-ended responses to justify ratings and to provide general feedback to the project team in their development efforts.

Table IV-7
Post-Workshop Questionnaire Results: Item-Level Descriptive Statistics Across all Four Modules

Prompt	$N_{responses}$	*M*	*SD*	*Min*	*Max*
1. The workshop provided adequate feedback and coaching.	117	5.71	0.51	4	6
2. The workshop included applicable theory.	117	5.71	0.52	4	6
3. † The workshop did ***not*** include helpful demonstrations.	117	5.82	0.50	5	6
4. The workshop included opportunities for practice.	117	5.68	0.50	4	6
5. The goals and objectives of this workshop module were clearly stated.	117	5.64	0.68	4	6
6. The workshop's learning climate was respectful.	116	5.63	0.87	2	6
7. The workshop improved my capability incorporate aquatic science in my classes.	116	5.62	0.58	4	6
8. The workshop included helpful demonstrations of teaching science as inquiry.	117	5.72	0.53	4	6
9. † The workshop did ***not*** deepen my subject-matter knowledge.	117	5.66	0.60	3	6
10. The workshop deepened my pedagogical knowledge.	117	5.10	0.97	1	6
11. Sufficient time was provided for completing tasks during the workshop.	117	5.28	0.91	2	6
12. The workshop instructors were knowledgeable and helpful.	117	5.88	0.36	4	6
13. † The workshop activities were ***not*** well organized.	116	5.67	0.68	3	6
14. The workshop provided adequate time for discussion and reflection.	117	5.37	0.91	2	6
15. New practices were modeled well and thoroughly explained.	117	5.56	0.56	3	6
19. I was encouraged to try new practices or strategies.	117	5.68	0.56	3	6
20. The workshop provided content and pedagogy that will be useful in the classroom.	117	5.69	0.48	4	6
21. † The workshop content and pedagogy were ***difficult*** to grasp.	117	4.76	1.30	2	6
Mean	117	5.54	0.68	3.22	6.00

Note. Data are from Cohorts 4 and 5 teachers combined and across all four modules' workshops. 1 = "Strongly disagree," 2 = "Somewhat disagree," 3 = "Slightly disagree," 4 = "Slightly agree," 5 = "Somewhat agree," 6 = "Strongly agree"
†Ratings were reverse coded (e.g., from "6" to "1", "5" to "2," etc.) to place all items on scale where higher numbers are more positive.

Table IV-8
Post-Workshop Questionnaire Results: Descriptive Statistics of the Aggregate Responses per Module and per Cohort

Cohort	Module	*N*	*M*	*SD*	$s.e._M$	Min, Max	Cronbach's α
4	1	15	5.67	0.50	0.13	4.44, 6.00	.64
4	2	15	5.67	0.64	0.17	4.00, 6.00	.89
4	3	14	5.56	0.60	0.16	4.22, 6.00	.88
4	4	16	5.57	0.66	0.17	3.89, 6.00	.71
5	1	16	5.56	0.60	0.15	4.33, 6.00	.90
5	2	14	5.58	0.59	0.16	4.17, 6.00	.82
5	3	15	5.57	0.58	0.15	4.28, 6.00	.76
5	4	12	5.44	0.78	0.23	3.56, 6.00	.91

Note: The Items were on a 1–6 scale. The mean of Cohort 4 across all four modules was 5.59; the mean of Cohort 5 across all modules was 5.54. Across two cohorts, the mean of Module 1 = 5.61, Module 2 = 5.57, Module 3 = 5.57, and Module 4 = 5.51.

The teachers' responses to open-ended items were used for formative-evaluation purposes to help the project team provide appropriate feedback to the teachers during follow-up meetings. The teacher reflections were completed after they had implemented target activities in their focus class; they included multiple response options, Likert scale items, multiple-choice items, and open-ended response items.

The teachers were required to complete a minimum of three reflections in each group of the four modules' target activities. The results of the reflections were aggregated across the four modules, and descriptive statistics were calculated. Only the items that addressed the three FOI constructs and PD quality are reported here. The results are presented in Table IV-9 by construct.

To investigate further the teachers' use of the primary TSI Aquatic strategies—namely the extent to which they perceived how well they guided their students through the 10 modes of inquiry and the 5 phases of inquiry—we plotted the mean responses across the four modules. We present the results in Figures IV-3 and IV-4.

Post-Cohort Questionnaire

We developed the Post-Cohort Questionnaire to collect data on the teachers' experiences with the project. The evaluators identified topics that addressed the scope of the PD and revised them somewhat after consulting with the project team. The topics were features of FOI. After the evaluators tried out the instrument at the conclusion of Year 2, they added additional items. The final version included items constituting 14 scales.

The scales are listed in Table IV-10. Of the 14 scales, one addressed adherence, one addressed exposure, three addressed teacher responsiveness, two addressed teacher quality, one addressed student responsiveness, and five addressed the quality of the PD. All the scale items were answered with Likert scales, with *1* low and *6* high. (The anchor descriptors varied among the scales; see Appendix C for the instrument.)

Table IV-9

Descriptive Statistics of the Activity Reflections by Construct

Construct	Item	$N_{\text{activity reflections}}$[a]	*M*	*SD*	SE_M	Min, Max	α
Adherence	1. Extent teacher connected the activity to the ocean	15	3.23	.69	.13	2.17, 4.67	.71
	2. Extent teachers had their students follow the Exploring Our Fluid Earth (EOFE) procedures	14	4.05	.38	.07	3.33, 4.75	.79
	3. Proportion of activity components/questions addressed[b]	14	.68	.15	.03	0.40, 0.97	.77
	4. Extent teachers explicitly address the components of TSI with their students (e.g. phases, modes, demeanors of scientists, or metacognition)	8	3.12	.64	.12	2.25, 4.25	.60
	5. Extent teacher explicitly addressed the *Phases of Inquiry* component with their students	7	2.68	.96	.18	1.00, 4.83	.80
	6. Extent teacher explicitly addressed the *Modes of Inquiry* component with their students	7	3.18	.88	.17	1.33, 4.67	.64
	7. Extent teacher explicitly addressed the *Demeanors of scientists* component with their students	7	3.02	1.08	.20	1.00, 4.83	.89
	8. Extent teacher explicitly addressed the *Practices of scientists* component with their students	7	3.16	.94	.18	1.00, 4.83	.81
	9. Extent teacher explicitly addressed the *Metacognition* component with their students	7	2.63	.97	.18	1.00, 4.67	.69

Table IV-9
Descriptive Statistics of the Activity Reflections by Construct (continued)

Construct	Item	$N_{\text{activity reflections}}$ [a]	*M*	*SD*	SE_M	Min, Max	α
Responsiveness	10. Extent teachers thought connecting the activity to the ocean helped engage their students	15	3.18	.88	.17	1.42, 4.75	.76
	11. How successful the teachers thought that the process of planning using TSI improved their understanding of TSI?	7	3.90	.64	.12	2.00, 5.00	.84
	12. Overall, how useful the teachers thought their questioning strategies were in helping them guide their students through the TSI phases and assess their students' progress	7	3.88	.62	.12	2.33, 4.75	.79
Teaching Quality	13. Teachers' understanding of the activity's content after having implemented the activity	14	4.36	.35	.07	3.73, 5.00	.70
	14. Extent that implementing the activity enhanced teachers' understanding of teaching science as inquiry	15	4.00	.51	.10	2.77, 4.92	.82
	15. How confident teachers were with teaching the content after having implemented the activity	14	4.40	.40	.07	3.25, 5.00	.78
	16. How well teachers thought they guided their students through *Authoritative knowledge*	15	3.69	.41	.08	2.56, 4.33	.33
	17. How well teachers thought they guided their students through *Curiosity*	15	4.16	.41	.08	2.88, 5.00	.45
	18. How well teachers thought they guided their students through *Deduction*	15	3.51	.33	.06	2.72, 4.42	.18
	19. How well teachers thought they guided their students through *Description*	15	3.94	.37	.07	3.25, 4.79	.45

Table IV-9
Descriptive Statistics of the Activity Reflections by Construct (continued)

Construct	Item	$N_{activity\ reflections}$ [a]	*M*	*SD*	SE_M	Min, Max	α
Teaching Quality (cont.)	20. How well teachers thought they guided their students through *Experimentation*	15	4.05	.44	.08	2.92, 4.83	.71
	21. How well teachers thought they guided their students through *Induction*	15	3.52	.39	.07	2.83, 4.50	.70
	22. How well teachers thought they guided their students through *Product Evaluation*	15	3.46	.71	.13	2.17, 5.00	.59
	23. How well teachers thought they guided their students through *Replication*	15	3.79	.40	.08	3.17, 4.50	.34
	24. How well teachers thought they guided their students through *Technology*	15	3.47	.60	.11	2.48, 4.50	.66
	25. How well teachers thought they guided their students through *Transitive Knowledge*	15	3.66	.37	.07	3.00, 4.42	.56
	26. How well teachers thought they guided their students through *Initiation*	15	3.96	.40	.08	3.17, 4.88	.60
	27. How well teachers thought they guided their students through *Invention*	15	3.80	.40	.08	3.13, 4.92	.60
	28. How well teachers thought they guided their students through *Instruction*	15	4.02	.37	.07	3.42, 4.88	.58
	29. How well teachers thought they guided their students through *Interpretation*	15	3.79	.39	.07	2.83, 4.42	.64
	30. How well teachers thought they guided their students through *Investigation*	15	4.09	.43	.08	3.00, 4.92	.74
	31. How well teachers thought they used good questioning strategies	8	3.83	.42	.08	3.00, 4.67	.51

Table IV-9
Descriptive Statistics of the Activity Reflections by Construct (continued)

Construct	Item	$N_{\text{activity reflections}}$ [a]	*M*	*SD*	SE_M	Min, Max	α
Teaching Quality (cont.)	32. How well teachers thought they implemented their assessment strategies	8	3.66	.43	.08	2.83, 4.33	.48
	33. Overall, how successful teachers thought they were in carrying out their planned TSI inquiry questioning strategies	7	3.80	.49	.09	2.50, 4.75	.73
PD Quality	34. Overall, how well teachers thought the PD covered the content needed to teach activities	14	4.53	.27	.05	3.79, 5.00	.55
	35. Teachers' level of understanding of content *after* the PD	14	3.97	.34	.06	3.23, 4.63	.58
	36. Teachers' level of understanding of content *before* the PD	14	2.75	.49	.09	1.88, 3.50	.60
	37. Difference in teachers' understanding of content before and after PD.[c]	8	1.22	.37	.07	0.58, 1.92	
	38. Teachers' confidence with teaching content *after* the PD	14	3.82	.46	.09	2.54, 4.50	.66
	39. Teachers' confidence with teaching content *before* the PD	14	2.62	.61	.11	1.58, 3.88	.64
	40. Difference in teachers' confidence of teaching content before and after PD.[c]	8	1.20	.41	.08	0.25, 2.21	

Note. These variables were calculated based on the teachers' responses to reflection questions across multiple activities across the four modules. The reflection questions used a five-point Likert scale, except for Item 3 (which included check-boxes). The number of teachers responding to the questions on each variable was 28.
SE_M = standard error of the mean; α = Cronbach's alpha estimate.
[a] This is the number of activity reflections, across the four modules, that included questions asking about this variable. [b] This variable was calculated using teachers' responses to questions asking about which activity and components they covered in the PD. These questions were tailored to the specific activities within each activity.
[c] These difference estimates were the average of the after-PD questions (across the four modules) minus the average of the before-PD questions (across the four modules). Reliability estimates were not calculated for these difference scores.

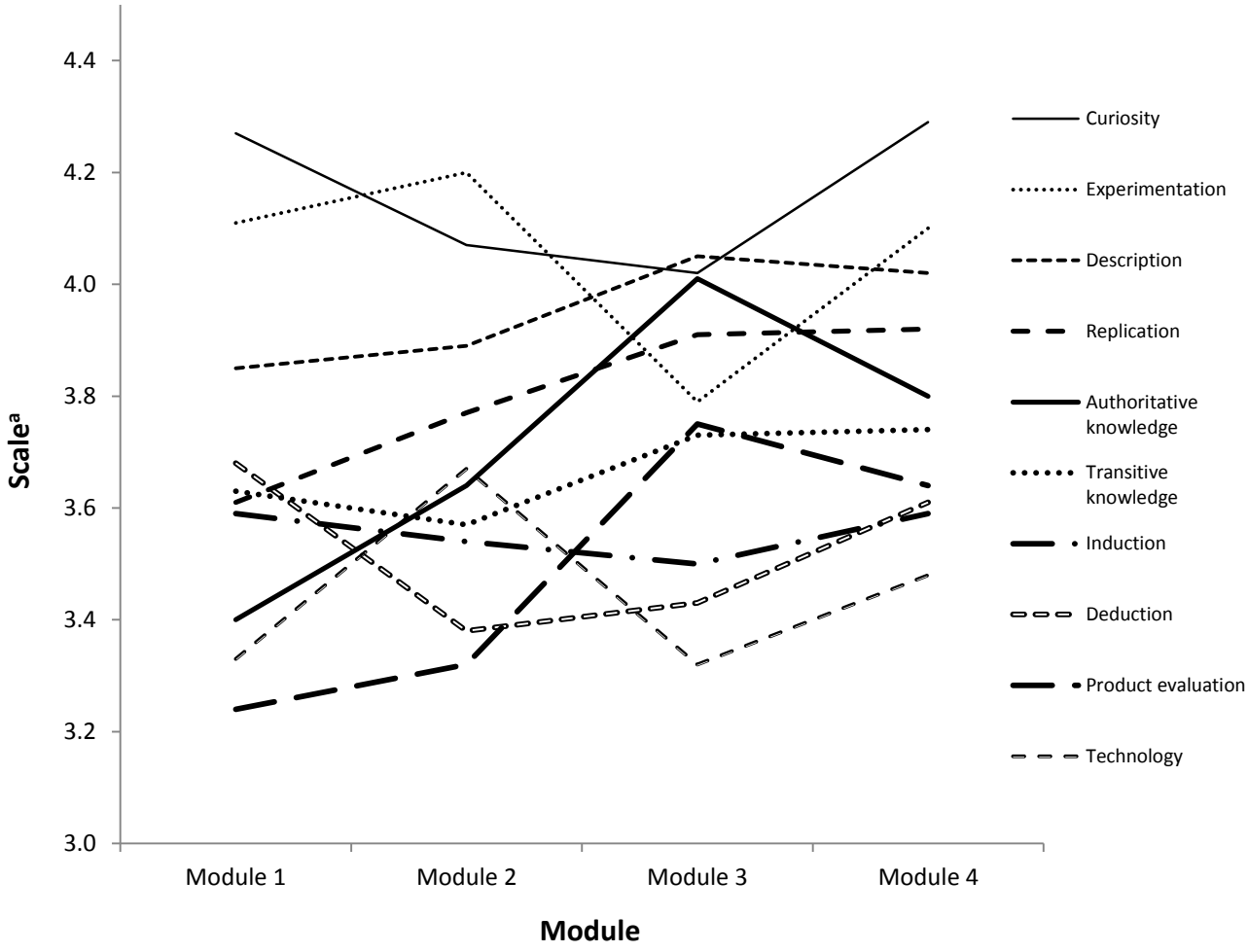

Figure IV-3. Mean teacher responses, by module, to the activity reflection item about how well they guided their students through the modes of inquiry.
[a] The teacher responses were on a 5-point Likert scale. All means were above 3.0 across the modules; to enhance the distinction between the modes across modules, the scale in the figure was truncated from 1-to-5 to 3-to-4.5.

The scales ranged between 3 and 10 items (mean = 6.21); Cronbach's alpha for the scales ranged from .83 to .96, with nine of the estimates being greater than .85. The results for one of the PD quality scales was reported as difference scores between a posttest administered at the same time as a retrospective pretest. All the teachers completed the instrument online within five weeks of the end of their cohort. As seen in Table IV-10, mean scores ranged from 4.61 to 5.51 (mean = 5.06), and standard errors of the mean ranged from 0.11 to 0.23. These results suggest the teachers had high levels of implementation. The two highest means show that the teachers found that the target activities were helpful and that the training was valuable and relevant. The two lowest

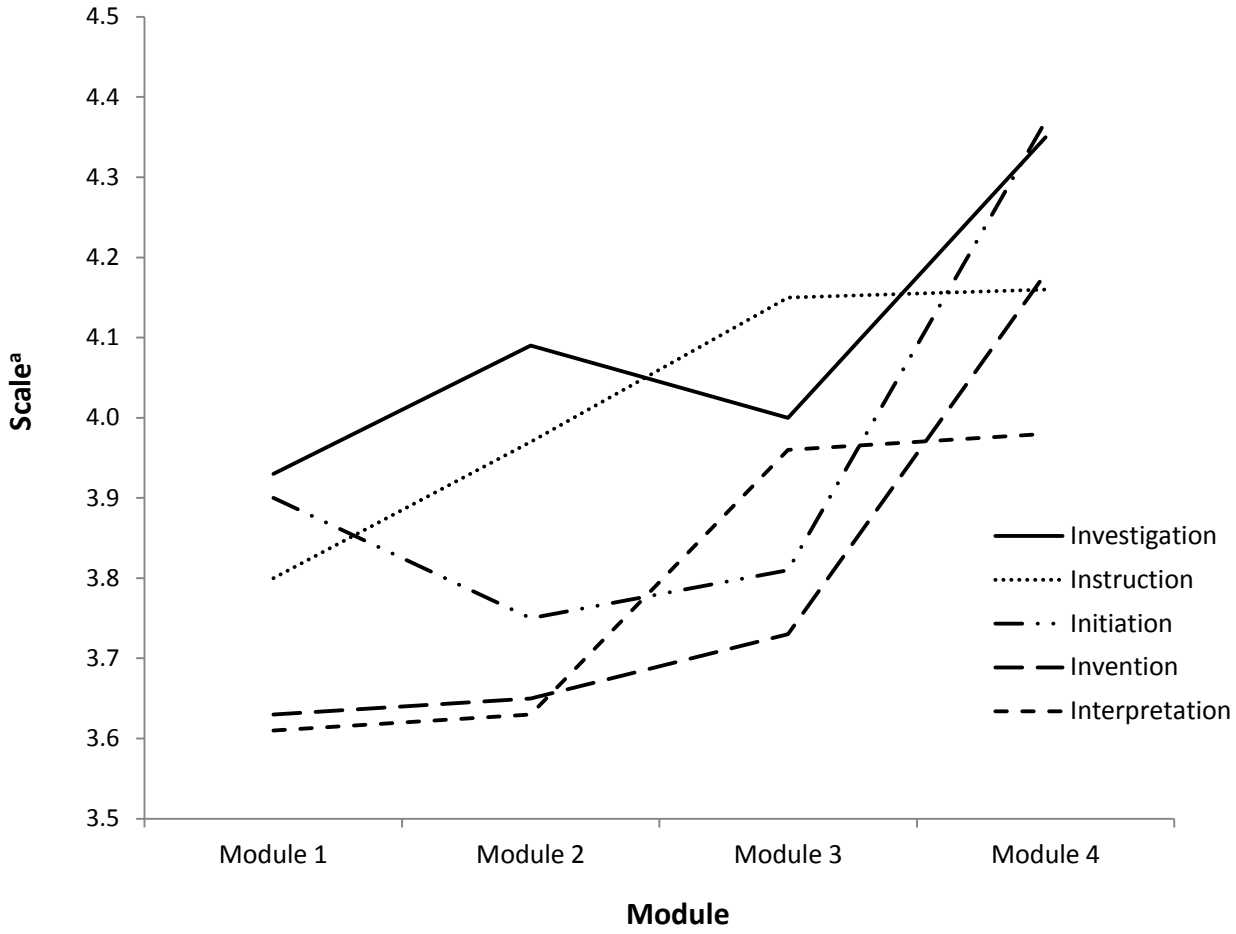

Figure IV-4. Mean teacher responses, by module, to the activity reflection item about how well they guided their students through the phases of inquiry.
[a] The teacher responses were on a 5-point Likert scale. All means were above 3.5 across the modules; to enhance the distinction between the phases across modules, the scale in the figure was truncated from 1-to-5 to 3.5-to-4.5.

means (below 4.70), however, suggest that there were some issues about the implementation of two key features of the TSI model—the inquiry modes and inquiry phases. The modes might not have been as well-received as desirable, and the phases might not have been perceived as highly useful in the future.

Post-Cohort Interview

We developed an interview protocol to administer to the teachers at the conclusion of the cohort. The purpose of the interview was to collect rich data that paralleled the Post-Cohort Questionnaire, including data on the teachers' overall experience with the PD, their perceptions of the value and relevance of the project, their implementation of the project in the classroom, and the extent to which they intend to use what they learned in the project in their future teaching. For each general topic, question prompts reminded teachers about the specific aspects of the PD and solicited teachers to talk about their

experience. The evaluators developed an interview script (the full version of the interview script is presented in Appendix C)—drawing on interview protocol procedures that had been developed and refined at CRDG over the years—and prepared slides to present to the teachers while conducting the synchronous online video interviews using Blackboard Collaborate technology, which the teachers were familiar with as it was part of the PD. The teachers were asked to provide ratings on scales of *1* to *10* for each of the major topics and then asked several open-ended questions. We report primarily on the open-ended responses. The complete summary of the interview results are reported in Appendix D.

The interviews were conducted live (synchronously) with 22 teachers at the end of the cohorts. For the 6 teachers with whom we were unable to schedule interviews, a written version of the instrument (comprising the same questions) was prepared and administered online, asynchronously. The interview data were collected in the final stages of the PD during the month of May 2013. The 22 synchronous online interviews via Blackboard lasted on average 30 minutes; the median time of the six asynchronous responses was 1 hr. 20 minutes.

The 22 synchronous interviews were transcribed and merged with the data from 6 teachers who completed the asynchronous interview. The interview data were analyzed using a grounded theory approach (Corbin & Strauss, 2008) in which a member of the evaluation team read through the data and coded for emerging themes. The final analysis revealed a total of 854 coded segments that were categorized into seven major categories and 43 subcategories. To verify the code system, an outside rater evaluated 10% of the coded segments in each category and subcategory. The agreement between the initial coder and the verifier was 98%. The different categories and subcategories are presented in Table IV-11.

In the interviews, all 28 teachers commented on the PD being structured so that it spread out over an entire year and nearly all of them found the structure satisfying. One teacher mentioned that a shorter PD would have been preferred with the explanation that this individual had already completed several PDs and therefore only needed a short experience. One of the main components of this PD was the TSI Aquatic content that focused on the four areas—physical science, chemistry, biology, and ecology. All content was presented in the context of aquatic science. The teachers expressed appreciation for this, and many of them talked about the positive effect it seemed to have on their students. Overall the teachers' comments suggested that the physical and the chemical content were regarded as more valuable than the biological and the ecological content. Some mentioned that the last two modules' content, on biology and ecology, seemed less rigorous and less in-depth.

Compared to the TSI Aquatic content, the pedagogy was perceived as more difficult to apply in the classroom. When asked about the value and relevance of the pedagogy, some teachers seemed to greatly appreciate the pedagogy whereas others were critical

and hesitant to use it. The teachers' responses suggested that, for the majority of them, the pedagogy was not an issue when they encountered it during the TSI workshops, but once they were expected to use it themselves to teach the TSI framework and language to their students, several of them struggled. The core emphasis of the pedagogy was around the TSI phases and modes of inquiry, with the other components tying into these. The teachers seemed most comfortable with these central components.

When asked about the PD's effect on the teachers' understanding of inquiry, 25 of the 28 teachers reported that they believed the PD had had a significant impact on their inquiry understanding. These teachers frequently attributed their increase in understanding to both the TSI Aquatic content and the pedagogy components of the PD. The remaining three teachers who did not believe that the PD really affected their understanding of inquiry explained that their existing beliefs were confirmed rather than changed. Since these teachers had knowledge of inquiry prior to this PD, perhaps these teachers may have entered with an already solidified definition of inquiry.

When asked if there were any unintended consequences having participated in the PD, most teachers responded that it was "all positive" without explanation. Two teachers mentioned that an unintended consequence of the PD was the positive responses they received from their students being excited about their teacher's PD participation.

The post-cohort interview responses suggest that, overall, the TSI Aquatic PD was perceived as a success, particularly in the way it was structured and in its provision of aquatic content activities that teachers could use in their classes. Although some teachers did not fully embrace the pedagogy in their practice, others adopted it and applied it to teaching contexts outside of those identified for the project. The teachers' observations of their own growth in their understanding of inquiry, their knowledge of the content, and their reports of how they developed collaborative relationships with their peers, suggest the project achieved what it had set out to do.

Student Instruments

The evaluators iteratively developed, piloted-tested, and administered a student questionnaire, the *Student Science Questionnaire*, to measure the two student-level outcomes—students' understanding of the nature of science (NOS) and their knowledge of the aquatic science content that was addressed in the four modules of the PD. To measure NOS understanding, two types of items were used: (a) Likert-scale items asking students about the degree to which they believed statements about NOS to be true (12 items) and (b) best-answer multiple-choice items asking students to read a short scenario and select the best response (18 items). The content items were also best-answer multiple-choice in format (17 items). These content and NOS items made up the 47-item instrument, the Student Science Questionnaire, which is in Appendix C.

Table IV-10
Results on the 14 Scales Included in the Post-Cohort Questionnaire

Scale	$N_{teachers}$	N_{items}	*M*	*SD*	*s.e.*$_M$	Min, Max	α
1. *Adherence*: The extent to which the teachers implemented all the steps of the target activities	28	4	5.04	0.64	0.12	4.00, 6.00	.91
2. *Exposure*: The extent to which the teachers used TSI inquiry modes in the classroom	28	10	4.61	0.79	0.15	3.20, 6.00	.89
3. *Teacher Responsiveness*: The extent to which the teachers thought the training was valuable and relevant	28	6	5.29	0.73	0.14	3.00, 6.00	.89
4. *Teacher Responsiveness*: The extent to which the teachers valued the TSI inquiry modes	28	10	5.24	0.63	0.12	4.00, 6.00	.88
5. *Teacher Responsiveness*: The extent to which the teachers intend to use the TSI toolbox components in the future	28	7	5.16	0.78	0.15	3.43, 6.00	.84
6. *Teacher Responsiveness*: The extent to which the teachers intend to use the TSI phases in the future	28	3	4.67	1.22	0.23	1.33, 6.00	.90
7. *Teacher Quality*: The extent to which the target activities were successful	28	4	5.34	0.66	0.12	4.00, 6.00	.88
8. *Teacher Quality*: The extent to which the teachers were comfortable in implementing the TSI activities	28	7	4.92	0.76	0.14	2.86, 6.00	.87
9. *Student Responsiveness*: The extent to which received TSI-A instruction favorably	28	6	4.87	0.74	0.14	3.50, 6.00	.93
10. *PD Quality*: The pre-post differences in the teachers' comfort in implementing the TSI inquiry modes	28	10	1.40	0.89	0.17	-0.20, 3.00	—
11. *PD Quality*: The extent to which the toolbox components were useful	28	7	5.10	0.82	0.15	3.43, 6.00	.87
12. *PD Quality*: the extent to which the PD requirements helped improve understanding of inquiry	28	4	4.79	0.99	0.19	2.00, 6.00	.83
13. *PD Quality*: The extent to which the PD was valuable	28	5	5.24	0.65	0.12	3.80, 6.00	.83
14. *PD Quality*: The extent to which the target activities helped the teachers teach inquiry-based science	28	4	5.51	0.57	0.11	4.00, 6.00	.96

Note. All items constituting the scales were on a six-point Likert scale. No Cronbach's α is shown for Scale 10 because the item results were reported as difference scores.

Table IV-11

Major Categories and Subcategories of Themes Identified in the Content Analysis of the Post-Cohort Interview

Major categories	Subcategories	Number of comments	Percent of the comments in a category	Percent of all comments by category
Implementing TSI		4	3.81%	
	Target activities	25	23.81%	
	M&M activity	16	15.24%	
	The effect of supplies	29	27.62%	
	School contexts	31	29.52%	
		105		**12.30%**
Post TSI PD				
	Future use of TSI	32	29.63%	
	Recommending TSI	27	25.00%	
	Recommendations for PD	27	25.00%	
	Thank you TSI Team!	22	20.37%	
		108		**12.65%**
Research instruments		6	5.66%	
	PD questionnaires	9	8.49%	
	Negatives	2	1.89%	
	Observations	10	9.43%	
	Inquiry assessment (ITA)	8	7.55%	
	Implementation checklist	7	6.60%	
	Lesson plans	14	13.21%	
	Activity reflections	19	17.92%	
	Teacher content assessment	14	13.21%	
	Student content assessment	17	16.04%	
		106		**12.41%**
Website		3	10.34%	
	Positive	11	37.93%	
	Negative	15	51.72%	
		29		**3.40%**

Table IV-11

Major Categories and Subcategories of Themes Identified in the Content Analysis of the Post-Cohort Interview (continued)

Major categories	Subcategories	Number of comments	Percent of the comments in a category	Percent of all comments by category
	Building community	6	2.87%	
	PD effect on inquiry understanding	33	15.79%	
	PD expectations	32	15.31%	
	Positives	13	6.22%	
	Workshops	10	4.78%	
	Follow-up	12	5.74%	
	Blackboard	13	6.22%	
	Length of PD	3	1.44%	
	Issues around Time	30	14.35%	
		209		**24.47%**
TSI pedagogy		43	32.33%	
	Phases of inquiry	31	23.31%	
	Modes of inquiry	18	13.53%	
	Metacognition	15	11.28%	
	Questioning strategies and practices of inquiry teaching	11	8.27%	
	Practices and demeanors	15	11.28%	
		133		**15.57%**
TSI content		62	37.80%	
	Transfer TSI	31	18.90%	
	Positives	5	3.05%	
	Difficulty level	4	2.44%	
	Relevance	20	12.20%	
	Physical	10	6.10%	
	Chemical	11	6.71%	
	Biological	11	6.71%	
	Ecological	10	6.10%	
		164		**19.20%**
Total number of major categories	**Total number of subcategories**	**Total number of comments**		**Total percentage of all comments by category**
7	43	854		**100%**

Nature of Science Assessment

The NOS Likert-scale items had been developed as part of a previous NSF Interagency Education Research Initiative grant project (Brandon et al., 2007). They were based on a careful reading of the literature and shown to be reliable when administered to samples of Hawaii students. The NOS multiple-choice items complemented these Likert-scale items and addressed the themes of NOS described in the literature (e.g., Ayala, 2005; Lederman, 2007), the PD developers' definitions of NOS as informed by the program theory and science-education documents (e.g., National Research Council, 2012), and—in the initial development stages—the factors identified in a factor analysis of the NOS Likert-scale data in the earlier NSF grant project.

In several iterations, we drafted, content-reviewed, revised, pilot-tested, and further revised the NOS items. To address content validity and identify needed revisions, we (a) obtained a review of the items by inquiry science education experts, (b) obtained feedback from a representative group of students and teachers in a pilot test of the instrument (approximately 350 Grades 6–12 students in our affiliated laboratory school), (c) field-tested the instrument in the second year of the project (about 480 of the Cohort 2 and 3 students in the fall and spring and 470 students in prospective Cohort 4 and 5 teachers' classes in the spring), (d) analyzed the pilot-test and field-test data with classical-test-theory and Rasch-analytic methods, and (e) shared item-functioning data (such as item fit and distractor functioning) with members of the project team, who subsequently participated in the revision process and drafted new items for aspects of NOS that needed better representation. The Rasch analysis of the field-testing data revealed that two of the 12 Likert-scale items had a poor fit to the model; these items' stems had negating words such as *neither good nor bad* and *never* that likely explained their misfit. These two probationary items were retained in the final version of the instrument but were placed in a different location in the Likert-scale item section to determine if this change would improve their fit; it did not, so we excluded them from the final scoring because their poor functioning. The final version of the NOS assessment comprised 12 Likert-scale items (10 of which were used) and 18 multiple-choice items.

Aquatic Science Content Assessment

The aquatic science content items made up the other part of the student instrument. During the second year of the project, the project and evaluation teams identified the most important content areas of each of the four modules and drafted a set of items to measure students' knowledge in these components of aquatic science. As the project team further refined its aquatic science content, the two teams carried out further item edits to deal with distractor functioning and address linguistic and other construct-irrelevant features. Major revisions were made to these items in the summer preceding the final year. The edits resulted in a 17-item multiple-choice assessment, with items being interspersed among the 18 multiple-choice NOS items on the final student instrument.

Administering the instrument. The teachers administered the full set of items to consenting students, in teachers' focus classes, on paper-and-pencil tests that we provided to the teachers. The pretest was administered at the start of the school year (August and September, 2012), before the teachers implemented TSI Aquatic lesson plans in their classes, and the posttest was administered at the end of the school year (April and May, 2013), after the teachers had participated in the PD. Teachers were provided with careful instructions to administer the assessments in a controlled environment (included in Appendix C along with the instrument). The test booklets identified each student with an anonymous ID number to ensure the pre-to-post changes were recorded for the same individual while keeping that individual's identity confidential.

Designs for addressing the request to include comparison data. To collect comparison data on the NOS understanding outcome variable, we also administered the NOS items to prospective Cohort 4 and 5 teachers' students the spring before they participated in the project. The purpose of this design was to see if the students who had participated in TSI Aquatic did better on the NOS assessment than an equivalent group of students at the same time in the school year, the year before. This posttest-only design would have been meaningful if the two groups were indeed equivalent. We were unable to accomplish this, however: Not all Cohort 4 and 5 teachers were able to administer these assessments in the previous spring (and not all teachers administering the assessments in the spring were able to continue in the following year with TSI Aquatic), nor were the grade levels and subject areas of several teachers' students the same across the two years; furthermore, some teachers had classes of students with specific learning needs in one year but not in the other. Therefore, we could not assume the two groups of students were sufficiently similar enough to justify a group comparison. A second complication was that the NOS assessment instrument was still undergoing development until just before the beginning of the final year (Cohorts 4 and 5) of the project; that is, the two groups of students did not take exactly the same assessment. Because of these two complications, we did not compare the NOS scores of the two groups. We did, however, use these comparison data, along with NOS assessment data from students in Cohorts 2 and 3, to inform subsequent item revision.

Because the comparison-group students were not equivalent, we took another approach to examining program effect by comparing the final years' students' (Cohorts 4 and 5) pre-to-post gains with the penultimate years' students' (Cohorts 2 and 3) pre-to-post gains. The rationale for this design was that the project had been further developed and refined in the final year, and we wanted to know whether these changes were reflected in students' changes in understandings of NOS. Because the pretests of students in both groups were available, we were able to examine individual students' growth, ameliorating the group equivalence complication that we would have encountered in our posttest-only comparison-group design. However, the complication of having a revised version of the assessment in the final year and an earlier draft in the penultimate year was

still an issue. To deal with this, we linked the two instruments using the mean-sigma method under a Rasch analysis framework. The results for this model are in Table IV-12. Although the model showed a significant pre-to-post gain among students regardless of group, the effect of being in the final year versus being in the penultimate year had no statistically significant effect (at the .05 level) on students' pre-to-post changes. This was not surprising because students in the penultimate year of the program also engaged in TSI Aquatic, albeit in an earlier form, so the degree of program differentiation might not have been strong enough to show up in the assessment scores.

Table IV-12
Comparison of the Final Year's Students with the Penultimate Year's Students on the NOS Assessment

Parameter	Estimate	*SE*
Intercept	0.95**	0.08
Time[a]	0.18**	0.04
Group[b]	-0.17	0.12
Group*Time	-0.08	0.05

Note. Data are from students in Cohorts 2–5 (N = 780) clustered in 55 teachers' classes (27 in the penultimate year and 28 in the final year). Scores are on a partial-credit Rasch-modeled logit scale after equating the earlier and later tests (M_{pre} = 1.02, M_{post} = 1.17). This was a multilevel model, with Time as Level 1, Student as Level 2 (random intercepts and slopes), and Teacher (random intercepts) as Level 3. * = $p < .05$; ** = $p < .01$.
[a] Time was coded 0 for pre and 1 for post.
[b] Group was coded 0 for the penultimate year students and 1 for the final year students.

Scoring the responses. With the final year's Student Science Questionnaire data, the evaluators scored the responses using a multidimensional Rasch analysis (Adams, Wu, Haldane, & Xun, 2012), with NOS as one dimension and content as the other. The rationale for doing this rather than scoring the two dimensions separately was that the two constructs were assumed to be related (the correlation between the two dimensions was .61 on the pre and .67 on the post). Item difficulties were estimated with both the pre and post data run simultaneously to ensure equivalence across the two forms.[4] Descriptive statistics are shown in Table IV-13. The estimated gain in students' scores on the NOS, regardless of the nested structure of the data (i.e., the clustering of students within classes), was about one-tenth of a standard deviation unit; that of the content assessment

[4] In a strict sense, this would be considered a violation of the statistical assumption of local independence because the same individual is treated as two observations—one in the pre and one in the post; however, because the pre- and post-assessments were administered about 8 months apart and there were over 400 individuals (413 students took both the pre and the post), this violation was unlikely to cause model specification errors.

was one-third of a standard deviation (significance tests were conducted after accounting for the nested structure of the data and are reported in the analysis section below).

Table IV-13
Descriptive Statistics of the Student Assessment Scores

Instrument	*N* students	*M*	*SD*	Min, Max	Reliability
NOS Pre[a]	578	0.65	0.60	-1.45, 2.86	.74
NOS Post[a]	440	0.72	0.71	-0.76, 4.76	.80
Content Pre[b]	578	-0.34	0.68	-2.92, 1.65	.34
Content Post[b]	440	-0.06	0.82	-4.17, 2.92	.55

Note. Data are from students in Cohorts 4 and 5. Scores are on a partial credit Rasch modeled logit scale (using ConQuest by Adams, Wu, Haldane, & Xun, 2012) after anchoring the item difficulties to be the same at both time points. Reliability estimates were based on the Rasch-modeled maximum-likelihood person separation reliability. The effect size of the pre-to-post gain on the NOS (regardless of the nested structure of the data and for only those students taking both tests, $n = 413$) was Hedges' $g = 0.09$; that of the content pre-to-post gain (the same 413 students) was Hedges' $g = 0.34$.
[a]NOS = Nature of science assessment scores, comprising 28 items (18 multiple choice; 10 functioning Likert-scale items).
[b]Content = Aquatic science content assessment scores, comprising 17 multiple-choice items that measured knowledge of physical, chemical, biological, and ecological science concepts and knowledge in the context of aquatic science.

Reliability. The reliability (maximum-likelihood person-separation Rasch reliability) of the NOS dimension with the pre- and post-assessment data combined was .77; with the pre alone, it was .74; with the post alone, it was .80. These are reasonable given that NOS reliability estimates in previous studies are similar: For example, in Wenning (2006) the KR-20 of a 35-item multiple-choice NOSLit assessment was .79; in Chen et al.'s (2013) 47-item Likert-scale survey, reliabilities ranged from .67 to .85. Because NOS is a broadly defined construct, having multiple aspects, moderate reliability is typical with NOS assessments (Blalock et al., 2008; Chen et al., 2013).

Estimates of reliability of the content items were low: For the pre and post combined, it was .46; with the pre alone, it was .34; and for the post alone, it was .55. This is not surprising, because the content items were not adequately pilot tested after they had undergone major revisions. Additionally, the content assessment covered a very broad range of content, with only about four items for each of the four modules. Keeping the assessment short was a priority (to avoid respondent fatigue and to minimize time taken away from students' regular class time), which precluded development of a longer pre-post-cohort instrument to measure knowledge on each module's content. Because of the low reliability of the student content assessment, therefore, caution should be taken in interpreting the results of the student content assessment scores.

Analysis. Because the students were nested in classes, and because we needed to consider variables such as (a) school level, (b) teachers' overall teaching experience, (c)

amount of teachers' prior experience with science PDs, (d) teachers' prior understanding of what inquiry looks like in the classroom, (e) teachers' self-reports of their pedagogical content knowledge, self-efficacy in teaching, and metacognition, and (f) the teachers' FOI, we used a multilevel model to examine the pre-to-post change in students' NOS and content scores (an approach suggested by Zvoch, 2012). We included school-level (elementary-, middle-, and high-school) data to determine where the PD had a stronger effect; we did not operationalize this at each grade level because some teachers taught classes with more than one grade in the same class. We examined teacher background variables (years of teaching experience; number of science PD courses taken before entering the TSI Aquatic PD) to determine whether the PD better targeted contexts with less experience. We included measures of teachers' pre-PD scores to see if TSI better targeted classrooms taught by teachers with an incoming low degree of inquiry knowledge, PCK, self-efficacy, metacognition, or content knowledge. We examined three features of teachers' FOI: Their adherence to the project when they administered the lessons in their classes, their responsiveness to the project, and their quality of their implementation in their classrooms. These FOI variables were aggregate measures from the multiple *Teacher Reflections* and the *Post-Cohort Questionnaire*.[5] The descriptive statistics of these FOI measures (before centering them for the multilevel-model analysis) are in Table IV-14. The descriptive statistics of the teacher-level variables included in the multilevel models are in Table IV-15. The results of the two multilevel models, one for students' NOS scores and one for students' content scores, are provided in Table IV-16.

The results indicated that overall (i.e., when all the predictors were at their centered value of zero) there was a statistically significant gain in students' NOS scores (represented by the time estimate in Table IV-16). Furthermore, students whose teachers adhered more closely to the TSI Aquatic activity lessons were estimated to have significantly greater gains from pre to post on the NOS assessment than students in classes with teachers who did not adhere to the way the lessons were intended to be taught (represented by the time-by-teacher-adherence interaction estimate). Furthermore, those teachers who entered the project with a lower than average degree of pedagogical content knowledge had students who significantly improved in their NOS scores (represented by the time-by-pre-PD-pedagogical-content-knowledge interaction estimate). Other teacher-level variables, such as their science content knowledge and their prior understanding of inquiry-based science teaching, however, had no moderating effect on students' growth.

[5] Although Dane and Schneider (1998) also include exposure and program differentiation as features of fidelity of implementation, we did not include these in our analysis. With regard to exposure, all 28 teachers met the requirement of implementing at least 12 TSI lessons; although some students may have been exposed to more TSI than others, all were presumably exposed to at least the required amount. We did examine exposure in the Post-Cohort Questionnaire by asking teachers about how much they included each of the ten modes throughout the year, but we determined that this measure of exposure was too narrow in scope to include as a predictor here. Program differentiation was outside the purview of the evaluation.

Similar to what was observed with the NOS assessment, there was a statistically significant gain in students' content assessment scores. Also similar to what was observed with the NOS component, the students whose teachers adhered more closely to the TSI Aquatic activity lessons were estimated to have significantly greater gains from pre to post on the content assessment than students in classes with teachers who did not adhere to the way the lessons were intended to be taught. Additionally, the teachers with higher adherence likely had students who started out with higher content scores (represented by the main effect of teacher adherence). The main effect of pre-PD metacognition also indicates students in classes taught by teachers reporting high metacognition started out with higher pre scores than students in other classes; this variable had no significant effect on student content growth, however (the time-by-pre-PD-metacognition-in-teaching estimate was not significant). Those teachers who had taken fewer science PD courses in the past had students who significantly improved more on their content scores (compared to the gains of students in classes with teachers who had taken a lot of previous science PDs). Students in lower grade levels gained significantly more in their content compared to students in higher grades; and, as expected, students in higher grade levels had higher pretest scores, as represented by the main effect of school level.

Table IV-14
Descriptive Statistics and Reliability of the Teacher Implementation Variables Used in the Multilevel Models

Variable	No. items from Post-Cohort Questionnaire	No. items from Teacher Reflection	*M*	*SD*	SE_M	Min	Max	α
Teacher Adherence	4	9	3.51	0.47	0.09	2.76	4.59	.86
Teacher Responsiveness[a]	4	3	4.00	0.52	0.10	2.63	4.79	.85
Teacher Quality of Implementation	11	21	3.99	0.33	0.06	3.30	4.58	.93

Note. The data are from the 28 teachers completing Cohorts 4 and 5, from teachers' self-reports of fidelity of implementation on the Teacher Reflections and Post-Cohort Questionnaire. The data are on a 1-to-5 scale. The items from the Post-Cohort Questionnaire were transformed from their 1-to-6 scale to the 1-to-5 scale. One Teacher Reflection item measuring adherence was transformed from its 0-to-1 scale to the 1-to-5 scale. All three variables met the assumption of normality (Shapiro-Wilk tests did not reveal non-normality; $p > .05$ for all three). α = Cronbach's alpha reliability. [a] For this measure, we used the four scales of the Post-Cohort Questionnaire (reported in Table IV-10) rather than the items constituting those scales because the number of items used in each scale varied from 3 to 10 and we believed the construct was better measured by equally weighting the four scales.

Table IV-15
Descriptive Statistics of the Teacher-level Predictors Used in the Multilevel Models

Predictor	*M*	*SD*	Min	Max	*Kurtosis*	*Skew*
Pre-PD No. Years Teaching Science[a]	0	6.96	-8.25	20.75	1.39	1.07
Pre-PD No. Science PD Courses Taken[b]	0	1	-1.14	1.38	-1.56	0.08
Pre-PD Inquiry Teaching Assessment	0	1	-1.48	2.82	0.88	1.03
Pre-PD Pedagogical Content Knowledge	0	1	-1.64	2.05	-0.88	0.41
Pre-PD Self-Efficacy in Science Teaching	0	1	-1.60	2.37	-0.38	0.49
Pre-PD Metacognition in Teaching	0	1	-1.86	1.49	-0.89	-0.05
Pre-PD Aggregate Content Score	0	1	-1.77	1.80	-0.96	-0.20
Teacher Adherence[c]	0	1	-1.63	2.31	0.01	0.49
Teacher Responsiveness[c]	0	1	-2.67	1.52	0.25	-0.67
Teacher Quality of Implementation[c]	0	1	-2.12	1.79	-0.23	-0.16

Note. Data are from the 28 teachers completing Cohorts 4 and 5, from the Background Questionnaire, the Inquiry Teaching Assessment, Classroom Instruction Questionnaire, the aggregate of the four standardized pre-module content assessments, and teachers' self-reports of fidelity of implementation on the Reflections and Post-Cohort Questionnaire. The first variable was centered and the others were standardized (to reduce multicollinearity in the multilevel model).

[a] This was an open-response question asking for the number of years.

[b] This was a Likert-scale question, where 1 = 0; 2 = 1–2 courses; 3 = 3–4 courses; 4 = 5 or more science PD courses.

[c] These three fidelity of implementation variables were from aggregate scores from the Reflections and the End-of-Cohort Questionnaire (all scores were on a 1-to-5 scale before being standardized).

Table IV-16
Multilevel Model Results of the Student Assessments

Parameter	NOS			Content		
	Estimate	*SE*	*t*	Estimate	*SE*	*t*
Intercept	0.56**	0.06	9.85	-0.47**	0.05	-8.69
Time[a]	0.09*	0.04	2.42	0.34**	0.04	7.78
School Level[b]	0.11	0.09	1.11	0.24*	0.09	2.68
Time*(School Level[b])	-0.08	0.06	-1.32	-0.25**	0.07	-3.48
Pre-PD No. Years Teaching Science[c]	0.00	0.01	0.38	0.01	0.01	0.74
Time*(Pre-PD No. Years Teaching Science[c])	0.00	0.01	0.15	0.00	0.01	0.44
Pre-PD No. Science PD Courses Taken[d]	-0.07	0.06	-1.23	-0.06	0.05	-1.09
Time*(Pre-PD No. Science PD Courses Taken[d])	-0.06	0.04	-1.52	-0.13**	0.04	-2.98
Pre-PD Inquiry Teaching Assessment[d]	0.09	0.07	1.23	0.11	0.07	1.65
Time*(Pre-PD Inquiry Teaching Assessment[d])	-0.02	0.05	-0.40	0.07	0.06	1.23
Pre-PD Pedagogical Content Knowledge[d]	0.04	0.07	0.54	-0.08	0.07	-1.10
Time*(Pre-PD Pedagogical Content Knowledge[d])	-0.13**	0.05	-2.80	-0.09	0.06	-1.49
Pre-PD Self-Efficacy in Science Teaching[d]	-0.02	0.07	-0.22	0.01	0.07	0.16
Time*(Pre-PD Self-Efficacy in Science Teaching[d])	0.07	0.04	1.45	0.03	0.05	0.50

Table IV-16
Multilevel Model Results of the Student Assessments (continued)

Parameter	NOS			Content		
	Estimate	*SE*	*t*	Estimate	*SE*	*t*
Pre-PD Metacognition in Teaching[d]	0.06	0.07	0.87	0.15*	0.07	2.12
Time*(Pre-PD Metacognition in Teaching[d])	-0.06	0.05	-1.11	-0.05	0.06	-0.82
Pre-PD Aggregate Content Score[d]	-0.02	0.09	-0.21	0.03	0.09	0.30
Time*(Pre-PD Aggregate Content Score[d])	-0.02	0.06	-0.31	0.01	0.08	0.14
Teacher Adherence[d, e]	0.10	0.09	1.09	0.19*	0.09	2.22
Time*(Teacher Adherence[d, e])	0.14*	0.06	2.43	0.19**	0.07	2.72
Teacher Responsiveness[d, e]	-0.08	0.10	-0.74	-0.08	0.10	-0.80
Time*(Teacher Responsiveness[d, e])	-0.09	0.06	-1.42	-0.11	0.08	-1.48
Teacher Quality of Implementation[d, e]	-0.11	0.08	-1.38	-0.14	0.07	-1.82
Time*(Teacher Quality of Implementation[d, e])	0.05	0.05	1.05	0.02	0.06	0.31

Note. Data were from 413 students (those who took both the pre and the post) in Cohorts 4 and 5. Scores are on a Rasch-modeled logit scale after anchoring the item difficulties to be the same at both time points. The NOS and Content scores were modeled as separate but related dimensions, based on a partial credit model to account for polytomous and dichotomous data. Time was Level 1, Student was Level 2 (random intercepts and slopes), and Teacher (random intercepts) was Level 3.
* = $p < .05$; ** = $p < .01$.
[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] This predictor was centered. [d] These predictors were standardized.
[e] These three fidelity of implementation variables were from aggregate scores from teachers' reflections and the Post-Cohort Questionnaire.

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CHAPTER V
SUMMARY OF THE FINDINGS FOR EACH EVALUATION QUESTION

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In this chapter, we (the evaluation team) introduce the findings addressing each evaluation question and provide conclusions about these findings. The data and results presented in Chapter IV are referenced as support for these findings.

Question 1: To what extent was the PD structured in the intended manner?

We considered four types of information in determining the extent to which the TSI Aquatic PD was structured in the intended manner: the intended and actual number of PD hours provided to participants, the intended and actual timetable of PD events, the intended and actual structure of PD activities, and the intended and actual content that was delivered in the PD. The data for addressing this question primarily came from records of the PD events, including project team' documents, evaluators' observations of the workshops, and meeting notes after debriefings with the project team. Most of these data-collection activities had been prepared for formative evaluation purposes and did not include rigorous data collected for summative evaluation purposes. The project team intended the PD to include activities distributed throughout the school year rather than as a densely packed set of activities provided in a short period of time. This was fully achieved. The intended total number of face-to-face (both virtual and in-person) hours with teachers was 84. This was fully achieved.[6] The intended structure was to provide four modules, each with a two-day in-person workshop, an evening follow-up session, and an online virtual meeting. This was fully achieved.[7] The intended content of the workshops—the inquiry pedagogy and aquatic science content—was fully implemented. Evidence for these conclusions came from records from the project team (e.g., Chapter II), the evaluators' observations of the workshops, debriefings with the project team (e.g., the consultant meeting after Year 2, described in Chapter II), and the very high response rate from the teachers on the Post-Workshop Questionnaires and their qualitative comments about the PD structure in the Interviews (Appendix D).

Question 2: To what extent did the teachers find the PD valuable and relevant to ongoing practice?

The teachers' responses on the Post-Cohort Questionnaire, the Post-Cohort Interview, and the Post-Workshop Questionnaires suggest that the teachers perceived the PD to be valuable and relevant to their continued practice. On the Post-Cohort Questionnaire, the aggregate responses on the four relevant teacher-responsiveness scales (Scales 3–6 in

[6] The project team had also intended to provide 16 asynchronous contact hours with teachers. The evaluation team did not collect data on this component.

[7] The project team had also intended to provide an online component, through the Online Learning Community, which is discussed in Chapter III. The evaluation team did not collect data on this component of the structure.

Table IV-10) were moderate to high. Of these four scales (which were based on six-point Likert-scale items), the first one, which addressed the teachers' perceptions of the value and relevance of the training, was the highest (M = 5.29 on the 1-to-6 scale). The lowest scale was the one asking about the teachers' intent to use the TSI Aquatic phases in the future (M = 4.67); this scale also had the highest variability among the teachers (SD = 1.22), suggesting some of the teachers found the phases to be very relevant whereas others did not. Compared to the modes (Scale 4; M = 5.24), the phases were perceived as less valuable and relevant. The aggregate responses on the two relevant PD quality scales on the Post-Cohort Questionnaire were also high. The scale addressing the extent to which the teachers believed the overall PD was valuable was moderately high (M = 5.24). Slightly below this was the scale addressing the extent to which the toolbox components of the PD were useful (M = 5.10). These two PD quality scales were consistent with the two teacher responsiveness scales that addressed the extent to which the teachers valued the PD and found the TSI Aquatic toolbox components to be relevant.

The interview results support these findings: All of the teachers conveyed (some to a greater extent than others) that they found the PD to be valuable to their learning and teaching about science as inquiry. In response to the question, "On a scale from 1 to 10, how valuable do you think this PD has been to your understanding of TSI (please explain your answer)," most of the teachers lauded the program, and some described it as the best PD experience they had ever had. One teacher said, "I think [the PD] was extremely valuable in every way; I feel more comfortable teaching other subjects too as a result. I feel that I have gained a lot, and believe that every science teacher should have access to this PD." One value-and-relevance feature that emerged from the interviews was that the PD facilitated teacher community building.

The interview results also support the earlier reported finding observed on the Post-Cohort Questionnaire in that the teachers varied in their perceptions of the value of understanding and using the terminology of the phases, which were presented as a core feature of the pedagogy. Some of the teachers conveyed that they greatly appreciated the pedagogy, whereas others were critical of the phases and said they were hesitant to implement them in their classes. One teacher, for example, said "I really … like the phases and the modes of inquiry—it really caught my attention and my students' attention. I keep telling them that science is not linear, so that is why I like the phases because I am able to relate the information to my students. It was very meaningful because we have always taught science to be linear, especially through the scientific method and the scientific process, through science experiments, so it was nice for me to learn and also nice for my students." By another teacher's account, "The phases and the modes, even though I understand them, to me, to have that be a big part of what you teach students—it takes more time than what you get out of it. It is an alternate way of teaching the scientific method, but the vocabulary and the context of it, I am not just sure it is worth the time to teach it. I am not sure that it is that important for the students to

know about the difference between investigation and invention, it takes a lot of effort." Several other accounts with similar competing perspectives about the TSI Aquatic pedagogy are provided in the interview summary (Appendix D).

The responses on the Post-Workshop Questionnaires, which were administered at the end of each module's workshop, also included data relevant to the findings. The mean responses for all the items except one exceeded 5.0 (on a 1–6 scale). For the most part, the teachers perceived the workshops as helpful in improving their ability to incorporate TSI in their classrooms (Prompts 7 and 20 exceeded 5.60). The content knowledge they gained was rated highly (the mean of Prompt 9 = 5.66), which was consistent with the prompt asking about the capability to incorporate aquatic science in the classroom (Prompt 7). The lowest mean rating was on the prompt addressing the difficulty of both the content and pedagogy (Prompt 21 = 4.76); given that this was a double-barreled question, it could have been either the content or the pedagogy that was perceived as difficult. However, because the second-to-lowest rating was on the pedagogy (Prompt 10 = 5.10), it suggests that compared to content and other features of the workshops, the pedagogy (which included the phases) was perceived as less valuable to, and perhaps more difficult for, the teachers (though still high, given the range of the scale was 1 to 6). This finding is consistent with data collected in the interviews and the Post-Cohort Questionnaire, although in this questionnaire, the phases and modes were not separately addressed. Furthermore, the notes from the informal PD observations (conducted for formative-evaluation purposes and not reported here) were also in keeping with this finding that the pedagogy aspect of the workshops might need closer attention in future TSI Aquatic PDs.

Overall, the findings suggest that the teachers valued the PD and found it to be relevant to their practice. Highly rated features were the science content and the community building; there was less agreement among the teachers in their perceptions of the value of the pedagogy—particularly with the phases.

Question 3: To what extent did the teachers improve in their pedagogical content knowledge, self-efficacy in teaching science, and metacognition in teaching?

The data for addressing this question came from the Classroom Instruction Questionnaire, the Teacher Reflections, and the Post-Cohort Interviews. The results suggest that the teachers detected improvements in their self-efficacy in teaching science through the process of inquiry and that, for the most part, their perceptions of their pedagogical content knowledge and of their metacognition in teaching science improved as well, but to a lesser degree, with variability among teachers in their pre-to-post changes. The three scales on the Classroom Instruction Questionnaire provided pre-to-post data on these three components; the interview responses provided data suggesting that the teachers varied in their perceptions of their TSI teaching.

The teachers' gains on the Pedagogical Content Knowledge Scale from pre to post were moderate, with an effect size of about one-quarter of a standard-deviation unit.

Because the gain was not statistically significant, we cannot conclude that this result would exist with a group of similar teachers under the same conditions, but the effect size does indicate there was a moderate improvement among the teachers in this instance of the project.

The teachers' gains on the Self-Efficacy in Science Teaching Scale from pre to post were strong, with an effect size of about 150% of a standard deviation unit. This instrument, which was a self-report questionnaire, targeted aspects of the TSI Aquatic pedagogy, particularly the phases of inquiry, that were emphasized in the PD; because of this narrow focus in construct, this gain was not surprising. Insofar as the teachers would have been unfamiliar with the terminology used in TSI prior to their participating in the PD, responses on a pre-test questionnaire would have misrepresented their self-efficacy with the practices, posing a threat to the validity of the pre-to-post-change interpretation. Therefore, to ensure teachers understood the prompts, we administered it as a retrospective pre-post questionnaire. The trade-off for ensuring respondents understand the prompts, though, is that the retrospective pre-post design may have invited a social-desirability effect. Caution should be taken, therefore, when interpreting these results. Nonetheless, it was probable that the teachers actually did improve in their self-efficacy, with the large effect (150% of a standard-deviation-unit) likely being an upper estimate of this improvement.

The teachers' gains on the Metacognition in Teaching Scale from pre to post were small, with an effect size of about one-fifth of a standard deviation unit. Because the gain was not statistically significant, we cannot presume that this gain was not due to chance. One possible explanation for this weak improvement may have been that the teachers gained a more nuanced understanding of metacognition while participating in the PD, which may have caused their self-ratings to be closer to reality compared to their relatively less-nuanced and perhaps inflated perceptions of their practice before participating in the PD.

We found in the interview that the majority of the teachers perceived the pedagogy to be easy when they encountered it during the PD workshops as participants but when some of these teachers implemented the pedagogy in their classrooms, they struggled. This might be construed as contradictory to the gains observed on the Self-Efficacy in Teaching Scale; however, the interview did not prompt the teachers to discuss their changes in their self-efficacy throughout the year. Another qualification to the teachers' perceptions of their TSI Aquatic pedagogy was that some of the teachers said they perceived the content as easier to implement than the pedagogy. Some teachers expressed appreciation with the content lessons because they were able to appropriate new activities into their teaching repertoire.

On the Teacher Reflections, there were two scales that were relevant to this evaluation question. The first one, Scale 15, addressed the teachers' confidence in teaching the content after having implemented the target activity. On the 1-to-5 scale, the

mean of this was 4.40, which was the second highest scale among the 37 scales having the same range of possible scores (Table IV-9). The second scale, Scale 40, was a measure of teachers' gains in confidence in teaching the content. This gain score was high, with a mean difference of over one full scale point as a result of the teachers' participation in the PD. These results suggest the teachers perceived their content gains to improve after implementing the TSI Aquatic lessons in their classrooms.

Across the results from the Classroom Instruction Questionnaire and the Teacher Reflections, a consistent finding is that participants improved in their self-reports of their self-efficacy in teaching science. The Post-Cohort Interview and Teacher Reflections results suggest this gain was likely stronger in the content component of the PD than in the teaching components. With the TSI Aquatic teaching components, there was variability among the teachers in their perceptions of their ability to actually implement them in the class. On the Classroom Instruction Questionnaire, the results indicated that for the Cohort 4–5 teachers, there were weak to moderate gains in self-reports of pedagogical content knowledge and metacognition in teaching, but the findings cannot be generalized beyond this particular PD with this group of teachers.

Question 4: To what extent did the teachers gain in their understanding of inquiry-based science teaching?

The teachers' gains on the Inquiry Teaching Assessment from pre to post were strong, with an effect size of about 125% of a standard deviation unit. This suggests that the teachers participating in the project improved in their understanding of what inquiry looks like in the classroom.

Although there were no comparison group data for examining the counterfactual (i.e., teachers that had not participated in the program), it is safe to assume that this strong gain would be unlikely with teachers not participating in the project. It is unlikely, for example, that regular maturation effects of teachers would explain gains in scores. Because it was a constructed-response assessment, with the post-test eight months after the pre-test, it was also unlikely that the teachers' gains were explained by their experience with the pre-test.

One caveat for interpreting these gains, however, is that teachers' responses reflected what they write about inquiry-based teaching, not what they actually do in the classroom. Nonetheless, based on the corroborating evidence from the interview responses (described immediately below) and from one pertinent item on the Teacher Reflections (also described below), we can confidently conclude that the teachers' gains on this assessment were strong and that they were due, at least in part, to their participation in the TSI Aquatic PD.

On the Post-Cohort Interview, one question posed to the teachers explicitly asked them about the PD's effect on their understanding of inquiry. From among the 28 teachers interviewed, 25 reported that they believed the PD had a noticeable effect on their inquiry understanding. One teacher said, "I remember when I first wrote down my

definition of inquiry, and now after the PD when we were asked to write it again I could really see the difference. I really liked that [the PD] stressed the fact that there are different ways and methods of inquiry—that inquiry doesn't always have to be open-ended." Another teacher stated, "[the PD] helped me crystallize or focus my ideas about science teaching, and now I realize it has a name; inquiry based science. I knew how I wanted to do what I want to do, but now I have a better idea of how to [teach inquiry]." The three teachers who did not believe that the PD really affected their understanding of inquiry explained that their existing beliefs were confirmed rather than changed. Since these teachers had knowledge of inquiry prior to this PD, it was likely that these teachers entered with an already solidified definition of inquiry.

On the Teacher Reflections, one item (Item 14, which comprised the aggregate responses across 15 activities) addressed teachers' perceptions of the effect of the TSI Aquatic activities on their understanding of teaching science as inquiry. The mean on this item was 4.00 on the 1-to-5 scale. This moderately high rating supports the conclusion that the PD was what contributed to the observed gains on the Inquiry Teaching Assessment.

Question 5: To what extent did the teachers gain knowledge about aquatic science content?

The teachers' scores on the content tests improved consistently for each of the four modules, with effect sizes ranging from two-thirds to one full standard deviation unit. An important thing to consider when interpreting these results is that the items were sampled from the content taught in the module rather than from a larger sample of all possible aquatic science content items. This method of sampling, however, was the intention, as the assessments were meant to serve a criterion-referenced interpretation rather than as a measure of the teachers' overall knowledge of science content, which would have required a very broad, and therefore less precise, sample of the content domain. In other words, the teachers' scores reflect their improved knowledge of the content that was addressed in the TSI Aquatic PD. A second caveat in interpreting these scores is that teachers completed these assessments online at their own convenience; although they were instructed to do their best without consulting outside sources or materials from the PD, there was no way for the evaluators to monitor this. Insofar as teachers completed these assessments without outside aid, the consistent strength and statistical significance of their gains suggest the PD was successful at improving the teachers' knowledge in this domain.

Question 6: To what extent did the teachers implement the project activities in the intended manner with fidelity?

Findings based on aggregated items of adherence, responsiveness, and quality of implementation

To investigate the extent to which the teachers implemented the project activities in the intended manner, the evaluation team examined the aggregate variables calculated

from responses to the Post-Cohort Questionnaire and the Teacher Reflection (presented in Table IV-14). These provided rough estimates of three features of the teachers' fidelity of implementation (FOI): adherence (the extent to which teachers adhere to the steps in the TSI activities when implementing them in their classes), teacher responsiveness (the extent of teachers' enthusiasm for and degree of participation in the program activities), and the teachers' quality of implementation (how well teachers implement the activities in their classes).

One advantage to collecting fidelity data at the end of a project is that teachers likely have a more mature understanding of the project components than at any other time in the project, suggesting responses have high accuracy. One potential drawback of end-of-project implementation surveys is that teachers might not accurately recall events occurring in their classes throughout the span of the project. Previous work addressing this concern (Brandon et al., 2007; Mullens & Kasprzyk, 1996) found moderate correlations between teachers' end-of-project surveys and their regular teachning logs, suggesting the end-of-project data are indeed usable. With our implementation data, the high reliability estimates (Cronbach's alpha on all three FOI features exceeded .84, as shown in Table IV-14) provided evidence that the teachers were consistent in their responses to items constituting these variables across the two instruments—the Post-Cohort Questionnaire and the Teacher Reflection.

Of the three teacher FOI variables, the lowest was adherence, with a mean of 3.51 on the 1-to-5 scale; this was about one standard-deviation unit below the means of the other two variables. The teacher-responsiveness and teacher-quality-of-implementation variables were at about 4.00 on the same scale. The results of this broad measure of teacher FOI suggest two conclusions. First, it might be said that many of the teachers tended to be responsive to the TSI Aquatic content and pedagogy and that they were comfortable in the quality of their implementation of the activity lessons in their classrooms, but that several teachers did not closely adhere to the components of the lessons and pedagogy. Alternatively, it might be said that teachers' opinions about responsiveness and quality of implementation (concepts that, more than adherence, address teachers' affect and perceptions of self-worth) might be inflated due to a social desirability effect. Our findings in the next section tend to confirm the second conclusion.

Adherence Findings. In looking more closely at the adherence variable, we found that at the end of the project, when the teachers were asked to reflect back on the extent to which they implemented each module's lessons (on the Post-Cohort Questionnaire), they had moderate to moderately high self-ratings: The mean rating on Scale 1 of Table IV-10 was 5.04. Of the 13 1-to-6-point FOI scales on this instrument, this adherence scale was at about the middle in its degree of endorsement (five items were lower than it and seven were higher).

Of the eight five-point Likert-scale adherence items (administered across multiple reflections) on the Teacher Reflections, the two lowest rated items were those addressing

the teacher's explicit inclusion of the metacognition (M = 2.63) and phases of inquiry (M = 2.68) components. The two highest-rated items addressed the teachers' adherence to the EOFE component (M = 4.05) and the connection of the activity to the ocean (M = 3.23). One item, on a 0-to-1 scale, addressed the proportion of the activity components (and activity prompts) that the project intended the teachers to cover in the activity lessons. The mean proportion across all the activity reflections and across all teachers was .68, suggesting that the teachers adhered to about 68% of the project activities. Based on this more detailed examination of the adherence data, the findings are that the teachers adhered less to the phases of inquiry and metacognition aspects of the pedagogy and that they adhered more closely to the features of the activity lessons that addressed the content (the connection to the ocean and the EOFE procedures).

Teacher Responsiveness Findings. In looking more closely at the teacher responsiveness variable, we found that at the end of the project, the teachers rated three out of the four scales highly (responses of Scales 3–5 in Table IV-10 ranged from 5.16 to 5.29 on the 1-to-6 scale). The highest rated scale addressed the perception of the value and relevance of the training. The lowest was the scale addressing teachers' intent to use the phases of inquiry in their future classroom practice (the mean of Scale 6 was 4.67), which was the second-to-lowest-rated scale on the instrument. (We addressed this same scale in Evaluation Question 2 when discussing the teachers' perceptions of the PD's value for ongoing practice.) That is, with the phases, some of the teachers were highly responsive; others were not.

Of the three five-point Likert-scale items on the Teacher Reflections, the lowest-rated one addressed the teachers' belief about the extent to which connecting the activity to the ocean helped to engage students (the mean of Scale 10 was 3.18). This was moderately low, ranking as the 29th highest rating among all 37 five-point items on this instrument. The other two items, which were moderately rated, addressed the teachers' beliefs about the effect of implementing the lessons on their understanding of teaching science as inquiry (M = 3.90) and their beliefs about the usefulness of the questioning strategies (M = 3.88). We have no reasonable speculations about why some teachers believed the connection to the ocean did not engage students as strongly as it could have. This finding merits further investigation.

Teacher Quality of Implementation Findings. In looking more closely at the teacher quality of implementation variable on the Post-Cohort Questionnaire, we found that at the end of the project, the teachers rated their success in implementing the target activities highly (the mean of Scale 7 in Table IV-10 was 5.34 on the 1-to-6 scale). They rated their comfort in implementing the TSI activities a little lower (the mean of Scale 8 was 4.92).

Of the 21 five-point-Likert-scale items on the Teacher Reflections, the lowest-rated addressed teachers' success in guiding their students through some of the modes of inquiry; those modes were product evaluation (M = 3.46), technology (M = 3.47),

deduction (*M* = 3.51), and induction (*M* = 3.52). The highest-rated items addressed teachers' understanding of the content (*M* = 4.36) and their confidence in teaching the content after having done the activity (*M* = 4.40). These findings suggest the teachers had greater confidence implementing the content aspects of the activities than the pedagogy aspects; a finding that is consistent with the interview results.

To examine whether there appeared to be any change in the teachers' quality of implementing the modes and the phases, across the four modules, we examined the plots of the teachers' self-reports on the Teacher Reflections across time (Figures IV-3 and IV-4). One of the intended outcomes of the project was for teachers to expand their repertoire of modes and place less emphasis on the experimentation mode. In examining whether this was the case, we found only moderate evidence of changes in mode use. There appeared to be a slight decrease in use of the experimentation mode, supporting the project's goal to deemphasize the overuse of this mode. There appeared to be moderate increases in authoritative knowledge, product evaluation, and replication. We can surmise that the teachers' increases in quality of implementation of these modes were due, at least in part, to their participation in the project. The induction, deduction, and technology modes tended to be implemented with less quality throughout the year, suggesting future TSI Aquatic PDs examine these modes and determine whether more attention needs to be devoted to them in the PD or whether the activities should be designed to be more amenable to these modes' implementation. Because some activities lent themselves to particular modes to a greater extent than others, these trends in mode use across the modules should be interpreted with caution.

In examining a similar plot of the quality of implementation of the phases from the Teacher Reflections (Figure IV-4), we found that overall the use of the phases increased as the project progressed. Notable were the increases in the use of the interpretation and invention phases. This increase in quality of implementing the phases corresponds with teachers' improvements on the Inquiry Teaching Assessment.

Question 7: To what extent did the students gain in their nature-of-science understanding and in their aquatic-science-content knowledge?

For both of the student assessments, the multilevel model results (Table IV-16) permitted an examination of the students' gains while accounting for the nested structure of the data. The students' pre-to-post change in the model was measured with the *time* parameter, where the estimate is the amount of expected gain in scores from the pre to the post. The model results also permitted examination of gains in light of (a) a rough measure of grade level, where some classes had students in multiple grade levels and we did not have access to individual students' grade levels, (b) teachers' baseline assessment scores and self-reports of prior experience and practice, and (c) teachers' self-reports of their fidelity of implementation of the TSI Aquatic classroom activities.

Changes in Students' Nature-of-Science Understanding. The results of the time parameter in the multilevel model of students' NOS scores revealed that when all of the

other model predictors (besides time) were set to zero (i.e., when they were at the mean across the 28 teachers), the students were estimated to gain in their pre-to-post scores by about 0.09 points (on the Rasch-scored logit scale), which was statistically significant at the .05 level. This modest effect, which had the strength of about 13% of a standard-deviation unit, indicates that, for the most part, the students in classes of teachers participating in the project improved in their understanding of the nature of science.

The extent to which students' NOS improvement was due to the intervention—rather than to regular maturation effects—is revealed in the significance and strength of the time-by-teacher-adherence parameter. The results indicated that the students enrolled in classes taught by teachers who closely adhered to the program were estimated to gain significantly more on the assessment than students in classes with teachers who did not adhere to the program. The strength of this effect was about 21% of a standard deviation unit. This 0.14 point gain above the estimated 0.09 point gain (when all teacher variables are at the mean) suggests that when the teachers adhere to the TSI Aquatic pedagogy and content in their lessons, their students improve in NOS understanding; when they do not adhere to the TSI Aquatic pedagogy and content, their students are not as likely to improve. When this effect (0.14 point gain) is added to the estimated typical gain (0.09 points), the total estimated effect is an increase in 0.22 points, which translates into an effect size of about one-third of a standard-deviation unit on the NOS scores.

Additionally, the teachers' pedagogical content knowledge predicted how much students would gain from pre to post on the NOS assessment. The teachers one standard deviation below the mean on the Pedagogical Content Knowledge Scale at the beginning of the project were estimated to have students that gained 0.13 points (20% of a standard-deviation unit) more than students in classes where teachers were at the mean. The total estimated gain for these students was 0.22 points, which translates into an effect size of about one-third of a standard-deviation unit on the NOS scores. This suggests the program benefitted students in classrooms taught by teachers who, in the beginning, had lower levels of pedagogical content knowledge. Because the Pedagogical Content Knowledge scale comprised self-report items, this may indicate that teachers with more modest views of their pedagogy may have been more receptive to implementing TSI Aquatic.[8] More research into this phenomenon is warranted. Because we could not obtain pre-post scores of students not participating in TSI Aquatic (nor could we obtain post-only data from an equivalent group of students), we could not provide an estimate of NOS scores (or gains) for students who did not participate in TSI Aquatic. We did investigate the effect of the program's improvement from the penultimate (the year prior to the final year) to the final year by treating the penultimate year's students as a comparison group. Both groups were estimated to gain from pre to post, but they did not

[8] To investigate this, we ran the model again with a new parameter for the three-way interaction among adherence, pre-PD pedagogical content knowledge, and time. The estimate was close to zero, with no significance, so we retained the original model, excluding this parameter.

differ significantly in their growth; based on these results, it is safe to say that the students in the TSI Aquatic program improved in their NOS understanding regardless of which year of the program they were in. As was revealed by the multilevel model of the final year's data, with teacher-level FOI predictors, the teachers adhering more closely to the TSI Aquatic lessons had students with notable gains in their NOS scores. This suggests that when teachers implement TSI Aquatic lessons in the manner that is intended, students will benefit.

Changes in Students' Aquatic-Science-Content Knowledge. The results of the time parameter in the model of students' content scores revealed that when all of the other model predictors (besides time) were set to zero, the students were estimated to gain in their pre-to-post scores by about 0.34 points, which was statistically significant at the .01 level. This effect, which had the strength of about 45% of a standard-deviation unit, indicates that, for the most part, the students in classes of teachers participating in the project improved in their content knowledge as operationalized by this instrument. Caution should be taken, however, in interpreting the content assessment results because the reliability was low.

Similar to what was observed with the NOS assessment, the time-by-teacher-adherence parameter was significant, having an effect of about 25% of a standard deviation unit. This 0.19 logit-scale point gain above the estimated 0.34 point gain (when all teacher variables are at the mean) suggests that when teachers adhere to the TSI Aquatic pedagogy and content in their lessons, their students likely improve in content knowledge to a greater extent than when they do not adhere to the TSI Aquatic lessons. The total estimated effect is an increase in 0.52 points, which translates into an effect size of 70% of a standard-deviation unit on the content assessment.

The results indicated that teachers' experience in previous science PDs likely predicted how much students would gain from pre to post on the NOS assessment. Teachers one standard deviation below the mean on this measure were estimated to have students that gained 0.13 points (18% of a standard-deviation unit) more than students in classes where teachers were at the mean. This suggests the program benefitted students in classrooms taught by teachers who, in the beginning, had less experience in previous PDs. The evaluators and members of the project team speculated that the teachers with less experience in previous science PDs may have been more open to the TSI Aquatic PD.[9]Students in lower grade levels were estimated to improve in their content scores to a greater extent than students in higher grades (by about a third of a standard-deviation unit). For example, the middle-school students were estimated to gain by 0.34 points, whereas high-school students were estimated to gain only 0.09 points (0.34 minus 0.25). With high-school students, this translates into an estimated effect size of about 11% of a

[9] Similar to our investigation of the three-way interaction in the NOS model, we ran the Content model again with a new parameter for the interaction among adherence, number of science PD courses, and time, but found the estimate to be close to zero, with no significance. We retained the original model, excluding this parameter.

standard-deviation unit. This large discrepancy may have been due to older students having been exposed to the content in prior to their participation in the TSI Aquatic project, a pattern which is confirmed by the statistical significance of the school-level main effect (comparing elementary-, middle-, and high-school students), which was estimated as 0.24 logits. (In the pre-test, the observed mean score of the high-school students was 0.27 points higher than that of the middle-school students.) Assuming there were no differences between middle- and high-school students in their motivation or degree of effort in responding to the instrument, these results suggest that the PD successfully targeted the middle-school students; for the high-school students, the small gains suggest the aquatic science content may have been somewhat too easy.[10]

Conclusions about the Evaluation Findings

The PD was successfully implemented in the intended manner. Structurally, the amount of face-to-face time with teachers, the distribution of the PD activities throughout the year, the modular structure of the PD, and the content that was delivered in the PD were documented and observed to be implemented in the manner that the project team intended. The evaluation findings showed that the teachers perceived the PD to be valuable and relevant to their teaching practice—particularly the science content and the community building features of the PD. There were diverging opinions among the teachers about the value of the TSI pedagogical features. In terms of the EOFE curriculum and OLC website, teachers reported that they would continue to use the EOFE site after the PD for course activities and curriculum content and that they would continue to use the OLC aspect of the website to interact with each other. About half of the teachers (16 out of 28 in the final two cohorts) have continued to use the EOFE site, but only one has posted to the OLC.

With the caveat that we assumed growth would not have occurred due to maturation in non-PD conditions, the teachers' self-reports on the three teacher scales suggested that the PD helped them improve on all three measures: pedagogical content knowledge for teaching science (effect size = 0.24, $p = .21$), self-efficacy in teaching science through the process of inquiry (effect size = 1.50, $p < .01$), and metacognition in teaching (effect size = 0.18, $p = .38$). Among these three, the strongest gain was in teachers' self-efficacy; gains in the other two were meaningful but not statistically significant. For the most part, there was a consistent perception among the teachers that the PD was helpful in improving their ability to teach the science content, but some teachers explained in the interview that they found parts of the pedagogy to be difficult to implement in their classrooms.

These findings suggested several possible conditions that might need to be considered in future TSI Aquatic PD if the objective is to make the pedagogy aspect of the PD accessible to all teachers: (a) participating teachers may need more time with the

[10] Caution should be taken in interpreting these results, however, given the low reliability of the student content assessment.

pedagogy before being expected to fully implement it in their classes; (b) teachers may need more scaffolding with the pedagogy in the early stages of the PD (which some teachers suggested in the interviews); (c) the pedagogy might need to be adjusted to better suit some grade levels; and (d) some features of the pedagogy, such as the call for explicit teaching of the TSI phases of inquiry to students, may need to be refined or altered.

The teachers' gains in the aquatic science content knowledge assessments were unambiguously positive. Their four module-level assessments were consistently significantly higher in the post-test than in the pre-test (effect sizes ranged from 0.66 to 1.01; all $p < .01$). Although we could not be certain that the teachers did not consult their materials when taking the posttest, the significant improvements provide a testament to the PD's success in delivering content that was accessible to the teachers. Consistent with other findings, the teachers reported having success implementing the content aspects of the target activities in their classrooms, and the evaluation results suggested that teachers improved in the quality of their implementation of the TSI phases of inquiry as the project progressed. The teachers also improved in their understanding of the nature of inquiry-based science teaching, as measured by the Inquiry Teaching Assessment (effect size = 1.24, $p < .01$). The substantial gains on this instrument suggested that the teachers matured in their breadth and depth of knowledge about teaching science through the process of inquiry.

The findings of the student level assessments suggested that students gained in their understanding of the NOS while participating in the project (in typical classrooms, effect size = 0.13, $p < .05$). Teachers with a low baseline in pedagogical content knowledge tended to have students with stronger than average pre-to-post gains (effect size = 0.20, $p < .01$). It is notable that the students of teachers who reported adhering more closely to the PD gained significantly more than the students in classes taught by teachers with lower adherence ratings (effect size = 0.21, $p < .01$). This supports the tentative conclusion that the PD had an effect on students' NOS understanding.

The results of the student content assessment were similar to those observed with the NOS assessment. In typical classrooms, the effect size = 0.45, $p < .01$; in classrooms with teachers adhering more to the PD, there was an added effect size of 0.25, $p < .01$. In addition, we found that high-school students did not gain as strongly in content as middle-school students (effect size = -0.34, $p < .01$). We also found that students of teachers with little prior science PD experience showed significant gains in content knowledge (effect size = 0.18, $p < .01$), suggesting that the project benefited students in contexts with teachers that had less science PD exposure. However, because of the low reliability on this component of the student assessment, more research should be conducted before making decisions about this aspect of the PD.

Future Directions

The overall success of this TSI Aquatic PD project merits continued offerings of this PD to science teachers. The areas in which the PD was most successful were teachers' improved content knowledge, self-efficacy in teaching science, and understanding of teaching science through the process of inquiry. The teachers' positive perceptions of the value and relevance of what they experienced in the PD—particularly in their classroom implementation of the content, the community building among teachers, and in having the PD spread across an entire year—further support the value of continuing this PD. Furthermore, the students benefited from their teachers' participation. Their gains in NOS and content knowledge were positive, with a stronger effect among students in classes of teachers adhering more closely to the PD guidelines.

For researching the efficacy of future TSI Aquatic PDs, there are several considerations for the evaluation component. Several instruments were developed out of this project, and are now available for future evaluation and research work. The Inquiry Teaching Assessment (adapted from Schuster et al., 2007) will likely serve as a reliable instrument for measuring teachers' changes from pre to post in their understanding of what inquiry looks like the classroom. The NOS assessment will likely serve as a useful tool for evaluators tasked with comparing the gains of treatment- and comparison-group students. Future development of this instrument can address the need to represent all eight NOS themes described in Appendix H of the Next Generation Science Standards (NGSS; NGSS Lead States, 2013) and examining the effects of future PDs on each of these NOS themes. (The NGSS were released as the project was coming to a close, precluding their inclusion in the original assessment blueprint.) The student content assessment will require more development before it becomes appropriate for future use. One course of action is to develop an assessment for each module's content rather than a single measure addressing the entire set of TSI Aquatic content (the project team has begun developing four such instruments for module-level formative assessment purposes in the PD).

For future TSI Aquatic PD series, some PD topics warrant further attention: (a) the amount of practice participating teachers are given with the pedagogy before being expected to implement it in their classes; (b) the amount of scaffolding with the pedagogy in the early stages of the PD; (c) a PD component on ways to adjust the pedagogy to better suit some grade levels; and (d) the emphasis placed on specific TSI toolbox components when the teachers are asked to explicitly teach these components to their students. The project team recommended that future PDs using the Online Learning Community include explicit instruction to teachers in navigating the online components.

For future TSI Aquatic PDs, the PD project team recognized several structural and logistical components that are worthy of consideration. First, holding an orientation session with prospective teachers will likely streamline the PD. The orientation meeting permitted many housekeeping and question-and-answer issues to be addressed, saving

precious time that otherwise would have detracted from the actual PD, and it was ideal for introducing the project and its personnel. Second, holding a meeting with external consultants will likely focus the PD and enhance communication between the project and evaluation teams. The consultant meeting held in the current project prompted the project and evaluation teams to showcase their work to date and fostered communication between the project and evaluation teams. Third, having a modular structure of the PD will likely provide repeated exposure with the content, pedagogy, and with fellow participants. In the current project, several teachers attributed their community-building experience with the extended PD exposure and multiple opportunities to interact. Holding follow-up meetings was time-consuming, however, and there were concerns about scheduling the meetings during convenient times. Fourth, including teacher leaders will likely facilitate teacher recruitment and yield valuable feedback to improve the PD; however, a structural component—such as a training course specifically targeting teacher leaders—is likely needed if the objective is train these leaders to become future PD facilitators. Finally, providing teachers with supplies will likely facilitate their implementation of the classroom activities; teachers in the current project expressed appreciation for the supplies provided to them.

Lastly, with the release of the NGSS (NGSS Lead States, 2013), future TSI Aquatic PDs will explicitly align the content and pedagogy with the NGSS. As the project is implemented in other regions, as well, the content and pedagogy will be adapted to suit these contexts.

In a way, the development of this PD was an inquiry process in itself, with project activities requiring engagement in multiple modes, and movement through multiple phases of inquiry, among other inquiry processes. In this endeavor to develop science educators' teaching practice, a great deal was learned and achieved. The success of this development project calls for further investigation of the TSI Aquatic PD series. We urge the project development team to consider whether the PD needs further refinement. If it is not needed, we believe that TSI Aquatic is ready to be proposed for an Institute of Education Sciences efficacy (Goal 3) study consisting of randomly assigned teacher treatment and control groups.

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APPENDIX A

MODULE AGENDAS

TSI Aquatic Agenda – Module 1 Day 1 – PHYSICAL

Time	Activity	Activity Details	Selected TSI Practice of Inquiry Teaching
AM	Logistics	Transparency about PD	Align objectives, teaching strategies, and assessments
AM	Research team feedback	Transparency about evaluation and assessment	
AM	**Mandatory Activity** The practices of scientists	Science as discipline Demeanors and values of scientific disciplinarians Practices of science	Recognize and teach science as a human endeavor Model and require students to exhibit the demeanors of scientists Engage students in the practices of science
AM	What is inquiry?	10 minute inquiry free-write	Require evidence of student thinking
AM	**Choice Activity** Soda and scientific reasoning	Investigate floating and sinking cans of soda using scientific reasoning Introduction of metacognition	Initiate new concepts and activities
Lunch			
PM	Water density stations	Explore density via variety of activities Introduction of TSI phases (use of TSI reflective diagram)	Plan and guide students through the phases of inquiry Recognize and teach science as a multi-directional process with multiple pathways to knowledge generation Be transparent about the process of teaching and learning via inquiry
PM	Ocean Literacy Principles (OLP)	Thought swap	Provide access to multiple sources of information
PM	Exploring Our Fluid Earth (EOFE)	Navigation of curriculum website	Design or use a curriculum grounded in the history and content of the scientific discipline.
PM	Logistics Comment Cards		Value student perspectives
Evening	Homework	Upload bio to website	Provide time for reviewing and revisiting concepts

TSI Aquatic Agenda – Module 1 Day 2 – PHYSICAL

Time	Activity	Activity Details	Selected TSI Practices of Inquiry Teaching Modeled
AM	Logistics Comment Cards Review of TSI phases		Value student perspectives
AM	**Mandatory Activity** Density bags	Predict, then investigate floating and sinking of bags of liquid Complete individual TSI reflective diagram	Emphasize the importance of careful observations, predictions, and hypotheses prior to beginning an investigation Share predictions and hypotheses
AM	Standing waves	Investigate wave properties by making a series of wave prints	Model and require recordkeeping
Lunch			
AM	Density demonstrations	Gravitational currents	Scaffold scientific content, practices, and skills
AM	Processes of inquiry	Introduction to TSI Modes	Plan and guide students through the phases of inquiry via the modes of inquiry
PM	**Choice Activity** Kinesthetic moon model	Model the movements of the earth, moon, and sun	Avoid front-loading too much content Focus on capturing the reasoning behind student judgments and explanations
PM	Planning and Reflection Requirements	Explicitly go over progress list focusing on activity requirements.	Be clear about expectations and performance criteria Clarify goals and task understanding Explicitly model your own thought processes
PM	Logistics Post workshop survey		Value student perspectives

TSI Aquatic Agenda – Module 2 Day 1 – CHEMICAL

Time	Activity	Binder	Activity Goals	Selected TSI Practices of Inquiry Teaching Modeled
AM	Logistics	Logistics: Agenda Learning Progression Research: Implementation Interest	Initiate day Review requirements	Align objectives, teaching strategies, and assessments Model and require recordkeeping
AM	Matter Concept Map	Workshop Activities: 1st activity		
AM	**Choice Activity** Electrolysis	Target Activities: 3rd activity		
Lunch				
PM	TSI Pedagogy	TSI Pedagogy: TSI Theoretical Framework	Review and extend understanding of TSI pedagogy	Focus on capturing the reasoning behind student judgments and explanations Scaffold scientific content, practices, and skills
PM	Still	Workshop Activities: 2nd activity	Describe how a still works and how it simulates the water cycle Examine the effects of a still with fresh and salt water	Allow students to design and refine models and build an understanding of a model's strengths and weaknesses Emphasize the importance of careful observations, predictions, and hypotheses Allow students to assess the quality of procedures, results, and conclusions
PM	Concentration	Workshop Activities: 3rd activity		
PM	Frisbee Bonding	Workshop Activities: 4th activity		
PM	Logistics Comment Cards	Logistics: Comment Card		Value student perspectives

TSI Aquatic Agenda – Module 2 Day 2 – CHEMICAL

Time	Activity	Binder	Activity Goals	Selected TSI Practices of Inquiry Teaching Modeled
AM	Logistics Comment Cards	Logistics: Agenda Learning Progression	Lingering logistics Initiate day	Value student perspectives
AM	Research team feedback		Transparency about PD	Transparency about evaluation and assessment
AM	Bonding Review			Provide time for reviewing and revisiting concepts
AM	**Mandatory Activity** Water Properties	Target Activities: 1st activity		
AM	**Mandatory Activity** Phases and Modes of Scientific Practice	Target Activities: 2nd activity		
Lunch				
PM	Requirements	Research: Mod 2 Lesson Plan Example Reflection	Go over lesson plans, reflections, and website	Be clear about expectations and performance criteria Clarify goals and task understanding
PM	Solubility	Workshop Activities: 5th activity		
PM	Recovering Salt From Seawater	Workshop Activities: 6th activity		
PM	**Choice Activity** Conductivity	Target Activities: 4th activity	Create a simple conductivity meter Classify solutions in terms of conductivi Apply knowledge about solubility to predict conductivity of solutions	Connect new information to prior knowledge (solubility) Allow students to develop their own hypotheses based on evidence Provide opportunities for creativity
PM	Water cycle (Continuation of Still)	Workshop Activities: 2nd activity	See Still	See Still
PM	Logistics Post workshop survey	Logistics: Supply List	Supplies	Value student perspectives

TSI Aquatic Agenda – Module 3 Day 1 – BIOLOGICAL

Time	Activity	Binder	Activity Goals	Selected TSI Practices of Inquiry Teaching Modeled
AM	Logistics	Logistics: Agenda Learning Progression	Initiate day Review requirements	Align objectives, teaching strategies, and assessments Model and require recordkeeping
AM	What is Alive?	Workshop Activities: 1st activity	Initiate biology Introduce common scientific language	Initiate new concepts and activities Discuss the context of definitions and point out exceptions
AM	Inquiry Questioning Strategies Part 1	TSI Pedagogy: Questioning Strategies	Introduction to research of questioning Introduction to TSI inquiry questioning strategies	Purposefully use effective questioning strategies to guide classroom discussions
AM	**Mandatory Activity** Scientific Language	Target Activities: 1st activity	Define, discuss, and identify commonly misused scientific language terms	Purposefully use scientific language
Lunch				
PM	TSI Pedagogy		Review and extend understanding of TSI pedagogy	Focus on capturing the reasoning behind student judgments and explanations Scaffold scientific content, practices, and skills
PM	Effects of different light wavelengths on photosynthesis	Workshop Activities: 2nd activity	Importance of autotrophs Examine the effects different light wavelengths on photosynthesis	Emphasize the importance of careful observations, predictions, and hypotheses Teacher as Research Director
PM	Inquiry Questioning Strategies Part 2	TSI Pedagogy: Questioning Strategies		
PM	Algae Identification	Workshop Activities: 3rd activity	Classification and use of identification keys	Require evidence of student thinking and provide students many varied opportunities to make their thinking visible
PM	Logistics Homework Comment Cards	Logistics: Comment Card Homework: Draw a Fish, Mod 2 Implementation Interest		Value student perspectives Incorporate multiple forms of formative assessment and use assessments to modify teaching strategies
After 5pm	Algae Pressing	Workshop Activities: 4th activity		Provide opportunities for creativity Provide time for multiple opportunities to practice

TSI Aquatic Agenda – Module 3 Day 2 – BIOLOGICAL

Time	Activity	Binder	Activity Goals	Selected TSI Practices of Inquiry Teaching Modeled
AM	Logistics Comment Cards	Logistics: Agenda Learning Progression	Lingering logistics Initiate day	Value student perspectives
AM	Research team feedback		Transparency about PD Mod 2 content results	Transparency about evaluation and assessment
AM	**Choice Activity** Fish Printing for Form and Function	Target Activities: 2nd activity	Fish classification, printing, and reason for different phenotypes	Develop student interest and make knowledge relevant through use of place and everyday situations, interests and life experiences, and societal or personal concerns Provide opportunities for creativity Monitor progress during investigations by circulating and interacting with students Utilize a range of inquiry activities, from directed to open-ended
Lunch				
PM	Requirements	Logistics: Due Dates Research: Mod 3 Lesson Plan Example Reflection	Go over requirements including lesson plans, reflections, and website Intro to NGSS	Be clear about expectations and performance criteria Clarify goals and task understanding
PM	**Choice Activity** Microevolution	Target Activities: 3rd activity	Understand evolution by natural section and microevolution	Allow students to design and refine models and build an understanding of a model's strengths and weaknesses Use graphs and data tables to represent data and in presenting and interpreting results of investigations Anticipate and explicitly address common misconceptions Provide time for reviewing and revisiting concepts
PM	Inquiry Questioning Strategies Part 3	TSI Pedagogy: Questioning Strategies		
PM	Logistics Post workshop survey	Logistics: Module 3 Supplies	Supplies & Supply Swap!	Value student perspectives

TSI Aquatic Agenda – Module 4 Day 1 – ECOLOGICAL

Time	Activity	Binder	Activity Goals	Selected TSI Practices of Inquiry Teaching Modeled
AM	Logistics	Logistics: Agenda Due Dates Learning Progression	Initiate day Review requirements	Align objectives, teaching strategies, and assessments Model and require recordkeeping
AM	**Mandatory Activity** Sampling Design	Target Activities: 1st activity	Initiate ecology Sample a bag of small colored objects	Develop student interest and make knowledge relevant through use of place and everyday situations, interests and life experiences, and societal or personal concerns Connect new information to prior knowledge
AM	**Mandatory Activity** Sampling for Abundance – Transects and Quadrats	Target Activities: 2nd activity	Introduce common ecological sampling tools and techniques, compare abundance measurements across different sampling methods	Provide time for multiple opportunities to practice new techniques Facilitate collaboration in groups
Lunch				
PM	TSI Pedagogy	TSI Pedagogy: TSI Practices of Inquiry Teaching	Review and extend understanding of TSI pedagogy	Focus on capturing the reasoning behind student judgments and explanations Scaffold scientific content, practices, and skills
PM	Experimental Design	Workshop Activities: 2nd activity	Examine a simple experiment	Teacher as Research Director
PM	**Field Trip Discipline Groups** - Tools and Techniques - Plan Sampling Design	Physical, Chemical, Biological Tabs	Choose study question(s) Design a sampling plan around study questions Learn tools and techniques needed to implement sampling plan	Recognize and teach science as a discipline that integrates concepts and skills within a context, not as a collection of isolated facts Guide students in continually monitoring, adjusting, and explaining their approaches to problems
PM	Logistics Homework Comment Cards	Logistics: Comment Card Directions to Intertidal Site Homework: Mod 3 Implementation Interest		Value student perspectives Incorporate multiple forms of formative assessment and use assessments to modify teaching strategies

TSI Aquatic Agenda – Module 4 Day 2 – ECOLOGICAL

Time	Activity	Binder	Activity Goals	Selected TSI Practices of Inquiry Teaching Modeled
AM	**Field Trip Discipline Groups** - Intertidal Field Trip	Logistics: Directions to Intertidal Site Module 4: Intertidal Field Trip How-To Guide	Investigate and intertidal site Implement Sampling Design	Model and require students to exhibit the demeanors of scientists Explicitly discuss ethics and safety
Lunch				
AM	Logistics Requirements	Research: Mod 3 Lesson Plan Example Reflection Presentation Prompts	Lingering logistics Go over requirements including lesson plans, reflections, blackboard, and website	Be clear about expectations and performance criteria Clarify goals and task understanding
AM	Research team feedback		Transparency about PD Mod 3 content results	Transparency about evaluation and assessment
PM	Data Representation	Workshop Activities: 3rd activity	Examine the use and abuse of common data representation strategies	Use graphs and data tables to represent data and in presenting and interpreting results of investigations Recognize and teach science as a human endeavor
PM	**Field Trip Discipline Groups** - Data Analysis - Share Analysis and Interpretation	Physical, Chemical, Biological Tabs	Analyze data, interpret data, and share results of interpretation	Require students to select and evaluate data, reason through the steps of analysis, interpret the findings of investigations to determine scientific explanations, and propose alternative explanations Allow students to evaluate whether data collection occurred as predicted, recognize discrepancies in data, discuss variations and identify sources of error Share knowledge among the wider student community, the scientific community, and the public
PM	Logistics Post workshop survey	Logistics: Module 4 Supplies	Feedback and supplies	Value student perspectives

APPENDIX B

TSI EVALUATION INSTRUMENT DEVELOPMENT AND DATA COLLECTION PROCEDURES

Outline of Evaluation Instrument Development and Data Collection Procedures

I. Teacher Instruments

1. Teacher Background Questionnaire

a. Reviewed the teacher background items on the questionnaire that CRDG developed as part of its Interagency Educational Research Initiative grant.
b. Selected items and prepared an online version.
c. Administered the instrument to the Cohorts 1–3 teachers shortly before each cohort participated in Module 1.
d. Calculated descriptive statistics for Cohorts 1–3.
e. Modified the questionnaire for use with Cohorts 4 and 5.
    1) Met with project team to identify teacher background information that would assist in preparing for the PD.
    2) Developed items addressing PD-related teacher background, including teachers' science teaching experience, research experience, previous PD experience, and experience using online resources for personal, pedagogical, and research purposes.
    3) Revised the new items by recursively editing with the project team to ensure content validity, by adhering to guidelines in Dillman (2000), and by piloting the instrument with project staff.
f. Prepared the instrument online and administered it to Cohorts 4 and 5 prior to the start of Module 1.
g. Collected responses and prepared reports of each cohort for project staff to use in planning their PD activities during Module 1.

2. Classroom Instruction Questionnaire

a. Adapted the Pedagogical Content Knowledge Scale
    1) Obtained the PCK scale from Tom Scarlett's (2008) dissertation study.
    2) Reviewed the items with project team for content validity.
        a) Eliminated seven items that did not align with the project's definition of pedagogical content knowledge.
        b) Prepared an online version of the PCK.
    3) Administered the PCK as a pre-PD questionnaire to Cohorts 1–3 teachers before they attended Module 1 and again as a post-PD questionnaire after they completed Module 4.
    4) Calculated internal consistency in the pre and post for Cohorts 1–3.
    5) Calculated each teacher's mean response across the items.
    6) Calculated descriptive statistics for each cohort and across all cohorts.
    7) Conducted a paired t-test, after examining statistical assumptions, and estimated the effect size of the within-subject change from pre to post for Cohorts 1–3.
    8) Revised the instrument to ensure content validity was still adequate after the project team had refined TSI pedagogy descriptions.
        a) Reviewed the items and item responses with the project team before the start of Cohorts 4 and 5.

b) Revised five items' wording to better align with the language used in the project.
c) Added nine items from CRDG's instruments used in the Interagency Educational Research Initiative grant.
d) Wrote five new items, following item-writing criteria in Dillman (2000), based on the project's documents specifying pedagogical content knowledge.

9) Administered the instrument pre- and post- Cohorts 4 and 5.

b. Developed the Teacher Self-efficacy Scale
1) Obtained a retrospective pre-post science teacher self-efficacy scale from Lawton (2005).
2) Adapted item stems to match the TSI pedagogy blueprint, particularly aspects of the phases of inquiry.
a) Borrowed the blueprint used in developing the analytic rubric for scoring teachers' responses on the Inquiry Teaching Assessment.
3) Reviewed items using item-writing criteria in Dillman (2000).
4) Made revisions based on repeated discussion with project staff.
5) Prepared online version, appending it to the PCK scale.
6) Administered to Cohorts 1–3 after they completed Module 4.
7) Did not identify any poorly functioning items; retained all items.
8) Added two items asking about self-efficacy in facilitating students' metacognition and thinking-like-a-scientist skills.
9) Calculated internal consistency and descriptive statistics.
10) Administered to Cohorts 4–5 after they completed Module 4.
11) Conducted paired t-test, after examining statistical assumptions, and estimated the effect size of the change from pre to post for Cohorts 4–5.

c. Borrowed Items for the Metacognition in Teaching Scale
1) The project team searched for existing scales addressing metacognition in teaching.
2) Three project-team members and one research-team member examined the items from a scale provided by Balcikanli (2011) and identified items that most closely represented the TSI Aquatic metacognition component.
3) Ten out of 24 items were selected from Balcikanli (2011) to avoid making the Classroom Instruction Questionnaire too long.
4) No modifications were made to the borrowed set of items.
5) Instructions were written and the items were added to the Classroom Instruction Questionnaire.
6) The items were administered with the other subscales in the instrument to Cohorts 4 and 5.
7) Descriptive statistics and reliability estimates were calculated.
8) The research team conducted paired t-test, after examining statistical assumptions, and estimated the effect size of the change from pre to post for Cohorts 4–5.

d. Borrowed Items for the Metacognition in Learning Scale

1) The project team searched for existing scales addressing metacognition in learning.
2) Three project-team members and one research-team member examined the items from a scale provided by Schraw and Dennison (1994) and identified items that most closely represented the TSI Aquatic metacognition component.
3) After review by the project-team, five out of 52 items were selected from Schraw and Dennison (1994) to avoid making the Classroom Instruction Questionnaire too long.
4) No modifications were made to the borrowed set of items.
5) Instructions were written and the items were added to the Classroom Instruction Questionnaire.
6) The items were administered as a pilot-test with the other subscales in the instrument to Cohorts 4 and 5.
   a) The Metacognition in Learning Scale items were not included in the evaluation.
   b) For record keeping, descriptive statistics, reliability, and the pre-to-post change effect size of the pilot-test data were calculated.

3. Inquiry Teaching Assessment (ITA)

a. Identified the intended outcome, as it was in the beginning of the project
   1) Developed the definition of the construct to measure
      a) Reviewed project documents describing the phases and modes of inquiry.
      b) Drafted a description of the phases of inquiry and met with Pottenger and the project team to clarify and revise.

b. Conducted an initial search for existing instruments.
   1) Considered concept-map assessments (e.g., Yin, Vanides, Ruiz-Primo, Ayala, & Shavelson, 2005) and determined that they were not feasible for this project because of uncertainty in designing prompts and in scoring reliably.
   2) Identified vignettes (as described in Ruiz-Primo & Li, 2003 and Stecher et al., 2006) as a plausible design to measure teachers' science teaching approaches.

c. Developed pilot-testing vignette prompts.
   1) Reviewed guidelines for vignette development in the literature (Ruiz-Primo & Li, 2003; Stecher et al., 2006).
   2) Used the construct description to develop a list of teaching behaviors to measure.
   3) Drew from these behaviors and from content from the CRDG Foundational Approaches in Science Teaching and Fluid-Earth/Living Ocean programs to create a draft with two vignettes.
   4) Requested feedback about this draft from four middle- and high-school content experts (University Lab School science teachers), specifically on the difficulty, the likely range of responses, and whether the teaching scenarios seemed realistic.

5) Based on content experts' recommended changes, developed a single pilot vignette, with the intent that it would measure all the phases of inquiry.
6) Revised the pilot vignette based on further feedback from content experts.
7) Prepared the pilot vignette for project teachers to complete online.
8) Pilot tested the vignette, using online survey software, with the first cohort of teachers prior to the first workshop.
9) Asked for feedback from teachers about their experience with the vignette, including their perceptions about the appropriateness and difficulty, their perceptions about the formatting, the length of the assessment, and which classroom context they had in mind while completing it.

d. Developed a pilot rubric for scoring vignette prompts.
   1) Reviewed guidelines for rubric development (e.g., Johnson, Penny, & Gordon, 2009).
   2) Drew from the construct definition and the list of plausible observable behaviors to draft the descriptions of the low and high ends of the rubric scale; then developed the middle category descriptions.
      a) Recursively revised the rubric by
         (1) reviewing and revising fellow team members' category descriptors in light of the construct definition,
         (2) identifying themes from Cohort 1's pre-PD vignette responses and editing the category descriptors,
         (3) revising category descriptors based on feedback from the project team, and
         (4) simplifying the category descriptors to make the rating task more feasible.

e. Searched for an alternative viable instrument.
   1) Tentatively concluded that our vignette instrument in its current form was unwieldy for the project. This conclusion was reached based on
      a) feedback from the project team suggesting that teachers' responses to the vignette might not adequately capture teachers' knowledge and understanding of inquiry-based science instruction,
      b) the time demands on teachers to complete the pilot vignette responses, and
      c) the difficulty in reliably rating teachers' responses.
   2) Identified the Pedagogy of Science Inquiry Teaching Test (POSITT) as a viable alternative to continuing development of our vignettes.
      a) Determined that the POSITT might be appropriate for measuring the construct (teachers' knowledge and understanding of inquiry-based science instruction).
      b) Determined that the time demands on teachers could be more easily managed.
      c) Determined that the scoring and rating of items would be feasible.

(1) The items included both selected-response prompts (multiple-choice and Likert-scale responses) and constructed-response prompts of science-teaching vignettes.
(2) Determined that selected-responses would be feasible for scoring and item analysis.
(3) Determined that it might be feasible to apply the existing rubric to scoring the constructed-responses.

d) Obtained permission from the POSITT developers to use and modify the instrument.
e) Requested reliability and validity data from the developers, who explained that these items were still under development.

f. Conducted item review with three content experts.
   1) Asked the experts for their judgments about the items' level of difficulty, how well the items appear to measure teachers' knowledge and understanding of inquiry-based science instruction, and any concerns or observations about the items.
   2) Determined, based on the positive comments from content experts, that the POSITT would serve as a viable alternative to developing our own vignettes.
g. Modified the instrument based on content experts' feedback.
   1) Formatted items for consistency, including creating headers in the stems of items which had not previously had headers, and specifying the grade level of the class described in each vignette scenario.
   2) Made minor modifications to item content.
      a) Determined the grade level of the class in each item's scenario, referencing the Hawaii Content and Performance Standards database (HCPS III) to identify appropriate grade level.
      b) Added labels to diagrams which had not previously had labels.
   3) Modified the multiple-choice options, while following guidelines in Haladyna, Downing, and Rodriguez (2002).
      a) Changed the title (Mr. or Ms.) of the teachers in each item's options so that the gender of the scenario's instructor in each option was the same within the item.
      b) Modified the order of the details in some of the options in order to make the options more parallel with each other.
      c) Modified the wording in some items so that the teachers would consider the teaching scenario rather than possible clues provided by vocabulary.
h. Conducted item pilot testing.
   1) Three project personnel took the test while recording their responses, the time it took to respond to each part, their reflections on their mental processes while responding, the difficulty of the content in the item (which we considered to be irrelevant to the construct), and which phases and modes each item appeared to be tapping into.
   2) Compiled the pilot-test results into a table for evaluating which items to use.

3) Ranked the items in feasibility based on
   a) agreement in responses (among project personnel) to the items,
   b) the mean number of minutes it took to respond to each item, and
   c) variability in the phases and modes the item seems to measure.

i. Conducted an item review by an additional content expert in the project team.
   1) Asked for judgment about
      a) each items' level of difficulty,
      b) how well the items appeared to measure teachers' knowledge and understanding of inquiry-based science instruction,
      c) any concerns or observations about the items.

j. Modified the instrument based on item review and project personnel pilot testing.
   1) Labeled the instrument Inquiry Teaching Assessment.
   2) Shortened the instrument to seven items to ensure maximum time required to complete the assessment was one hour.
   3) Changed the scoring to be limited to the constructed-response data.
      a) Determined that the selected-response (multiple-choice) components were not appropriate for scoring, but were appropriate as part of the prompt for the subsequent constructed-response component of each item.
   4) Changed the prompt in the multiple-choice stems to align more with the constructs of our project.
      a) For example, on the original instrument, one item's prompt was, "Thinking about how you might teach this lesson, whose approach below would you suggest is best to use?" This was changed to "Whose approach below do you believe best provides an inquiry-based approach to teaching the lesson objective?"
   5) Made minor edits to options to make them more plausible and parallel.
   6) Reviewed for copyedit errors and formatting.

k. Prepared online version, with instrument instructions.

l. Administered as a pre to Cohorts 2–3 before Module 1, as a post to Cohorts 1–3 after Module 4.

m. Scored pre and post constructed responses.
   1) Combined the pre and post responses into a single data file, randomly ordering responses on each of the seven items in order to ensure raters did not know whether the response was from the pre or post and to avoid rater drift.
   2) Raters used the rubric in rating the responses.

n. Calculated inter-rater reliability using generalizability theory.

o. Modeled the pre and post responses simultaneously, using multi-facet Rasch analysis.

p. Determined that the instrument functioned adequately, requiring no item edits:
   1) With 7 items and 2 raters on the nine-point rubric scale, the generalizability coefficient was estimated to be .82, suggesting the rating procedure and item functioning were adequate.

q. Slightly revised the scoring rubric descriptors to match the TSI program developments made in the summer of 2012; for example, included the TSI toolbox components.
r. Administered to Cohorts 4 and 5 as a pre prior to the start of Module 1 and as a post after the completion of Module 4.
s. In the same manner as was done with the Cohort 2 and 3 data, we combined the pre and post responses into a single data file, randomly ordering responses on each of the seven items in order to ensure raters did not know whether the response was from the pre or post and to avoid rater drift.
t. Simultaneously Rasch modeled the pre and post ratings using multi-facet Rasch analysis software, FACETS (Linacre, 2010).
u. Calculated descriptive statistics and reliability of the Cohorts 4–5 data.
    1) The generalizability coefficient, using variance components from SAS Proc Mixed on the raw ratings (prior to Rasch-model transformation onto the logit scoring scale) was .89.
    2) The Rasch reliability estimate of the teacher separation was .95.
v. Conducted a paired t-test, after examining statistical assumptions, and estimated the Hedges' *g* effect size of the change from pre to post for Cohorts 4–5.

4. Teacher Science Content Assessment

a. Identified the major topics intended to be addressed in each of the four modules.
b. Developed an assessment blueprint for each module.
c. Identified sources of existing items and obtained items, when available.
    1) Reviewed the items with the project team for content validity; revised some items.
d. Project team drafted complex multiple-choice items using research team's guidelines (best-answer items, experiment-interpretation items, and master list items).
    1) Aligned the items with each of the major topics in each module.
e. Conducted multiple iterative review-and-revision cycles of the items.
f. Prepared online pilot-test versions of the instrument for each of the four modules.
g. Administered to Cohorts 1–3, taking care to limit possible threats to internal validity.
    1) Administered the pre for each module prior to the module's workshop.
    2) Administered the post for each module after the post-Blackboard session for each module.
h. Scored and reported the responses for each cohort on each module's assessment.
    1) Prepared pre-module cohort reports for the project team to review content on which the cohort scored high or low.
    2) Prepared post-module cohort reports for project team and teachers to see aggregate gains (across teachers) on the assessment.
i. Conducted an item analysis.

1) Identified well-functioning and poor-functioning items, based on *p*-values and discrimination indexes, to inform subsequent item revision.
2) Conducted a distractor analysis to identified distractors needing revision.

j. Calculated descriptive statistics for each cohort and for all cohorts combined.
k. Revisited each module's content topics and the project team's refined content goals to identify gaps and irrelevant topics in the content assessments.
l. Revised the instruments using item-analysis data and the project's refined content goals.
    1) Eliminated items that measured irrelevant content or were poorly functioning and redundant.
    2) Edited items measuring key content but displaying less-than-adequate functioning.
    3) Developed and added items to measure content topics in the project's refined content goals.
m. Prepared online versions of the instruments for Cohorts 4–5.
n. Administered the instruments at the beginning and end of each module, taking care to avoid internal validity threats.
o. Scored and reported the responses for each cohort on each module's assessment.
    1) Prepared pre-module cohort reports for project team.
p. Prepared post-module cohort reports for project team and teachers to see aggregate gains on the assessment.
q. Calculated descriptive statistics for each cohort and for all cohorts combined.
r. Conducted paired t-tests for each of the four modules, after examining statistical assumptions, and estimated the effect size of the change from pre to post for Cohorts 4–5.

5. Post-Workshop Questionnaire

a. Prepared a version of CRDG's generic PD institute questionnaire (also used in Brandon et al., 2007).
b. Administered the instrument on paper at the conclusion of each workshop.
    1) Responses were anonymous and were entered by office assistant staff into Excel.
c. Recoded negatively worded items.
d. Calculated internal consistency.
e. Calculated descriptive statistics
f. Prepared chart essays and shared the findings with project project team after each workshop.

6. Teacher Reflections

a. Developed logs to track aspects of teachers' implementation of TSI target activities.
    1) The purpose of the logs was to examine the extent
        a) of the teachers' implementation of the TSI pedagogy and content;
        b) that the PD affected teachers' understanding of TSI;
        c) that teachers adhered to activity focus;

d) that teachers modified activity based on classroom and/or student characteristics, and;
e) the extent to which teachers engaged students during activity and increased students' aquatic science knowledge.

2) Developed a log for every TSI target activity lesson.
   a) Initially included questions about learning goals for each target activity, and about student demographics.
   b) After discussion and revision, simplified the log to include five general questions about implementation of each target activity.
3) Administered the logs online during each module.
4) Prepared descriptive statistics summarizing the results.
5) Shared the results with the project team for formative evaluation purposes.

b. Modified the instrument into its current form prior to final year of project (School Year 2012–1013 with the Cohort 4–5 teachers).
   1) Modified each reflection prompt to align with the PD's developments to date.
      a) Changed name from *Teacher Log* to *Teacher Activity Reflection* (which was shortened to *Reflection* in some discourses).
      b) Placed each lesson's Reflection online, to facilitate teachers' completion.
      c) Removed the description of activity procedure.
      d) Added Likert-scale items to collect information about how the teachers were using the activities in their classrooms.
      e) Added items to address extent to which, in their TSI target activities, teachers were using
         (1) the phases of inquiry,
         (2) the modes of inquiry, and
         (3) inquiry-based teaching practices.
      f) Added items to collect information on teachers'
         (1) understanding of the content and
         (2) their confidence when teaching the TSI target activities.

c. Categorized the items by construct.
   1) Four evaluators independently reviewed the items, placing each into a fidelity-of-implementation category.
   2) Agreed on final categorizations.
      (1) Discussed discrepancies in ratings in light of the PD's theory of change and the FOI literature.
   3) Aggregated the item responses across target activity reflections.

d. Analyzed the reflection data.
   1) Calculated the descriptive statistics and reliability of each item across multiple target activity reflections.
   2) Organized these descriptive statistics by items' categorizations into the implementation constructs.

7. Post-Cohort Questionnaire

a. Identified constructs to address in the questionnaire.
    1) Reviewed the components in the proposed evaluation questions and the project plan.
    2) Identified need to ask about value, relevance, perceived effect of the PD on teaching practice and on students' attitudes toward science, and on teachers' implementation of the PD in their classroom.
b. Identified constructs appropriate for the selected-response questionnaire (those more appropriate for the interview were addressed in the post-cohort interview).
c. Prepared draft of list of questionnaire questions.
    1) Revised for content and for format, referring to Dillman (2000) as needed.
d. Reviewed for content validity, through repeated discussion with project team.
e. Prepared the instrument online.
    1) Reviewed for language clarity and for online functionality.
f. Administered to Cohorts 1–3 after Module 4.
g. Calculated reliability and descriptive statistics.
h. Reviewed the instrument prior to administering to Cohorts 4–5.
    1) Identified need to categorize the items according to which feature of fidelity of implementation each item addressed.
    2) Team members added items for dissertation research, which were not included in the evaluation.
i. Administered the questionnaire to Cohorts 4 and 5 after the conclusion of Module 4.
j. Calculated the means of scales of items defined by their categorization into the fidelity-of-implementation features.
k. Calculated reliability and descriptive statistics.

8. Post-Cohort Interview

a. Identified the purpose of the interview.
    1) Identified key aspects of the evaluation and of teachers' implementation of the TSI activities.
        a) Reviewed components of the PD and project activities and identified the key aspects including content, PD structure and timing, and evaluation instruments.
        b) Identified questions that would be more answerable in an interview than in the Post-Cohort Questionnaire (which comprised selected-response prompts).
b. Drafted the interview script.
    1) Edited and modified the script based on repeated meetings with project personnel.
        a) Limited the interview to the most important topics.
        b) Planned to have the interviews last no more than 30 minutes.
    2) Prepared two methods for data collection, to ensure all teachers could be interviewed.

a) Via online virtual office software for collecting synchronous video interview data:
    (1) Set up a Blackboard Collaborate account.
    (2) Trained two interviewers in Blackboard interface.
    (3) Pilot-tested the interview in Blackboard using a project-team member as an interviewee; conducted minor edits to interview script.
    (4) Repeated pilot testing with two teachers from Cohort 1.
    (5) Conducted minor edits to interview script and added a new question to address identified gap in aspects addressed.
b) Via online survey software for collecting typed-response, asynchronous data:
    (1) The final interview script developed from the Blackboard session pilot testing was used in developing 21 constructed-response questions in SurveyMonkey.
    (2) Two evaluation staff reviewed the questions for accuracy.

c. Conducted the Cohorts 1–3 interviews.
    1) Randomly selected 50% of teachers in Cohorts 1–3 to participate in Blackboard verbal interviews; the remaining 50% were asked to complete the written-response interviews.
    2) Set up interview appointments in 45-minute slots.
    3) Verbal interviews were conducted by two research personnel, with the primary interviewer asking questions and the secondary interviewer taking notes and asking relevant follow-up questions when needed.
    4) Content-analyzing the data, checking for agreement between analysts.
d. Conducted the Cohorts 4–5 interviews.
    1) Selected all of the Cohort 4 teachers and randomly assigned 50% of the Cohort 5 teachers to participate in Blackboard interviews; the remaining 50% were asked to complete the written-response interviews via SurveyMonkey.
        a) All of the Cohort 4 teachers were selected to ensure complete data for the dissertation research of one of the evaluators (whose study was focusing on this cohort only).
    2) Set up interview appointments in 45-minute slots.
    3) Synchronous Blackboard interviews were conducted by the same two research personnel that had conducted the Cohort 1–3 interviews, with the primary interviewer asking questions and the secondary interviewer taking notes and asking relevant follow-up questions when needed.
        a) The audio, video, and visual information was video-recorded for each Blackboard interview.
    4) Recordings of the Blackboard interviews were reviewed by one of the evaluators on the research team
        a) Summary-style transcriptions were typed up for each interview.
    5) The data from the Blackboard and SurveyMonkey interviews were content-analyzed.
        a) Used a grounded theory approach (Corbin & Strauss, 2008).

b) Checked for agreement with an external analyst.
    (1) The external analyst reviewed 10% of the content.
    (2) Agreement between the initial coder and the verifier was 98%, supporting the content analysis results.

6) A summary of the findings from the content analysis was prepared.

II. Student Instrument

9. Student Science Questionnaire

a. *Student Self-Efficacy Scale*

1) Adopted a self-efficacy scale used in previous research (Brandon et al., 2007; Britner, 2002) to measure changes in students' self-reports of their self-efficacy in doing science.
2) Administered it to Cohorts 2–3 students as the final part of the Student Science Questionnaire.
3) Examined the raw data and detected that a large proportion of respondents included the same response across every item, suggesting students were not carefully reading and responding to the items.
    a) This suggested the validity of this component of the Student Science Questionnaire was questionable.
    b) Considered possible approaches to revising the instrument.
4) Deemed that students' nature-of-science understanding and their knowledge of content were of greater importance and that remaining instrument development efforts should focus on these instead of the Student Self-Efficacy Scale.
5) Removed the Student Self-Efficacy Scale from the instrument prior to administering to Cohorts 4 and 5 students.

b. *Student Nature of Science Assessment*

1) Identified the content domain
    a) Identified multiple sources describing the content domain, including
        (1) descriptions by the project team of the nature of science, demeanors of science, and misconceptions that students have about science and scientists;
        (2) descriptions of the modes and phases of inquiry in Pottenger's description of TSI;
        (3) a study on students' attitudes toward science, using scales developed in an Interagency Education Research Initiative (IERI) grant funded by the National Science Foundation (Brandon et al., 2007);
        (4) existing literature (Ayala, 2005; Lederman, 2007; McComas, 1998).
2) Searched for existing instruments.
    a) Identified the Nature of Science Scale used in the IERI grant funded by the National Science Foundation (Brandon et al., 2007) as a viable instrument.

(1) Determined that the instrument had sufficient validity for measuring students' self-reports about their understanding of the nature of science.
(2) Decided to include this as part of the instrument.
(3) Identified a need for an additional direct measure of students' nature-of-science understanding.

b) Conducted a search for existing direct-measure tests of nature of science that matched the content domain, were feasible in scoring with a large number of respondents, and that were readily available; none was found.
c) Decided to develop best-answer multiple-choice items.

3) Conducted preliminary best-answer multiple-choice item development.
a) Drew from a factor analysis of the Nature of Science Scale in Brandon et al. (2007) to identify content dimensions to include in the test blueprint.
b) Developed a checklist for evaluating multiple-choice item quality using the guidelines in Haladyna, Downing, and Rodriguez (2002).
c) Drafted approximately 15 items per team member, compiling a preliminary set of items.
d) Reviewed fellow team members' items to identify and suggest revisions using the Haladyna et al. checklist and keeping in mind the content domain and the student population.
e) Met as a group to discuss the items.
(1) Discussed the construct-relevant and irrelevant item features, including
(a) the degree to which each item appeared to measure the constructs in the content domain,
(b) language and prior knowledge required to understand the item (the difficulty of the item for the intended population of students, the plausibility of the distractors, and biases in the content or wording), and
(c) ideas for item improvement and new item development.
f) Compiled a second set of items
g) Reviewed each item for Flesch-Kincaid readability at a seventh-grade level.
(1) Vocabulary and expressions found to be too difficult were revised, unless the language was central to the content being measured.
h) Included the resulting items in the first draft of an assessment.
(1) Made further revisions, resulting in a 23-item assessment.
(2) Prepared assessment instructions.

4) Conducted multiple-choice item review by content experts.
a) Had five content experts review the 23-item assessment, provide suggested edits, and give feedback.
b) Revised the items based on the feedback of the content experts.

c) Developed additional items based on content expert feedback, broadening the content domain to include items measuring students' understanding of science as inquiry.
d) Drafted approximately 20 items based on the constructs defined in Pottenger's theoretical description of TSI and on the Pedagogy of Science Teaching Test (Schuster et al. 2007).
    (1) Edited the 20 items further, resulting in 9 items measuring aspects of science as inquiry.
e) Appended the 9 science-as-inquiry items to the 22 original nature-of-science items, resulting in a 31-item pilot test assessment.
f) Obtained a review of the instrument by a content expert.

5) Piloted the multiple-choice items.
a) Prepared two forms of the assessment, each with 24 items.
    (1) The shorter versions were created to ensure that students had sufficient time to complete the items.
    (2) The two forms shared 17 (70%) of the 24 items.
        (a) Of the 22 earlier developed nature-of-science items, the two forms shared 13 items.
        (b) Of the 9 later developed science-as-inquiry items, the two forms shared 4 items.
        (c) Both forms had 7 unique items.
b) Wrote directions for administering the assessment, including
    (1) an explanation to the students about the purpose and to make sure they understood how to complete the assessment,
    (2) instructions to get feedback about,
        (a) how difficult the students perceived the questions to be,
        (b) if they found any items confusing, and
        (c) if they had any comments about the assessment or items on the instrument;
    (3) the number of students completing the assessment, and
    (4) the greatest number of minutes it took for any student to complete the assessment.
c) Developed an item feedback sheet for the students' science teachers to complete while the students were completing the assessment.
    (1) For each of the 22 nature-of-science items, the teacher was asked to rate on a one-to-five Likert scale how well the item measured students' beliefs about the nature of science.
    (2) For each of the 9 science-as-inquiry items, the teacher was asked to rate on a one-to-five Likert scale how well the item measured students' understanding of science as inquiry.
    (3) For all 31 items, the teachers were asked if they had any comments.
d) Administered the assessments to Grades 6–12 students in their intact science classes in the laboratory school affiliated with CRDG, which had about 26 students each.

(1) Recorded the maximum time students needed to complete the assessment.
(2) Asked the students, in informal focus-group interviews, about their experiences with and perceptions of the assessment.
(3) Asked five middle- and high-school science teachers to complete the item feedback sheet; informally discussed the instrument with them after they completed the sheet.

6) Compiled and used feedback from teachers and students.
   a) Had each research team member summarize his or her notes taken from the students' focus-group comments.
      (1) Some notes were about the instrument itself, others about specific items.
   b) Compiled the responses from the five teachers' feedback about the quality of the items.
   c) Reviewed the feedback data and met to discuss problematic items, item revisions, and changes to the instrument.
7) Conducted analyses of the pilot-test multiple-choice item data.
   a) Calculated KR-20 reliability for each of the two forms.
   b) Rasch-analyzed the forms to examine item functioning.
      (1) Calculated item fit indexes.
      (2) Calculated item p-values.
   c) Calculated KR-20 reliability with the item deleted.
   d) Calculated discrimination indexes for each item, including the point-biserial index and the difference index between 12th and 6th graders.
   e) Recorded the *p*-values of the lower-, middle-, and higher-scoring examinees for each multiple-choice option for each item.
   f) Edited and revised the instrument based on the pilot-test results.
      (1) Prepared a final set of 19 items as a single form for administration to students in TSI project teachers' focus classes.
   g) Revised the instructions for administering the instrument for teachers to administer the assessment to their own students.
   h) Prepared assessment labels for teachers to administer the assessments to students whom we had received parent- and student-consent from.
8) Determined there was a need to include science content items in the instrument.
   a) Feedback from the pilot test suggested that students were able to guess the correct answer.
      (1) To help thwart test wiseness by countering the students' expectations about the purpose of the instrument, five content items addressing to the content in Modules 1 and 2 were identified from the teacher science content tests and added to and dispersed throughout the nature of science assessment.
      (2) The items also served the purpose of having a pilot measure of student content without overwhelming teachers and students with multiple assessment.

9) Prepared the 19-item assessment (plus the five content items) for Cohorts 2 and 3 teachers to administer in their classes during Module 1 (as a pre) and after completing Module 4 (as a post). Appended to this was the 12-item Nature of Science Scale, with 10-point Likert-scale items, which had been identified at the beginning as an existing self-report section of the instrument.
    a) Created unique student code labels for each consenting student's assessment.
    b) Revised administration directions to ensure procedures were the same across teachers.
        (1) Instructions included actions to maximize test security.
    c) Obtained school addresses for each teacher and prepared mailing labels and a return pre-paid envelope for the teachers to return all the testing materials.
10) Prepared responses for data entry.
    a) Contracted a professional data-entry firm to enter the responses, coding for ambiguous and missing responses.
11) Rasch-modeled, scored, and analyzed the responses.
    a) Used a dichotomous model with the multiple-choice items and a polytomous (partial credit) model with the Likert-scale items.
    b) Conducted item analyses to identify any poorly functioning items or distractors for subsequent editing.
    c) Equated the two pre and post assessment forms using Rasch-based equating procedures.
    d) Calculated internal consistency and descriptive statistics.
12) Conducted a paired t-test and estimated the effect size of the within-student change from pre to post for Cohorts 2–3.
13) Conducted item edits using distractor analysis and Rasch-model item fit statistics.
14) Administered the assessment to the post-only comparison-group (about 470 students).
    a) Had prospective Cohorts 4 and 5 teachers administer at the end of the 2011–2012 academic year with non-TSI students at the same grade level as their expected future TSI students.
    b) Prepared responses for data entry and sent to data-entry firm.
    c) Intended to use these responses as post-only comparison data with the same teachers who, in the 2012–2013 year, were to administer the assessment to TSI students.
15) Edited the assessment for use with Cohorts 4 and 5.
    a) Iteratively met with the project team to revise the assessment blueprint.
        (1) Discussed findings from the 2012 consultant meeting to identify ways the PD was intending to further develop.
        (2) Consulted the project team's TSI documents with a refined definition of the aspects of the nature of science that students should learn.

(a) The project team consulted the National Research Council's (2012) description of science education to inform the intended aspects of NOS to address.

b) Identified eight multiple-choice items to eliminate and four items to revise for wording based on redundancy, item analyses, and items no longer matching the assessment blueprint.
c) Identified nature of science aspects in the blueprint that were underrepresented on the multiple-choice assessment.
d) Developed seven new multiple-choice items to improve content validity.
    (1) Conducted iterative item edits.
e) Combined the seven new multiple-choice items with the existing 11 items.
f) Identified revisions needed with the 12 Likert-scale items in the Nature of Science scale.
    (1) Examined the scale functioning of items based on the partial-credit Rasch modeling of the Cohorts 2 and 3 data.
    (2) Reduced the number of scale categories from 10 to 6 based on these empirical data.
    (3) Reviewed the set of scale items for alignment with the revised test blueprint.
    (4) Identified one item not aligning with the project's definition of nature of science beliefs and identified one item to add in order to address a small gap in coverage.
    (5) Replaced the removed item with the new item.
    (6) Identified two poorly fitting items, which had the negating words *never* and *neither good nor bad*. Reordered the items to see if the reordering would ameliorate the poor fit with the subsequent year.

16) Compiled the 30 items into the Student Science Questionnaire, along with the student science content items described below.
17) Administered the instrument to Cohorts 4 and 5 students in the fall of 2012, prior to Module 1, and again in the spring of 2013, after Module 4.
18) Rasch-modeled and scored the responses.
    a) Placed all multiple-choice and Likert-scale items in the same partial-credit model.
    b) Simultaneously modeled pre and post responses for Cohorts 4 and 5 to ensure the scores were on the same scale.
19) Examined item functioning.
    a) Determined that the two misfitting scale items were still not adequate even after locating them in a different order on the instrument.
    b) Determined that these were misfitting because of the negative wording.
    c) Removed these two items from subsequent analyses.

20) Partial-credit modeled the responses to the 28 items (18 multiple-choice and 10 Likert-scale items) using ConQuest software (Adams, Wu, Haldane, & Xun 2012).
    a) Modeled these nature-of-science item responses with the student-science-content item responses (described below) in the same analysis but as a separate dimensions that were allowed to correlate (because of the expected relationship between science content and nature-of-science understanding in the nomological-network).
21) Calculated maximum-likelihood reliability estimates.
22) Calculated descriptive statistics of the pre and post data.
23) Elected not to use the post-only comparison data collected in the spring of 2012, because
    a) the comparison students were not from an equivalent group in terms of grade level, learning-assistance needs, and teachers (not all Cohort 4 and 5 teachers participated in the spring comparison administration);
    b) no student-level covariates, such as prior standardized test scores in other disciplines (sometimes used as a proxy for a missing pre in the content domain of interest), were available to account for existing systematic differences,
        (1) students were from both public and private schools (where the same standardized tests are not typically administered), meaning that missing covariate data would have been inevitable, and
        (2) the process of acquiring student-level public-school covariate data would have required extensive cumbersome paperwork relative to the potential benefit of having such data (given the missing private-school data); also,
    c) we had placed priority on revising the instrument in the summer of 2012 to reflect the developing program objectives, meaning that the two versions of the instrument shared only a subset of items.
24) Analyzed the pre-to-post changes using teacher-level variables as predictors in a multilevel model for change framework (Singer & Willett, 2003).
    a) Selected school grade level as a contextual variable.
        (1) Because some classes included students from multiple grades, the grade levels were collapsed into elementary (Grade 6), middle (Grades 7–8), and high-school (Grades 9–12) levels.
    b) Selected relevant teacher-level variables.
        (1) Identified number of years teaching science and number of science PD courses previously taken as relevant demographic variables.
        (2) Used pre-PD scores on the Inquiry Teaching Assessment, the Classroom Instruction Questionnaire, and an aggregate score on the four pre-model teacher content assessments.

(3) Identified three fidelity-of-implementation variables, at the teacher level, based on aggregated responses on the Reflections and Post-Cohort Questionnaire.

c) Modeled Time as Level 1, Student as Level 2, and Teacher (or classroom variables) as Level 3.

d) Calculated the intraclass correlations coefficients (ICCs) using null models of the pre- and post-tests and of the middle- and high-school students, separately.

(1) Deemed that the ICCs' magnitudes (ranging from .23 to .37) supported the use of the multilevel model.

e) Examined the pre-to-post gains as a parameter of the Time predictor.

f) Examined the effect of teacher- and context-level variables on the Time predictor to examine teacher-level and context-level moderating effects.

c. *Student Science Content Assessment*

1) Drew from teacher the content assessment blueprints to identify major science content topics.

a) Identified the most important content areas in each module.

b) Drafted large set of potential items measuring these content areas.

(1) Used same multiple-choice item format as that used in the student nature of science items.

(2) Project team developed items and distractors, reviewed and edited by research team.

(a) Iteratively revised the items, eliminating redundant items but maintaining representation of content in the assessment blueprint.

c) Selected 17 items, 4 for each module's content and 1 as a general ocean-literacy principle item, to serve as a pilot-testing set of items for use with Cohorts 4 and 5.

d) Interspersed these items throughout the student nature of science assessment.

2) Administered the items to Cohorts 4 and 5 students as part of the Student Science Questionnaire in the fall of 2012 and spring of 2013.

3) Partial-credit modeled the responses to the 17 items using ConQuest software (Adams, Wu, Haldane, & Xun 2012), and allowing the content dimension to correlate with the nature-of-science dimension in the same run (as explained previously with the Nature of Science Assessment).

4) Calculated maximum-likelihood reliability estimates.

5) Calculated descriptive statistics of the pre and post data.

6) Calculated ICCs, which ranged from .30 to .44 for the pre and post and the middle- and high-school students separately, supporting the use of the multilevel model with the these data.

7) Analyzed the pre-to-post changes using the same multilevel model for change method described previously with the Nature of Science Assessment.

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APPENDIX C

TSI EVALUATION INSTRUMENTS

TEACHER BACKGROUND QUESTIONNAIRE

Curriculum Research & Development Group (CRDG)

Teacher Background Questionnaire

The purpose of this questionnaire is to learn some general information about your teaching background and training as well as your experience interacting online. This will help us understand baseline practices when we examine the effects of the TSI project.

This questionnaire will take about 30 minutes to complete. ***You will need to submit all of your answers in one sitting.***

Thanks!
TSI Aquatic Research Team

***1. Please enter your *first* name:**

***2. Please enter your *last* name:**

Teacher Information

***3. What grade(s) are you currently teaching? (Check all that apply.)**

- ☐ Grade 5
- ☐ Grade 6
- ☐ Grade 7
- ☐ Grade 8
- ☐ Grade 9
- ☐ Grade 10
- ☐ Grade 11
- ☐ Grade 12

***4. How many *years* you have been teaching *science*?**

Enter number of years here: ☐

Items 5 through 8 ask about your *focus class*

***5. How many *minutes* is your focus class period?**

Enter number of minutes here: ☐

***6. How many *times per week* do you see your focus class?**

Enter number of times per week here: ☐

***7. Please list all the major curricula you use in your focus class:**

☐

8. Please provide any additional information about your focus class that you think is relevant to their participation in the TSI project:

☐

Educational Background

*9. For each item below, indicate whether you hold the specified degree or certificate. (Check all that apply.)

- [ ] Bachelor's degree
- [ ] Post baccalaureate certificate
- [ ] Master's degree
- [ ] Doctoral degree
- [ ] Hawaii teaching credential
- [ ] DOE highly qualified teacher (HQT) in science
- [ ] Other degree/certificate

Other (please specify)

Instructions for Items 10-14: For each degree or certificate held, record your major or minor fields of study. If you completed more than one degree or certificate at a level, or had a double major or minor, please provide information for all fields of study at that level. Also, please indicate any degrees in progress you are working toward.

10. Bachelor's degree areas of study:

Major (s):

Minor (s):

11. Post baccalaureate certificate areas of study:

Major (s):

Minor (s):

12. Master's degree areas of study:

Major (s):

Minor (s):

13. Doctoral degree areas of study:

Major (s):

Minor (s):

14. List any degrees or certificates that you are currently working toward.

Degree(s) or Certificate (s):	
Major(s):	
Minor(s):	

Science Background

***15. About how many *undergraduate* science courses (*not* including social science courses) have you taken?**

- 0
- 1-3
- 4-6
- 7-9
- 10 or more

***16. About how many *graduate* science courses (*not* including social science courses) have you taken?**

- 0
- 1-3
- 4-6
- 7-9
- 10 or more

***17. How familiar are you with Ocean Literacy Principles?**

Not at all familiar (1)	(2)`	(3)	(4)	Very familiar (5)
○	○	○	○	○

***18. To what extent do you talk about *ocean processes* with your students?**

Not at all (1)	(2)`	(3)	(4)	A lot (5)
○	○	○	○	○

***19. Do you have any experience conducting scientific research?**

- Yes
- No

Information About Scientific Research Experience

***20. At what level did you conduct your scientific research? (Check all that apply.)**

- [ ] High school
- [ ] Undergraduate
- [ ] Graduate
- [ ] Federal or state agency
- [ ] Non-government research employee
- [ ] Volunteer
- [ ] Other

Other (please specify)

***21. Using the scale below, please rate the extent of your experience conducting scientific research.**

	Very little (1)	(2)	(3)	(4)	Extensive (5)
Select one:	○	○	○	○	○

***22. For the scientific research that you conducted, please briefly explain what you did (e.g., volcano geology, urchin growth, etc.)**

***23. About how much time, among all your research endeavors (i.e., cumulative), did you spend conducting your scientific research?**

- ○ 3 months or less
- ○ 4 months to 1 year
- ○ 1 to 3 years
- ○ 4 years or more

Professional Development Background

***24. About how many *non-science* teacher professional development courses have you participated in over the *past five years*?**

- 0
- 1-2
- 3-4
- 5 or more

***25. About how many *science* teacher professional development courses have you participated in over the *past five years*?**

- 0
- 1-2
- 3-4
- 5 or more

Online Experience

Items 26 through 38 ask about your online experience

***26. Using the scale below, please rate your level of comfort using the Internet.**

Not at all comfortable (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	Very comfortable (10)
○	○	○	○	○	○	○	○	○	○

***27. How frequently do you use the Internet for work?**

- ○ Never
- ○ Less than once a week
- ○ Once a week
- ○ Two to three times a week
- ○ Daily

***28. How frequently do you use the Internet for personal purposes?**

- ○ Never
- ○ Less than once a week
- ○ Once a week
- ○ Two to three times a week
- ○ Daily

***29. How frequently do you access the Internet using a mobile phone or other mobile-type device (e.g., iPad)?**

- ○ Never
- ○ Less than once a week
- ○ Once a week
- ○ Two to three times a week
- ○ Daily

*30. What Internet browser do you primarily use?

- Firefox
- Chrome
- Safari
- Internet Explorer
- Other

Other (please specify)

*31. What computer operating system do you primarily use?

- Macintosh
- Windows
- Linux
- Other

Other (please specify)

*32. Do you have or use any of the following Internet tools or resources?

	For work only	For personal purposes only	Both for work and personal purposes	I do not have or use this
Email				
Email list-serve (e.g., Scuttlebutt, HaSTA, OCEANIA)				
Social networking account (e.g., Twitter, Instagram, Facebook, Linked-in)				
Membership in a hobby organization with online resources (e.g., games, recipes, etc.)				
Membership in a professional organization with online resources (e.g., HaSTA, OCEANIA, NMEA, etc.)				
Online forum (e.g., TED.com, Yahoo! Answers, ravelry.com)				
Your own blog				
Others' blog				
General videos (e.g., TV online, YouTube)				
Education videos (e.g., TeacherTube, TED talks)				

***33. How frequently do you check your e-mail messages?**

- Less than once a week
- Once a week
- Two to three times a week
- Daily

***34. How frequently do you use resources from the Internet during classroom instruction?**

- Never
- Less than once a week
- Once a week
- Two to three times a week
- Daily

***35. How frequently do you use resources from the Internet just for your own classroom planning purposes?**

- Never
- Less than once a week
- Once a week
- Two to three times a week
- Daily

36. Please list any Internet sites that you like a lot or use frequently in your teaching:

***37. Using the scale below, please rate the extent to which you modify Internet materials before using them with your students.**

Never modify (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	Extensively modify (10)
○	○	○	○	○	○	○	○	○	○

***38. Have you used the Internet as part of an online learning experience for your own learning?**

- Yes
- No

Extent of Online Learning Experience

Items 39 through 42 ask about the extent of your online learning experience

***39. In the list below, please check *all* the online learning experiences you have engaged in.**

- [ ] Read research articles or books online
- [ ] Searched for supplemental course content online
- [ ] Accessed course related information or documents from a course management system (e.g. Blackboard or Laulima)
- [ ] Posted messages to online course-related discussion groups
- [ ] Completed an asynchronous online tutorial (e.g., a self-paced learning tutorial)
- [ ] Had a live or synchronous online class session (e.g., virtual classroom or Web conferencing)
- [ ] Completed a semester-long (or equivalent) online *synchronous* (i.e., where everyone logs in at a specific time) course
- [ ] Completed a semester-long (or equivalent) online *asynchronous* (i.e., complete course at my own pace) course
- [ ] Completed a semester-long (or equivalent) *online blended course* that contained a mix of both synchronous and asynchronous sessions
- [ ] Completed an online academic program that consisted of a number of courses and earned a degree or certificate
- [ ] Taught an online course.
- [ ] Other

Please explain other online learning experience(s):

***40. Overall, I think my online learning experience to date has been...**

Very boring (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	Extremely interesting (10)
○	○	○	○	○	○	○	○	○	○

***41. Overall, I think my online learning experience to date has been...**

A complete waste of time (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	Extremely worthwhile (10)
○	○	○	○	○	○	○	○	○	○

42. In a few words, please explain your online learning experience *prior to TSI*:

Additional Comments

43. Using the space below, please add any additional comments about your background or experience that you think is relevant to your participation in the TSI project:

Thank you for your time in completing this questionnaire. Have a great year!

CLASSROOM INSTRUCTION QUESTIONNAIRE

Part 1: *Pedagogical Content Knowledge Scale*, adapted from Scarlett (2008)
Part 2: *Self-efficacy in Science Teaching Scale*, adapted from Ayala (2005)
Part 3: *Self-efficacy in Science Teaching Scale*, adapted from Brandon et al. (2007)
Part 4: *Metacognition in Teaching Scale*, adpated from Balcikanli (2011)
Part 5: Teachers' metacognition in learning items, adapted from Schraw & Dennison (1994)

Classroom Instruction Questionnaire

The purpose of this questionnaire is to learn about your science teaching practices and your beliefs about your ability to implement inquiry-based teaching. We will use the results to help us understand baseline practices and to help us examine trends over the course of the TSI Aquatic project.

This questionnaire will take about 30 minutes to complete. Please carefully read each question. ***You will need to submit all of your answers in one sitting.***

Thanks!

TSI Aquatic Research Team

Classroom Instruction Questionnaire

Part 1.

Instructions for Items 1–43

Please reflect on the activities that you and your students do in your science classroom. For each item, select the answer that best reflects your classroom.

	Never	Rarely	Sometimes	Often	Always
1. Students in my science classes talk with each other about how to solve problems.	○	○	○	○	○
2. Students in my science classes learn how science can be part of their daily lives.	○	○	○	○	○
3. I write comments on students' science work.	○	○	○	○	○
4. Students show respect for the ideas of others in my science classes.	○	○	○	○	○
5. Students in my classes share knowledge in the classroom science laboratory.	○	○	○	○	○
6. Students identify sources of error in experimental data in my classes.	○	○	○	○	○
7. Students propose alternative explanations to phenomena in my science classes.	○	○	○	○	○
8. My science students like to keep their data to themselves.	○	○	○	○	○
9. Students in my science classes work best individually.	○	○	○	○	○
10. Students in my science classes use mathematics to support convincing explanations.	○	○	○	○	○
11. Students in my science classes are able to interpret graphs.	○	○	○	○	○
12. Students in my science classes offer to explain their ideas to one another.	○	○	○	○	○
13. A grade is sufficient feedback for my science students.	○	○	○	○	○
14. Students in my science classes explain their ideas to each other.	○	○	○	○	○
15. Students in my science classes discuss the connections between classroom learning and their daily lives.	○	○	○	○	○
16. I provide science students with needed feedback to improve their work.	○	○	○	○	○
17. Science student time is best spent reading the book.	○	○	○	○	○
18. My primary assessment of students focuses on completion of work.	○	○	○	○	○
19. I use multiple science assessment types (e.g., quizzes, projects, reports, or lab practicals).	○	○	○	○	○
20. Quizzes are the best method for finding out what students understand in science classes.	○	○	○	○	○
21. Part of my job is to supply materials, tools, and	○	○	○	○	○

resources for my science students.					
22. New data from science investigations can change students' ideas.	○	○	○	○	○
23. My students feel safe in expressing themselves in science discussions.	○	○	○	○	○
24. My science students learn best when they work alone.	○	○	○	○	○
25. My science classroom supports collaboration among students.	○	○	○	○	○
26. My science classroom is arranged for interaction among students.	○	○	○	○	○
27. It is more important to teach for content than to teach for broad conceptual understanding.	○	○	○	○	○
28. In my science classroom, students must support statements with evidence.	○	○	○	○	○
29. In my science classes, learning science content is more important than learning science processes.	○	○	○	○	○
30. Learning science helps my students in their daily lives.	○	○	○	○	○
31. If students ask me if their data are correct, I answer yes or no.	○	○	○	○	○
32. Teachers should use a variety of assessments in the science classroom.	○	○	○	○	○
33. I commend students when they have done a good job.	○	○	○	○	○
34. Students in my science classes have opportunities to talk to each other about their classroom work.	○	○	○	○	○
35. I provide feedback to my science students.	○	○	○	○	○
36. I provide examples of how science concepts apply to daily life.	○	○	○	○	○
37. I ask students to evaluate their own data or conclusions.	○	○	○	○	○
38. I like to keep science student desks in straight rows.	○	○	○	○	○
39. I use item completion and fill-in-the-blank assessments.	○	○	○	○	○
40. I ask students in my science classes why they think their answers are correct.	○	○	○	○	○
41. I encourage my students to master their science textbook.	○	○	○	○	○
42. I change my science teaching based on assessment results.	○	○	○	○	○
43. I ask students if they agree or disagree with data presented by their peers.	○	○	○	○	○

Classroom Instruction Questionnaire

Part 2.

Instructions for Items 44-58

Please select the number that best estimates your ability as a science teacher to implement the activity. These items ask for you to estimate what your ability is *now*, after having participated in the TSI-A project.

	Low ability 1	2	3	4	5	High ability 6
44. My ability to include various modes of inquiry in my science classroom.	○	○	○	○	○	○
45. My ability to provide students with an activity, demonstration, or other experience which will address a problem or question that will be the focus of inquiry.	○	○	○	○	○	○
46. My ability to direct students to identify a problem or to pose a question that will become the intended focus of inquiry.	○	○	○	○	○	○
47. My ability to direct students to consider or explore possible approaches, procedures, and outcomes that will address a scientific problem or question.	○	○	○	○	○	○
48. My ability to direct students to develop a hypothesis that will address a problem or question.	○	○	○	○	○	○
49. My ability to direct students to develop, design, or identify a procedure that will address a problem or question.	○	○	○	○	○	○
50. My ability to direct students to invent or identify a means of collecting data.	○	○	○	○	○	○
51. My ability to direct students to implement the procedures and to revise them when needed.	○	○	○	○	○	○
52. My ability to direct students to assess the quality of the procedures.	○	○	○	○	○	○
53. My ability to direct students to test a hypothesis.	○	○	○	○	○	○
54. My ability to direct students to evaluate the quality of their plan, procedure, and results.	○	○	○	○	○	○
55. My ability to direct students to evaluate whether the data collection occurred as they had predicted.	○	○	○	○	○	○
56. My ability to direct students to discuss whether their procedures were appropriate for addressing the problem or question.	○	○	○	○	○	○
57. My ability to direct students to become aware of their own thinking processes.	○	○	○	○	○	○
58. My ability to direct students to think like scientists.	○	○	○	○	○	○

Classroom Instruction Questionnaire

Part 3.

Instructions for Items 59-73

Please select the number that best estimates your ability as a science teacher to implement the activity. These items ask for you to estimate what your ability was *before you attended the first TSI-A workshop*.

	Low ability 1	2	3	4	5	High ability 6
59. My ability to include various modes of inquiry in my science classroom.	○	○	○	○	○	○
60. My ability to provide students with an activity, demonstration, or other experience which will address a problem or question that will be the focus of inquiry.	○	○	○	○	○	○
61. My ability to direct students to identify a problem or to pose a question that will become the intended focus of inquiry.	○	○	○	○	○	○
62. My ability to direct students to consider or explore possible approaches, procedures, and outcomes that will address a scientific problem or question.	○	○	○	○	○	○
63. My ability to direct students to develop a hypothesis that will address a problem or question.	○	○	○	○	○	○
64. My ability to direct students to develop, design, or identify a procedure that will address a problem or question.	○	○	○	○	○	○
65. My ability to direct students to invent or identify a means of collecting data.	○	○	○	○	○	○
66. My ability to direct students to implement the procedures and to revise them when needed.	○	○	○	○	○	○
67. My ability to direct students to assess the quality of the procedures.	○	○	○	○	○	○
68. My ability to direct students to test a hypothesis.	○	○	○	○	○	○
69. My ability to direct students to evaluate the quality of their plan, procedure, and results.	○	○	○	○	○	○
70. My ability to direct students to evaluate whether the data collection occurred as they had predicted.	○	○	○	○	○	○
71. My ability to direct students to discuss whether their procedures were appropriate for addressing the problem or question.	○	○	○	○	○	○
72. My ability to direct students to become aware of their own thinking processes.	○	○	○	○	○	○
73. My ability to direct students to think like scientists.	○	○	○	○	○	○

Classroom Instruction Questionnaire

Part 4.

Instructions for Items 74–83

There are no right or wrong answers in this list of statements. It is simply a matter of what is true for you. Read each statement carefully and select the category that best matches how much you agree with the statement. **[Items adapted from Balcikanli (2011)]**

	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
74. I ask myself periodically if I meet my teaching goals while I am teaching.	○	○	○	○	○
75. I ask myself how well I have accomplished my teaching goals once I am finished.	○	○	○	○	○
76. I have a specific reason for choosing each technique I use in class.	○	○	○	○	○
77. I set specific teaching goals for myself before I start teaching.	○	○	○	○	○
78. I find myself assessing how useful my teaching techniques are while I am teaching.	○	○	○	○	○
79. I ask myself if I could have used different techniques after each teaching experience.	○	○	○	○	○
80. I am aware of what teaching techniques I use while I am teaching.	○	○	○	○	○
81. I use different teaching techniques depending on the situation.	○	○	○	○	○
82. I check regularly to what extent my students comprehend the topic while I am teaching.	○	○	○	○	○
83. After teaching a point, I ask myself if I could teach it more effectively next time.	○	○	○	○	○

Items 84–88 are similar to those above, but they ask about your learning. **[Items adapted from Schraw and Dennison (1994)]**

	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
84. I use different learning strategies depending on the situation.	○	○	○	○	○
85. I have control over how well I learn.	○	○	○	○	○
86. I can motivate myself to learn when I need to.	○	○	○	○	○
87. I am aware of what strategies I use when I study.	○	○	○	○	○
88. I reevaluate my assumptions when I get confused.	○	○	○	○	○

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INQUIRY TEACHING ASSESSMENT RUBRIC

INSTRUCTIONS FOR RATING THE INQUIRY TEACHING ASSESSMENT RESPONSES

George M. Harrison, Lisa M. Vallin, and Paul R. Brandon

Inquiry Teaching Assessment

Instructions for Rating the Inquiry Teaching Assessment Responses

July 2012

Description of the Assessment

The purpose of this assessment is to find out how well teachers understand what teaching science as inquiry looks like in the classroom. Teachers were given the Inquiry Teaching Assessment (ITA), which is an adapted version of the Pedagogy of Science Teaching Test (Schuster et al. 2007). In our version of this test, there were seven teaching scenarios, each followed by a four-option multiple-choice (MC) question that asks the teacher to select which choice best provides an inquiry-based approach to teaching the lesson and to meeting the lesson objective. Each MC question is followed by a prompt that asks teachers to explain their selected answer and to show what they know about teaching science as inquiry. Thus, there are seven items that teachers have responded to, each with a multiple-choice question and a constructed-response question. In effect, the teaching scenario and MC question serve as a vignette prompt for teachers to write their responses to.

The set of responses (which are in this document after the practice set) includes both pre- and post-project responses from teachers (so, each teacher has responded twice, once in the pre and once in the post).[1] The pre and post responses are randomly ordered and numbered so you cannot identify which are pre and which are post based on their position in this response set.

Here are the instructions on the cover of the ITA:

> We would like to know about your understanding of what inquiry-based science looks like in the classroom. For each question, read the description of the teaching situation, then select the option that you believe best matches an inquiry-based approach to teaching that lesson objective. ***Be sure to read all possible answers before making your selection***. After completing your selection for the item, provide your explanation for selecting that choice. Your explanations will be used to assess your understanding of inquiry in the context of each teaching situation. Please provide as thorough an explanation for each item as you can (avoid using explanations such as *see my previous response*).

Rating

Your task is to rate each response on the scale of understanding of what teaching science as inquiry looks like in the classroom. The scale is operationalized by the rubric. Attached to this document is the rubric, the ITA, a practice set of responses, and the full set of responses. Before you get started rating the full set of responses, please read these instructions and practice rating responses in the practice set. Then we need to share our ratings and discuss any discrepancies we have. This is to make sure we are in agreement about how we translate the rubric into our ratings. Discrepancies greater than, say, two points' difference are

[1] All responses, for the practice set and the full operational set, have been removed from this report for brevity.

especially important to discuss during this practice round. After we're in agreement, then we're ready to rate the full set of responses.

When you make ratings on the full set of items, do it independently. In other words, do not work with anyone else to make ratings.

It is best to rate each item's set of responses in one sitting before rating the next item's responses (that is, read and rate all the responses to Item 1 before rating Item 2, and so forth). Before you rate the responses, carefully read the rubric and the ITA item (including the teaching scenario, the possible MC choices, and item's constructed-response instruction prompt).

There are two dimensions we have to deal with: 1) the teacher's understanding of what inquiry looks like in the classroom (ranging from misconceptions to deep and comprehensive understanding), and 2) the relevance of the information in their response (how much they give us to work with in rating their response). Our main goal, of course, is to measure this first dimension.

For this first dimension, focus on the indicators that that suggest the teacher understands what teaching science as inquiry looks like. Do not focus too much on the TSI terminology, as this presents an unfair disadvantage to those taking the pretest. One teacher might, for example, use the term "curiosity mode" after having gone through the PD, while another teacher might provide a description that shows they are understand the curiosity mode even though they might not use the TSI terminology. Treat both of these equally when possible, and even consider the possibility that some post-PD responses might show that teachers know the terms but don't really understand what TSI looks like in practice.

To address the second dimension, the rubric includes statements such as "There is some evidence that…" or "There is strong evidence that…". Give a score of zero when there is not enough information in the response to make a judgment.

Rubric-based scores range from -1 to +3, with half points, which is a 9-point scale. Zero is the point where we would either expect the response to be too short or too vague to provide adequate information for us to judge. Zero is also the point where there is a balance between the teachers' understanding of inquiry and their misconceptions about what inquiry looks like. Negative scores should be given when there is evidence that the teacher has some misconceptions and when there is little or no evidence that the teacher understands what inquiry looks like.

When you rate the full set of ratings, it is best to break it up into chunks in order to avoid fatigue (which can affect your rating). That is, rate one item or even half of the set of an item's responses at a time. Each item may take around two hours to rate. You can go in any order you like (that is, you don't have to rate the first response first—you can start in the middle, the end, and so forth.).

Holistic Rubric for Rating the Inquiry Teaching Assessment Responses

Scale	Description
3.0	There is strong evidence that the teacher fully and accurately understands what teaching science as inquiry looks like in the classroom. The teacher accurately specifies several activities or explanations that demonstrate their knowledge of both the phases and the modes of inquiry, the movement among phases, the importance of teaching students to think like scientists, and a deep understanding of the nature of science.
2.5	There is strong evidence that the teacher has a very broad and very deep understanding of what teaching science as inquiry looks like in the classroom. The response shows knowledge of several phases, movement among phases, several modes, the importance of teaching students to think like scientists, and how teachers can bring the nature of science into classrooms.
2.0	There is good evidence that the teacher has both a broad and deep understanding of what teaching science as inquiry looks like in the classroom. The response may include explanation that shows accurate and precise knowledge of several aspects of teaching science as inquiry.
1.5	There is good evidence that the teacher has a good breadth or depth of understanding of what teaching science as inquiry looks like in the classroom. The response may include explanation that shows accurate and precise knowledge of what inquiry-based instruction would look like.
1.0	There is good evidence that the teacher has a fairly good breadth or depth of understanding of what teaching science as inquiry looks like in the classroom. The response may include mostly accurate and somewhat precise descriptions of what inquiry-based instruction would look like. There is no evidence of misconceptions.
0.5	There is some evidence that the teacher understands what teaching science as inquiry looks like in the classroom, or there is evidence that the teacher's knowledge appears to be developing.
0.0	There is either no evidence that the teacher understands what it means to teach inquiry in the classroom because the response is too short, vague, or off topic; or the response shows that the teacher has some developing knowledge of what inquiry looks like but also has minor misconceptions.
-0.5	There is some evidence that the teacher has misconceptions about what teaching science as inquiry looks like in the classroom. The misconceptions may be minor, or there may be other evidence that shows that the teacher partially understands what TSI looks like in practice.
-1.0	There is good evidence that the teacher has misconceptions of what teaching science as inquiry looks like in the classroom and there are no additional descriptions that would suggest the teacher understands fundamental aspects of TSI pedagogy.

Note. Knowledge of the aspects of TSI does not require knowledge of the terminology (a pre-PD teacher will not use terms such as *initiation phase*, e.g.); rather, knowledge of classroom activities that would match up with the TSI terms.

Practice Rating Sheet
Constructed Responses on the Inquiry Teaching Assessment

Practice using the rubric to rate the sample of responses to Items 1 through 4 (16 responses total) shown below. Be sure to read the item on the ITA (including the scenario and the MC options) before making ratings on its set and be sure to use the rubric when you're making your rating. Make your ratings on your own (do not discuss the response), and be prepared to discuss your rationale for your rating in case there are discrepancies with other raters' numbers. Do not begin rating the rest of the items until after discussing the practice set.

Each row in the table is a response from the teacher. Write your rating in the box at the right. Each response starts with several codes. For the first response below, the "985" is the teacher's ID, which you can ignore. The "Q1" stands for Question 1, which is followed by the MC answer that the teacher selected (Teacher 985 selected *b*). You might need to know which answer they selected when they share their response. Please ignore the "E1".

After you finish these, share your responses with the project team and with each other. If we have discrepancies in our ratings, it is important to discuss these items and the rationale based on the way you use the scale.

[The actual rating sheet, containing the practice set of responses and the operational set of responses, is excluded from this report for brevity.]

INQUIRY TEACHING ASSESSMENT

Curriculum Research Development Group (CRDG)

This instrument was adapted with permission from the Western Michigan University's Pedagogy of Science Teaching Test (POSITT) developed by Schuster et al., (2007).

Inquiry Teaching Assessment

We would like to know about your understanding of what inquiry-based science looks like in the classroom. For each question, read the description of the teaching situation, then select the option that you believe best matches an inquiry-based approach to teaching that lesson objective. ***Be sure to read all possible answers before making your selection***. After completing your selection for the item, provide your explanation for selecting that choice. Your explanations will be used to assess your understanding of inquiry in the context of each teaching situation. Please provide as thorough an explanation for each item as you can (avoid using explanations such as *see my previous response*).

This assessment will take about 30-60 minutes to complete. You need to submit all of your answers in one sitting.

Thanks!
TSI-A Research Team

(This instrument is adapted from the Western Michigan University's Pedagogy of Science Teaching Test.)

Question 1 out of 7

Lesson on Thermometers and How They Work

Objective:
Students develop an understanding of the basic structure and mechanisms of thermometers.

***1a. Four different 5th grade teachers each use a different approach. Whose approach below do you believe best provides an inquiry-based approach to teaching the lesson objective?**

A. Ms. Ash says, “Today you will make a mystery device, see how it behaves, and then tell me what you think it is for.” Each group has a bottle, a cork, a straw, and colored water, which they put together as she shows them. Students then explore what happens if they hold the bottle in their hands or in hot or cold water, etc. Students are then to explain what their product can be used for, what to call it, and how it works.

B. Ms. Brown says, “You will be discovering something for yourselves today.” Each group has a bottle, a cork, a straw, and colored water. She does not tell students how to assemble the materials or what they are for, but asks them to figure this out for themselves and to try anything they wish. Students are then to explain what their product can be used for, what to call it, and how it works.

C. Ms. Connolly writes the lesson title “Thermometers” on the board, draws a thermometer diagram and labels the parts. She then carefully explains how it works. She leads discussion based on student questions. Then groups try out various thermometers at their benches; for example, in hot and cold water.

D. Ms. Dole asks the class, “What do you already know about thermometers?” She lists responses on the board. Working from some of these, she draws a thermometer on the board and explains how a thermometer works. Then groups try out various thermometers at their benches; for example, in hot and cold water.

***1b. Please explain why you selected this teacher's approach for the lesson. In your explanation, show what you know about teaching science as inquiry.**

Question 2 out of 7

Lesson on Finding the Density of a Mystery Substance

Background:
Mr. Cobb's 8th-grade students have learned the concept of density in class by measuring the mass and volume of solid geometric objects. Students have also learned how to measure the volume of solid geometric objects using the liquid displacement method.

Task:
Mr. Cobb gives students an application experiment where they have to apply their knowledge of density. He provides a mystery element, which is insoluble in water and is in granular form. The students' challenge is to devise a method of finding the density of this substance, record the data, calculate the density, and suggest what the mystery element might be. (They will have to use a water displacement method to measure volume since there are air spaces between granules.)

***2a. Thinking about teaching science as inquiry, which one of the following approaches would you suggest that Mr. Cobb use for this activity?**

- A. Have students first propose a method they intend to use. Students then discuss this with the teacher, get feedback, revise their plans if necessary, and then go ahead with their experiment.
- B. Leave students to their own devices as much as possible. The teacher asks students to work out a method on their own and to decide what measurements to take and how. Students then write up their method, experiment, and results in their own way.
- C. Provide students with lab worksheets that have headings for the main steps in the procedure, blank tables for students to enter experimental data, and suitable spaces for calculations, results, and conclusions.
- D. Provide students with a lab instruction sheet which outlines the experimental method. Students follow this procedure and record data in their own lab notebooks. They then calculate density and write up their results in their own way.

***2b. Please explain why you selected this approach for Mr. Cobb's class. In your explanation, show what you know about teaching science as inquiry.**

Question 3 out of 7

Handling Student Misconceptions in Finding the Density of a Mystery Substance

Background:
Mr. Cobb's 8th-grade students have learned the concept of density in class by measuring the mass and volume of solid geometric objects. Students have also learned how to measure the volume of solid geometric objects using the liquid displacement method.

Task:
Mr. Cobb gives students an application experiment where they have to apply their knowledge of density. He provides a mystery element, which is insoluble in water and is in granular form. The students' challenge is to devise a method of finding the density of this substance, record the data, calculate the density, and suggest what the mystery element might be. (They will have to use a water displacement method to measure volume since there are air spaces between granules.)

***3a. One group of students decides to measure the volume of their granular sample by pouring the sample dry into a measuring cylinder. This will give an inaccurate value for the actual volume of granules because of air spaces. How do you think Mr. Cobb should address this?**

A. Tell them immediately that this method will give the wrong volume because of air spaces in the sample, and that they should use the water displacement method instead.

B. Before they go any further, ask them to think about their volume measurement, and prompt the idea of air spaces between granules if necessary. Once they recognize the problem, ask them to think of another method and then to continue.

C. Let them go through with the experiment using their method, allowing them to calculate an inaccurate density value and to suggest a possible element. If students do not notice the error, bring their attention to the anomalous result and ask them to think of an alternative method. Then, have them re-do the experiment.

D. Let them go through with the experiment using their method, allowing them to calculate an inaccurate density value and to suggest a possible element. But, do not ask students to re-do the experiment correctly; rather, have them attribute their anomalous result to "experimental error".

***3b. Please explain why you think Mr. Cobb should take this approach. In your explanation, show what you know about teaching science as inquiry.**

Question 4 out of 7

Lesson on Air as a Material Substance

Objective:

Ms. Harvey wants her 4th grade students to realize that air is a substance (is matter) with certain properties that are evidence for that.

Background:

She leads into the topic by saying: "Here are some questions of interest about air. Is it some sort of substance, or not? Air is invisible, so is there really something there? And how could we be sure if there was something there or not?"

***4a. After this opener to the lesson, and thinking about teaching science as inquiry, how do you think Ms. Harvey should continue? (Focus on overall approach rather than minor points of detail.)**

A. Tell the students that, yes, air is a substance. Say that although air is not very dense, there is something there that can be felt, exerts pressure, and occupies space. Then demonstrate these properties by showing how air can be felt (as wind from a fan), and by blowing up a balloon (showing the pressure and space aspects).

B. Tell the students that, yes, air is a substance. Say that although air is not very dense, there is something there that can be felt, exerts pressure, and occupies space. Then let each student experience feeling air (as wind from a fan), and have them each blow up a balloon (to see the pressure and space aspects).

C. Ask the students, "How can we tell if air is a substance or not and what could we do to test this?" Take students' suggestions, then guide groups toward feeling wind from a fan and blowing up balloons themselves in order to see evidence for these air properties. To close the lesson, groups report back to the class on the various things they did and what they found.

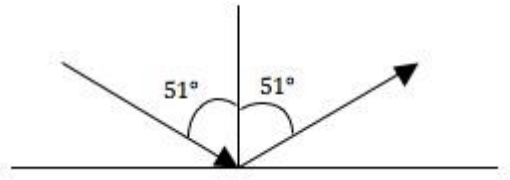
D. Ask student groups to think up ways to test if air is a substance. Then let them go ahead and try these as they wish, using any equipment they request that is available. Ms. Harvey should not prescribe, suggest, or interfere, but be available for individual help or discussion. To close the lesson, groups report back to the class on the various things they did and what they found.

***4b. Please explain why you selected this approach for Ms. Harvey. In your explanation, show what you know about teaching science as inquiry.**

Question 5 out of 7

Planning the First Steps in a Lesson on the Reflection of Light

Objective:
By the end of the lesson, Ms. Baker wants her 8th grade students to know how a light beam reflects when it strikes a mirror, and to be able to state and apply the law of reflection. Formally, this is "When a ray of light strikes a mirror surface, it reflects such that the angle of reflection is equal to the angle of incidence."



***5a. Ms. Baker has to decide on an approach for starting the lesson. Thinking about teaching science as inquiry, which one of the following first steps do you think she should use?**

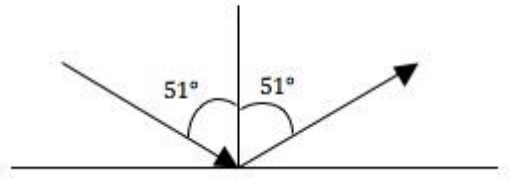
- A. Start by writing the law of reflection of light on the board, illustrating it with a diagram, and explaining it. With a light beam, a mirror, a protractor, and paper at each lab bench, students then model the illustration.
- B. Using a light beam and mirror, start by demonstrating what happens when a light beam strikes a mirror. With a light beam, a mirror, a protractor, and paper at each lab bench, students then model the demonstration.
- C. Start by having the students try out what happens to a light beam when it strikes a mirror. Provide each lab bench with a light beam, a mirror, a protractor, and paper. Encourage students to come up with specific questions about light behavior.
- D. Start by having students find out what they can about light behavior. Provide each lab bench with a light beam, a mirror, a protractor, and paper. Do not prescribe a specific goal for students.

***5b. Please explain why you selected this approach for Ms. Baker's class. In your explanation, show what you know about teaching science as inquiry.**

Question 6 out of 7

Planning the Second Part of the Lesson on the Reflection of Light

Objective:
By the end of the lesson, Ms. Baker wants her 8th grade students to know how a light beam reflects when it strikes a mirror, and to be able to state and apply the law of reflection. Formally, this is "When a ray of light strikes a mirror surface, it reflects such that the angle of reflection is equal to the angle of incidence."



***6a. Student groups, at their lab benches, have already used the light beam, a mirror, a protractor, and paper to have hands-on experience with the reflection of light. Now, Ms. Baker has to decide what she will do next. To get students to think like scientists and to reach the lesson objective, which activity below do you think she should use?**

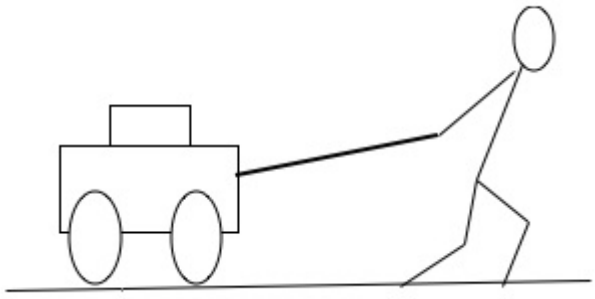
- A. Draw several different paths of light on an illustration on the board and ask students to explain why each one is the correct or incorrect path. Ms. Baker should then finish the lesson by restating to the class the formal law of reflection.
- B. Using the formal law of reflection, written on the board and illustrated with a ray diagram, Ms. Baker should ask student groups to verify whether their findings at their benches matched the diagram. If there are findings that do not match the law, she should have the class discuss the groups' methods and reasons for the discrepancy.
- C. Ask students to present their groups' hypotheses and findings to the class. The class discusses the findings and together formulates a law of reflection. Ms. Baker should then state the formal law of reflection and have students compare their law to the formal law.
- D. Ask students to present their groups' observations and discoveries to the class. The teacher then combines the groups' observations and discoveries into a large table, which the class then discusses. Ms. Baker should then finish the lesson by stating the formal law of reflection.

***6b. Please explain why you think Ms. Baker should take this approach. In your explanation, show what you know about teaching science as inquiry.**

Question 7 out of 7

Lesson on Force and Motion (Newton's Second Law)

Objective:
The instructional goal is for students to learn that a net force will cause an object to change (speed up or slow down) its motion. This is Newton's Second Law.



***7a. Four 5th-grade teachers all have the same teaching equipment available, including a loaded wagon to which a pulling force can be applied. But, they have different approaches to teaching this topic and they design their lessons differently. Of the following approaches, which approach do you believe is the best way to teach students to think like scientists?**

A. Mr. Adams writes up a clear statement of Newton's Second Law, and explains it carefully. He then demonstrates the law by pulling a loaded wagon in front of the class as students observe the motion and record what they see. The teacher asks students to restate the law while he pulls the wagon again.

B. Mr. Brandt writes up a clear statement of Newton's Second Law, and explains it carefully. He then has groups of students verify the law by pulling a loaded wagon, following his instructions and lab worksheet.

C. Mr. Campos raises the question, "What kind of motion results if there is constant force on an object?" He guides groups of students to explore this themselves by pulling a loaded wagon and observing what happens. From the evidence, they then propose a possible law. The teacher then introduces Newton's Second Law.

D. Mr. Doyle raises the question of whether there is any relationship between force and motion. Groups of students are free to explore this in any way they wish, using any suitable and safe equipment in the lab. He does not interfere but helps with any equipment that students request. Groups report back to the class with findings. The teacher then asks students what they know about Newton's Second Law.

***7b. Please explain why you selected this teacher's approach for the lesson. In your explanation, show what you know about teaching science as inquiry.**

Reference

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TEACHER SCIENCE CONTENT ASSESSMENT

MODULE 1: PHYSICAL AQUATIC SCIENCE

Joanna Philippoff, Kanesa Duncan Seraphin, Lauren J. Kaupp, and George M. Harrison

Teacher Science Content Assessment

Module 1: Physical Aquatic Science

These questions assess your knowledge of some of the content addressed in Module 1 of the TSI Aquatic project. Your responses will serve as useful information for the project team's planning and for measuring the project's effect on teachers' content knowledge.

This assessment will take about 30-40 minutes to complete. You will need to submit all of your answers in one sitting.

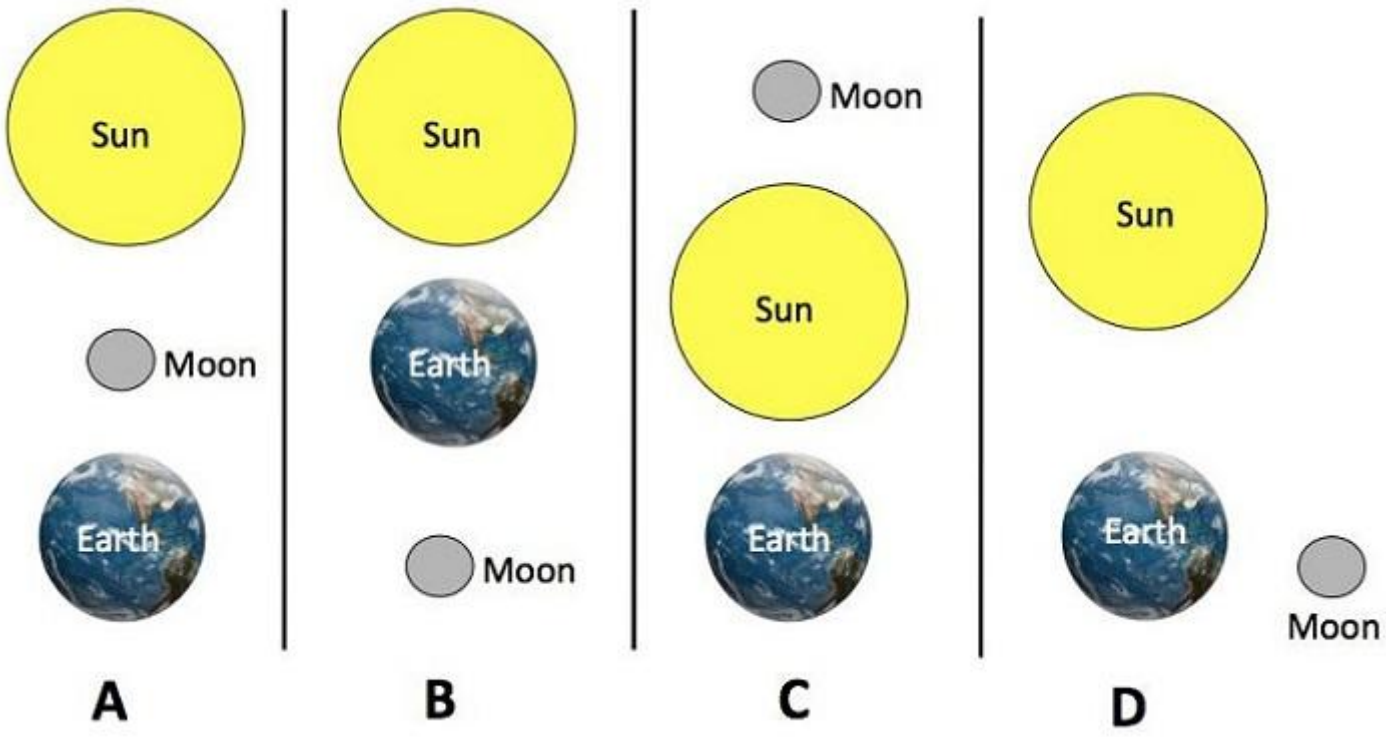
Directions:
Please answer each of the questions to the best of your ability (work on your own, without consulting any materials or other people). For each question, *select the single **best** answer*. Be sure to read the entire question and all possible answers.

Thanks!
TSI Aquatic Research Team

*1. Which of the following best describes the distribution of saltwater on Earth?

- There is one ocean.
- There are four oceans.
- There are five oceans.
- There are seven oceans.

Use this figure to answer Questions 2 and 3. (The figure is not drawn to scale.) Use the column designations (A, B, C, or D) to answer the questions.



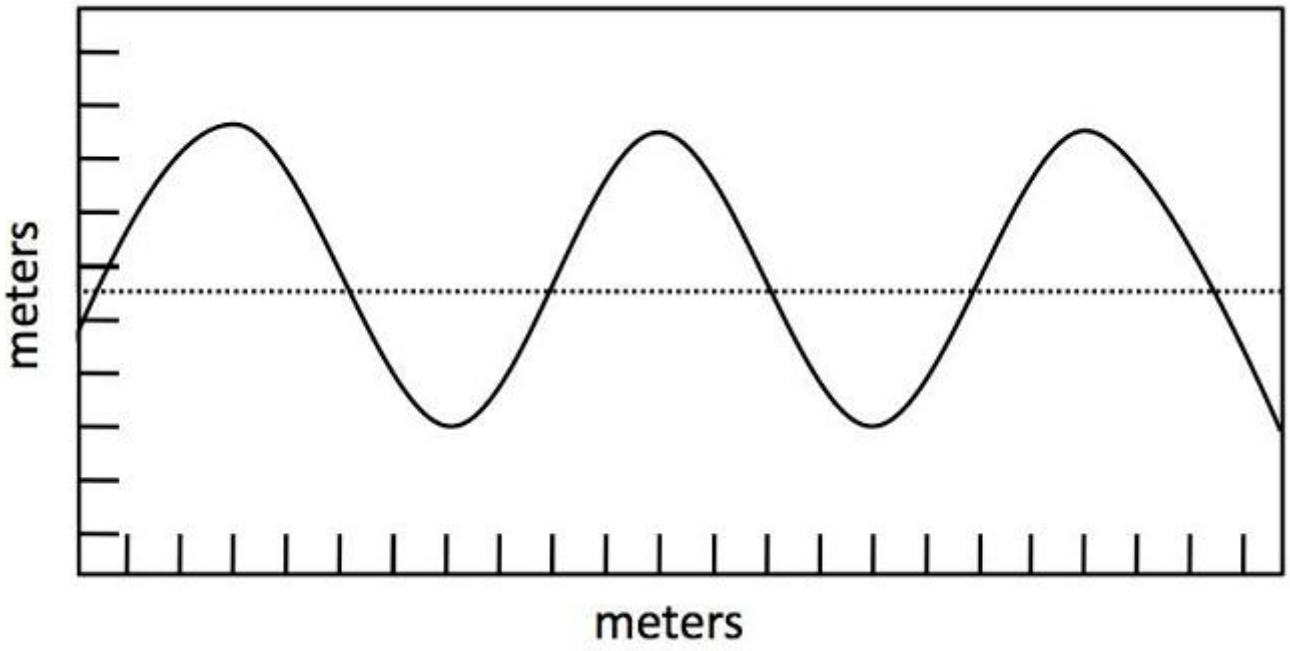
***2. Where is the moon in relation to the sun and Earth during a solar eclipse?**

- Column A
- Column B
- Column C
- Column D

***3. Where is the moon located in relation to the sun and Earth during a neap tide?**

- Column A
- Column B
- Column C
- Column D

Use this figure to answer Question 4. Each tick on the X and Y axes represents one meter.



***4. What is the wavelength?**

- 4.0 m
- 5.5 m
- 8.0 m
- 11.0 m

***5. Wave frequency is:**

- the time in seconds it takes for one complete wave to pass a fixed point.
- the vertical distance from the highest to lowest part of the wave.
- the number of wave crests that pass a fixed point per unit of time, usually in seconds.
- the speed of the wave in a certain direction expressed as distance per unit of time.

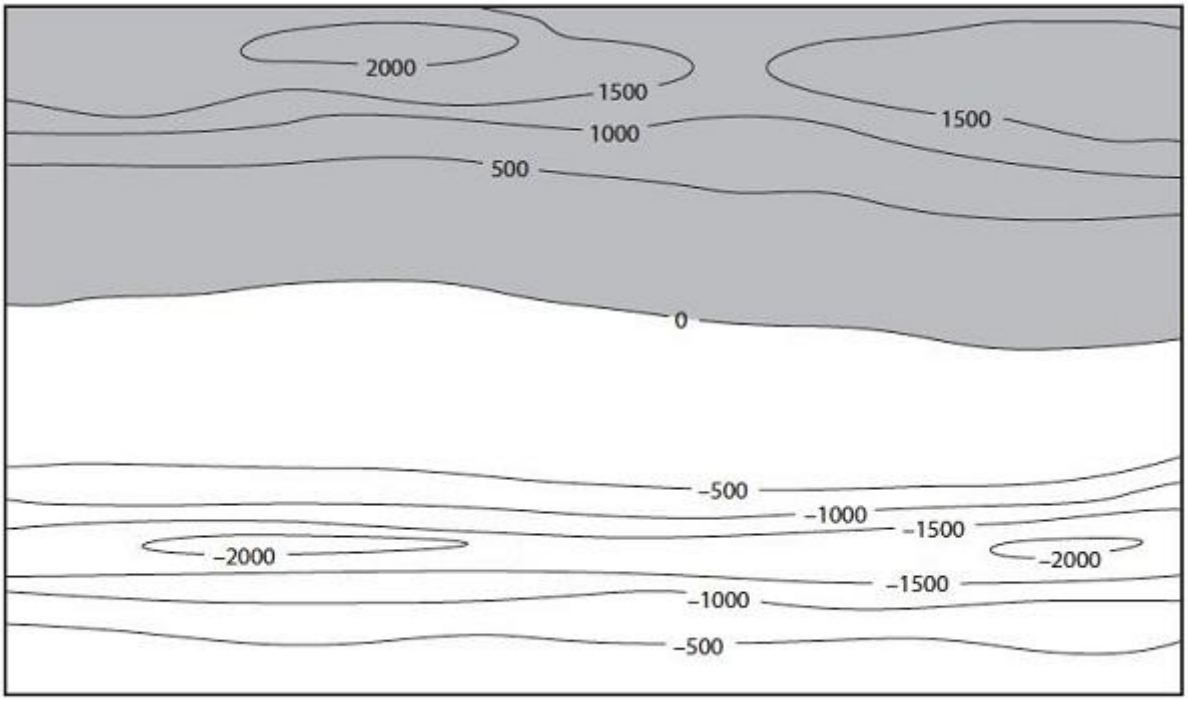
***6. Waves that do not advance but appear to move up and down in place are called:**

- standing waves.
- longitudinal waves.
- transitional waves.
- transverse waves.

***7. Water in the ocean depths is generally _____ water at the ocean surface.**

- colder than
- colder and saltier than
- saltier than
- the same salinity and temperature as

Use this figure to answer Question 8. The numbers in the figure below represent meters and the map represents an area approximately 1500 by 900 kilometers.



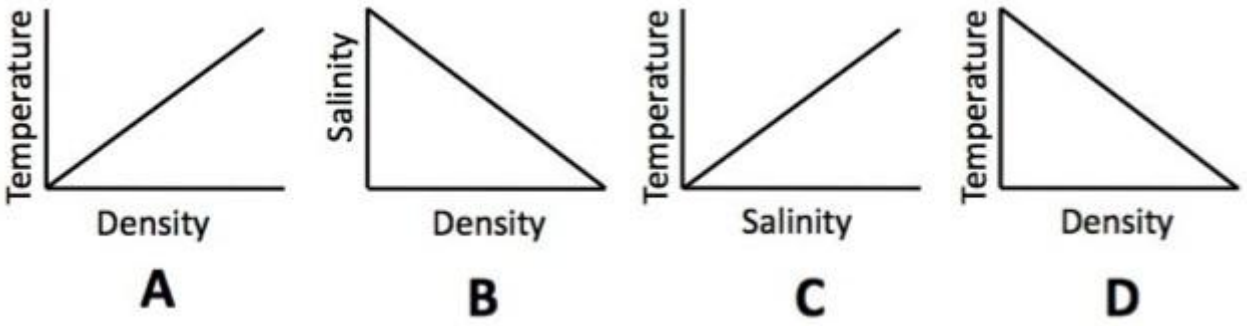
***8. One of the features represented in the above figure is:**

- a seamount.
- an abyssal plain.
- an ocean trench.
- a strait.

***9. Which of the following is the most dense?**

- Cold salty water
- Warm salty water
- Cold fresh water
- Warm fresh water

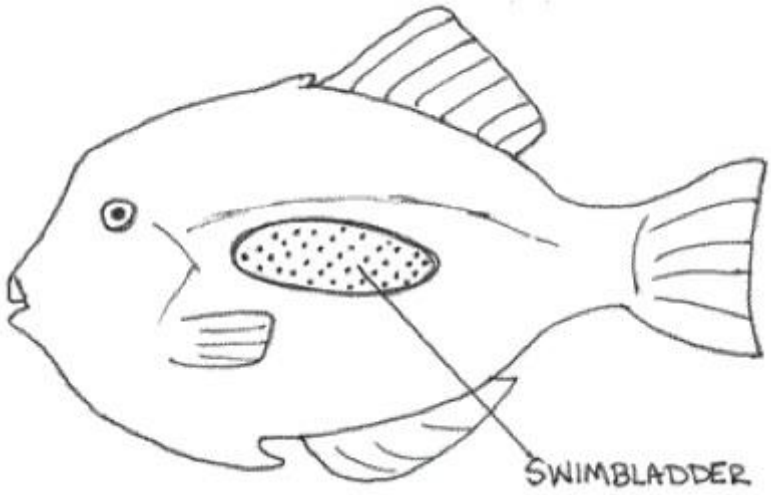
Use this figure to answer Question 10.



***10. Which graph shows the correct relationship in liquid water?**

- Graph A
- Graph B
- Graph C
- Graph D

Many fish have swimbladders (air filled sacs) in their bodies to help them stay neutrally buoyant (meaning they neither sink nor float) in the water.



***11. Using what you know about density, which of the following statements is most likely when comparing a freshwater fish and a saltwater fish that are the same size?**

- The saltwater fish will have a larger swim bladder.
- The freshwater fish will have a larger swim bladder.
- Both fish will have the same size swim bladder.

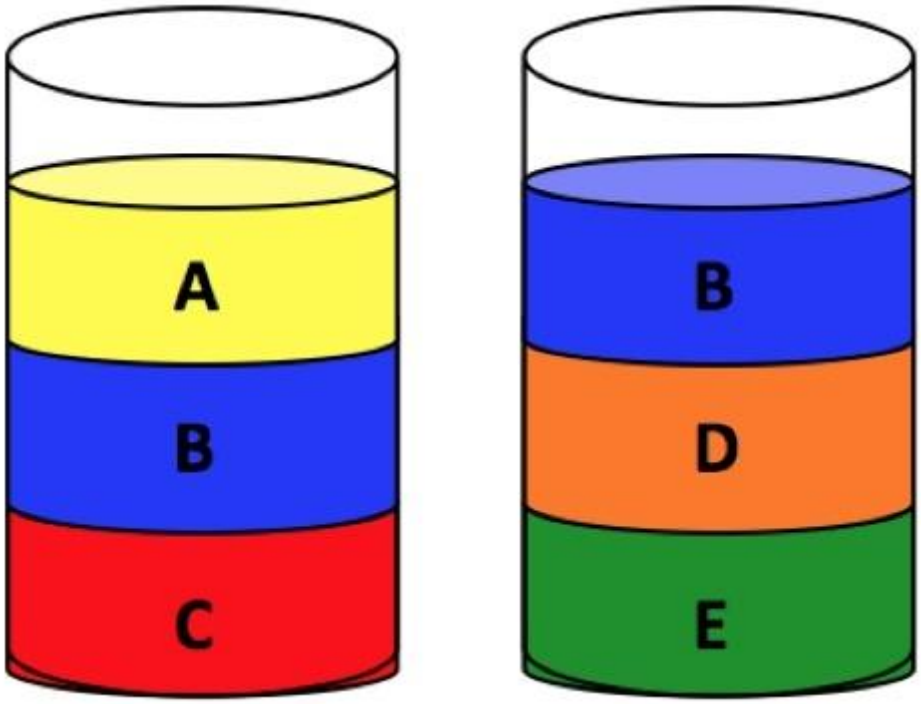
***12. The warm Amazon River flows into the warm Atlantic ocean basin. What do you expect will happen?**

- The river and ocean water will mix evenly.
- The river water will be repelled by the ocean water, and flow back up the river.
- The river water will sink in the ocean.
- The river water will float on the ocean water.

***13. The volume of a metal cube is 40 cm^3. The mass of the same cube is 20 g. How could you determine the density of the cube?**

- Multiply 40 cm^3 by 20 g
- Divide 40 cm^3 by 20 g
- Divide 20 g by 40 cm^3
- Add the lowest common denominator of 20 g and 40 cm^3

Use this figure to answer Question 14. The figure shows liquids in two glasses. Each letter and color corresponds to a different liquid.



***14. Which of the following statements is true?**

- C is less dense than E
- E is more dense than A
- D is less dense than C

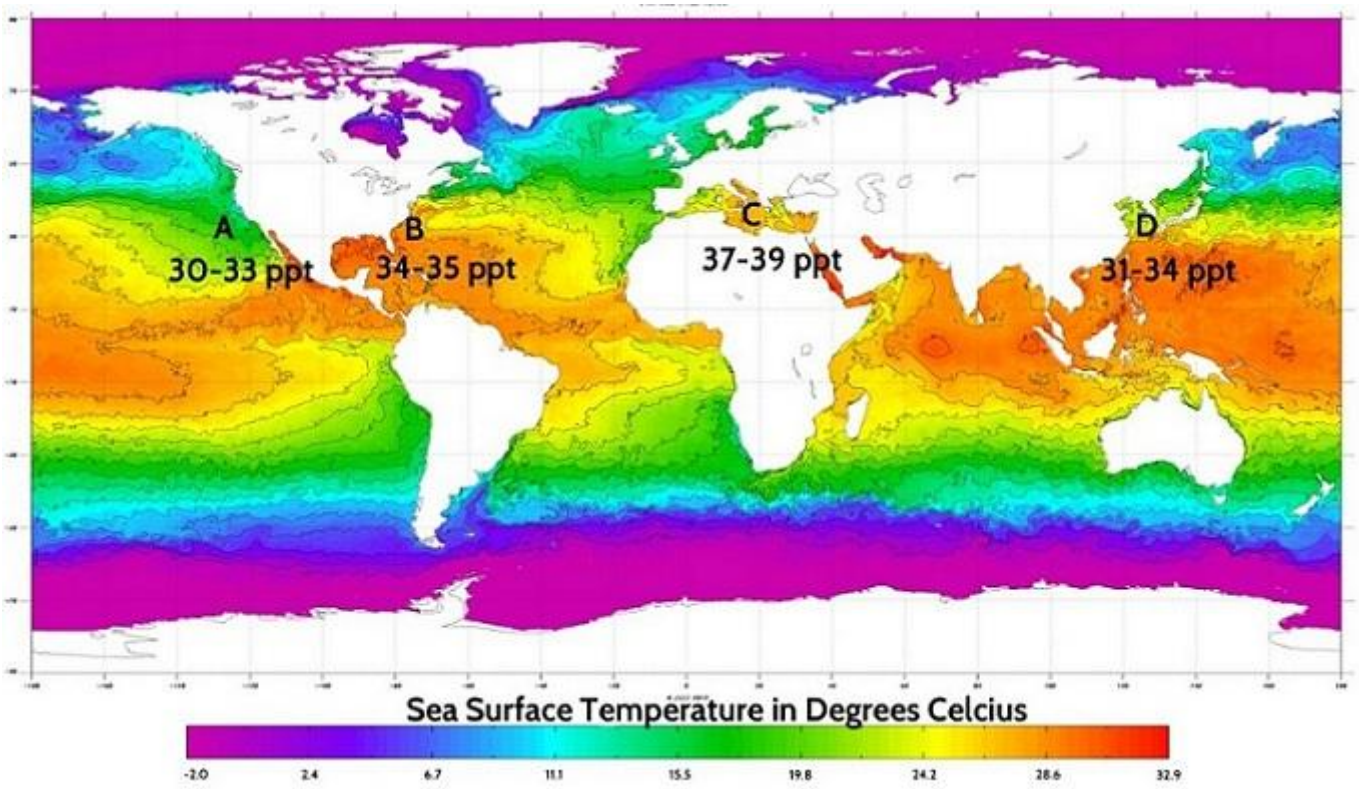
You measure an amount of popcorn kernels (A), which you then cook on the stove, resulting in popped popcorn (B).

A B

***15. Which of the following statements about the density of the popcorn is true?**

- The density of the popcorn did not change.
- The density of the popcorn increased.
- The density of the popcorn decreased.

Use the following figure and your knowledge to answer Question 16. This is a map of the average sea surface temperature. Purple areas indicate low temperatures and red areas indicate high temperatures. For locations A, B, C, and D, the average salinity in parts per thousand (ppt) is shown.



***16. Look at the locations marked A, B, C, and D on the map. In which of these locations do you predict you would have the easiest time floating on your back?**

- A
- B
- C
- D

***17. Contour maps:**

- can show relative depths and elevations.
- are sculpted scale models showing realistic geological features.
- are created by connecting the points on a bar chart.
- show average population density in different areas.

***18. Which of the following statements about density is true? Density is:**

- the opposing force to buoyancy.
- an indirect relationship between mass and volume.
- a stable, unchanging, property of matter.
- affected by temperature.

***19. When an object is subsurface floating (neutrally buoyant):**

- the gravitational force is greater than the buoyant force.
- the buoyant force is greater than the gravitational force.
- the gravitational force and the buoyant force are equal.

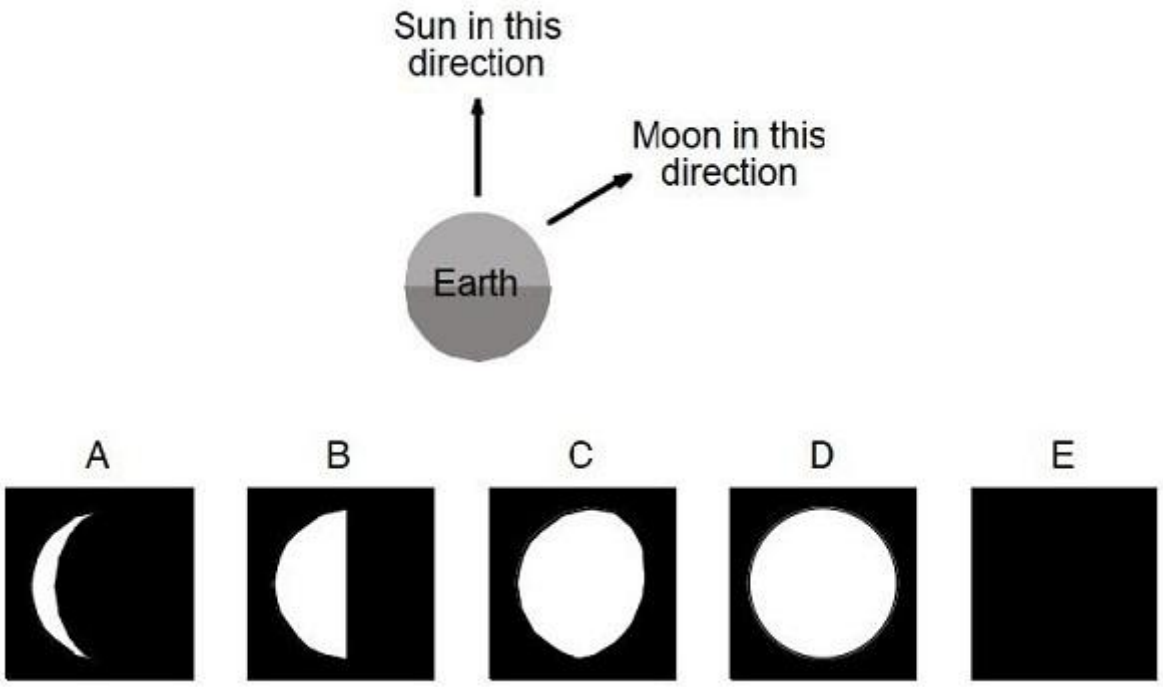
***20. You are pet-sitting for a friend who has a saltwater aquarium. After a few days, you notice the level of the water has decreased. There are no leaks in the aquarium. The fish don't look very healthy. What should you add to the aquarium to save the fish?**

- Brackish water
- Salt
- Fresh water
- Seawater

***21. Imagine that the moon suddenly disappeared. What would happen to the tides in Earth's oceans?**

- The tides would be the same as before the moon disappeared.
- There would only be smaller tides caused by the sun.
- There would be a permanent low tide everywhere.
- There would be no tides.

Use the following figure to answer Question 22.



***22. If you could look down from space at Earth from far above its north pole, the sun and moon would be in the directions shown by the arrows in the picture above. What would the moon look like to a person on Earth facing the moon? (*Select from among the boxes above labeled A through E.*)**

- A
- B
- C
- D
- E

***23. Which of the following is the cause of the phases of the moon?**

- Clouds covering different parts of the moon
- The shadow of the sun blocking parts of the moon
- The shadow of the earth blocking parts of the moon
- The position of earth in relation to the sun and moon

***24. The Moon _____ on its axis. (*Select the best choice to fill in the blank.*)**

- rotates once a day
- rotates once a month
- rotates once a year
- does not rotate

***25. Gravitational currents are caused by:**

- density differences between water masses.
- the gravitational pull of the moon and sun on the ocean.
- earthquakes on the seafloor.
- wind pushing surface water.

***26. The majority of surface currents are produced by:**

- wind.
- waves.
- tides.
- density differences.

***27. Which is true about a day when there are strong surface water currents?**

- There are lots of waves.
- There is a storm.
- The water is moving.
- All of the above.

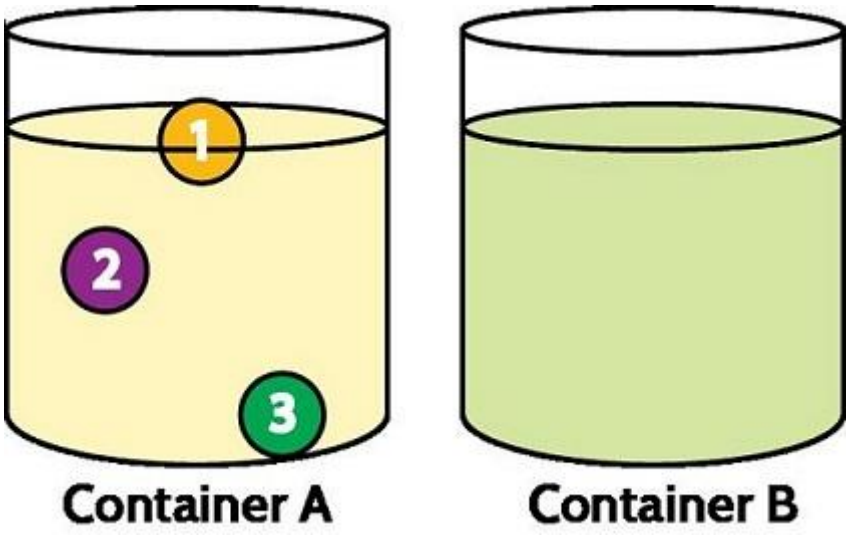
***28. Several factors contribute to ocean circulation. Which of the following does not affect ocean circulation?**

- Gravitational currents
- Earthquakes
- Wind
- Seafloor features
- Positions of the sun and moon

***29. As wave frequency increases:**

- wave period increases.
- the amount of energy increases.
- wave height increases.
- wavelength decreases.

Use the following figure to answer Question 30.



***30. Look at the figure above. In Container A, there are three different objects with the same size and shape, and each is either floating, subsurface floating, or sinking. Which of these three objects would you use to see if the liquid in container B is more or less dense than the liquid in container A?**

- Object #1
- Object #2
- Object #3

TEACHER SCIENCE CONTENT ASSESSMENT

MODULE 2: CHEMICAL AQUATIC SCIENCE

Lauren J. Kaupp, Kanesa Duncan Seraphin, Joanna Philippoff, and George M. Harrison

Teacher Science Content Assessment

Module 2: Chemical Aquatic Science

These questions assess your knowledge of some of the content addressed in Module 2 of the TSI Aquatic project. Your responses will serve as useful information for the project team's planning and for measuring the project's effect on teachers' content knowledge.

This assessment will take about 30-40 minutes to complete. You will need to submit all of your answers in one sitting.

Directions:
Please answer each of the questions to the best of your ability (work on your own, without consulting any materials or other people). For each question, *select the single **best** answer*. Be sure to read the entire question and all possible answers.

Thanks!
TSI Aquatic Research Team

*1. A molecule is:

- the smallest unit of an element that can exist by itself.
- an individual unit of a mixture of one or more types of atoms bonded together.
- the smallest unit of any compound.
- an individual unit of some compounds or elements, made of at least two atoms bonded together.

*2. Pure water is a/an:

- compound.
- element.
- mixture.
- solution.

***3. Water can be separated into its elemental components of hydrogen and oxygen by:**

- boiling, condensing, and then freezing.
- digestion by ultraviolet sensitive bacteria.
- passing an electric current through liquid water.
- heating to high temperatures (e.g., in volcanic eruptions).

***4. The ratio of hydrogen to oxygen in water is:**

- 2:1
- 1:1
- 1:2
- 2:2

***5. Chemically separating water into its elemental components is what kind of reaction?**

- Single replacement
- Double replacement
- Synthesis
- Decomposition

***6. In 1000 grams of seawater, approximately how much salt is dissolved?**

- 25 grams
- 35 grams
- 100 grams
- 350 grams

***7. Water is a(n)_____compound. Sodium chloride is a(n) _____ compound.**

(Please select the pair of terms that correctly fills in the blank spaces.)

- covalent, ionic
- covalent, covalent
- ionic, covalent
- ionic, ionic

***8. In an ionic bond, electrons are:**

- shared.
- combined.
- transferred.
- orbiting.

***9. What do you look at when determining how many protons are in an atom?**

- Atomic weight
- Atomic number
- Mass number
- Ionic weight

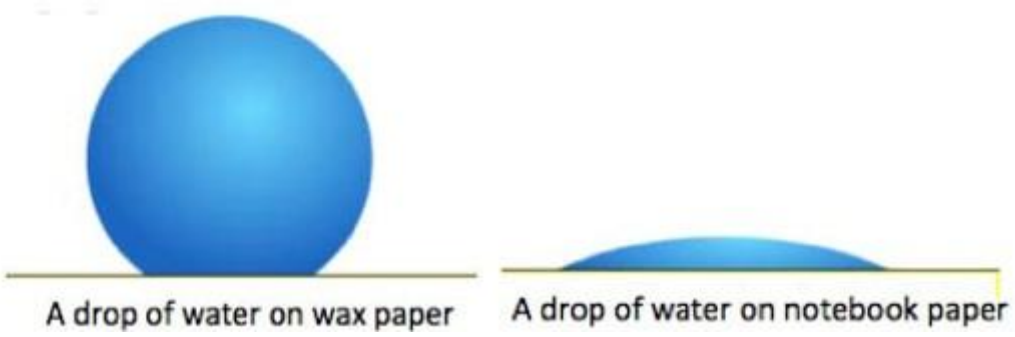
***10. Which of the following forces best explains the surface tension of water?**

- Ionic bonds
- Non-polar covalent bonds
- Strong forces
- Hydrogen bonds

***11. After you take a shower, your hair remains wet for some time. The property of water that helps explain its wetting ability is:**

- adhesion.
- cohesion.
- surface tension.
- holding capacity.

Use the figure below to answer Question 12. The drops of water in the figure below demonstrate how water behaves on two different types of surfaces.



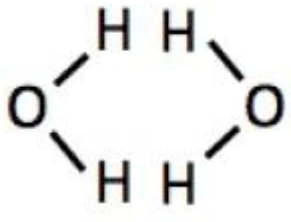
***12. What forces affect the shape of the water droplet?**

- Holding capacity and gravity
- Adhesion and cohesion
- Capillary action and pressure
- Density and salinity

***13. Hydrogen bonds are _____ caused by the _____ sharing of electrons in the O-H bond.**

(Please select the pair of terms that correctly fills in the blank spaces.)

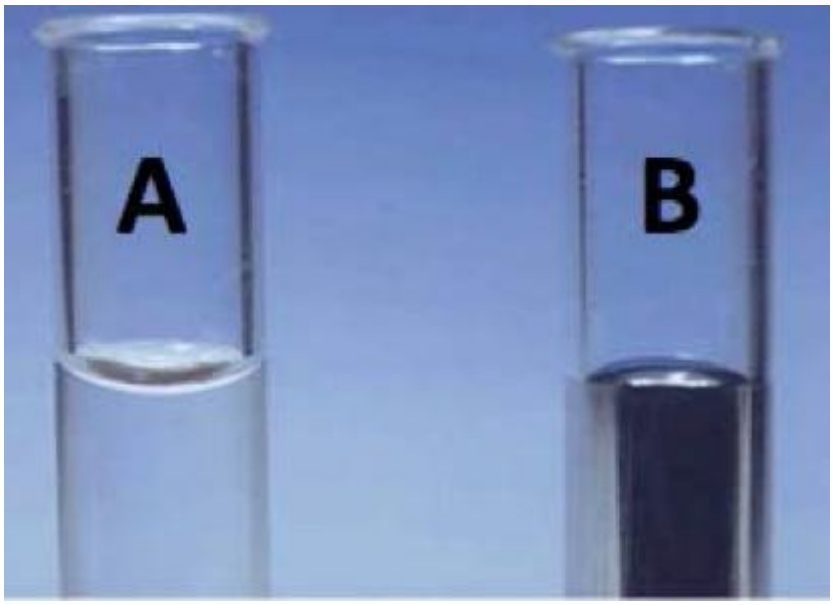
- bonds within the water molecule, equal
- intermolecular forces between water molecules, equal
- bonds within the water molecule, unequal
- intermolecular forces between water molecules, unequal



***14. Referring to the diagram directly above, which of the statements are true regarding how water molecules are likely to orient themselves in a container of pure water?**

- This orientation is likely because the molecules of water create “cells”.
- This orientation is unlikely because the oxygen atoms would attract each other and be positioned adjacent to each other.
- This orientation is unlikely because the hydrogen atoms would repel each other.
- This orientation is likely because the positive and negative forces in the water molecules are balanced.

Use the figure below to answer Question 15. Tube A shows how water appears in a glass tube. Tube B shows how the same volume of mercury appears in a glass tube. Why do water and mercury take on different shapes in a glass tube?



***15. The _____ forces between molecules of mercury are stronger relative to the_____ forces between the molecules of mercury and those of the glass container.**

(Please select the pair of terms that correctly fills in the blank spaces.)

- cohesive, cohesive
- cohesive, adhesive
- adhesive, adhesive
- adhesive, cohesive

This description of *transpiration* is background information for Question 16.

Transpiration is the movement of water from the roots of a plant up through the vascular tissues. Transpiration is possible because as water molecules evaporate from the leaves, they pull neighboring water molecules up through the vascular tissues.

***16. What is the name of the phenomenon which explains the behavior of water in transpiration?**

- Capillary action
- Holding capacity
- Evaporative cooling
- Xylem specificity

***17. Three glass tubes of equal height, but different diameters, are placed upright in a Petri dish of water. In which tube will water rise the highest?**

- The water will rise to the same height in each tube.
- The water will rise the highest in the tube with the smallest diameter.
- The water will rise the highest in the tube with the largest diameter.
- The water will probably not rise in any of the tubes.

***18. Water is a good solvent for salts because it:**

- is a polar compound.
- is a very cohesive liquid.
- dissolves nonpolar substances easily.
- has a high surface tension.

***19. Although water is often called the "universal solvent" for its ability to dissolve a large range of matter, water is not an effective solvent of oil. This is because:**

- water is denser than oil.
- oil is a nonpolar compound.
- oil is more cohesive than water.
- oil is made largely of carbon.

***20. Which of the following statements best explains why ocean water is a better conductor of electricity than pure water?**

- Ocean water has free electrons.
- The greater density of ocean water allows charges to move between molecules.
- The dissolved ions in ocean water allow charges to move through the water.
- Ocean water dissolves non polar substances more easily than pure water.

***21. Which of the following substances will most increase the conductivity of pure water?**

- Sugar
- Alcohol
- Starch
- Baking soda

***22. Which of the following forces is most responsible for why ice floats?**

- Hydrogen bonds
- Covalent forces
- Nonpolar bonds
- Ionic bonds

***23. Which atmospheric gas contributes primarily to ocean acidification?**

- CO_2
- CO
- SO_2
- H_2SO_4

***24. Ocean acidification refers to the phenomenon of:**

- the ocean becoming an acid.
- the ocean increasing in pH.
- the ocean decreasing in pH.

***25. pH is a(n) _____measurement of the _____ concentration in a solution.**

(Please fill in the blank spaces with one of the following choices presented directly below)

- direct, oxygen
- direct, hydrogen
- logarithmic, oxygen
- logarithmic, hydrogen

***26. You have a sample of carbon monoxide and a sample of copper. Fill in the blank: _____ contain(s) some kind of bond.**

- The copper sample
- The carbon monoxide sample
- Both samples
- Neither sample

***27. Emma claims that diamonds and the graphite in an ordinary pencil are made of the same material. A scientist would say that Emma's claim:**

- is true. The substances look different because what's inside them is arranged differently.
- is true. The substances look different because they have different atoms.
- is false. Every substance is unique; no two substances are made of the same material.
- is false. The two substances are too different to be made of the same material.

***28. Which of the following is the best example of a chemical change?**

- Osmosis of water
- Electrolysis of water
- Distillation of water
- Dissolution of salt in water

***29. If you were to hammer some gold into a thin sheet, the atoms:**

- would each flatten out.
- would weigh less.
- would be pushed closer together.
- would be unchanged.

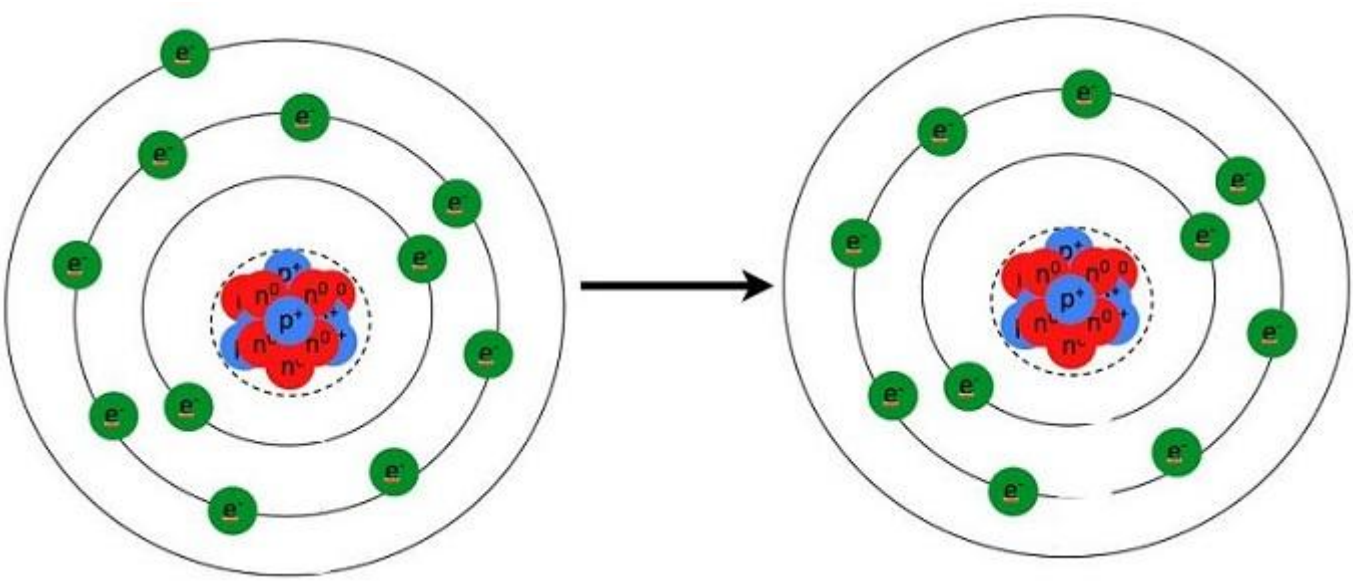
***30. Which of the following distinguishes a solution from a mixture?**

- A mixture has things dissolved.
- A solution is evenly mixed at the molecular level.
- A solution precipitates.
- A mixture is transparent.

***31. The charge in the nucleus of an atom is:**

- neutral.
- negative.
- positive.
- continuously changing.

Use the figure below to answer Question 32.



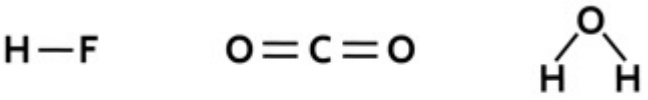
***32. In this model, sodium (atomic number 11) has become:**

- a negative ion
- a positive ion
- a neutral atom
- neon (atomic number 10)

***33. Valence electrons:**

- are in the electron shell closest to the nucleus.
- are held together by electrostatic forces.
- are likely to become positive in an ionic bond.
- determine how the atom behaves in a chemical reaction.

Use the figure below to answer Question 34.



***34. Which of the compounds above is/are very likely to be polar?**

- A and B
- A and C
- B and C
- only C

***35. Taylor dissolves two grams of salt in pure water. He then tries to get the salt back by evaporating the water. How would the mass of salt recovered compare with the initial mass of salt?**

- It would be less, because some of the salt evaporates with the water.
- It would be the same, because salt does not evaporate with water.
- It would be more, because a chemical change occurred.
- It would be the same, because salt is an ionic compound.

***36. For a material to be a good electrical conductor, it must:**

- be a flexible solid.
- be magnetic.
- allow electrons to flow easily.
- have metallic bonds.

***37. Water that has evaporated from the ocean surface is most similar to:**

- salt water.
- fresh water.
- brackish water.
- filtered water.

***38. Water is contained in glaciers as ice. Which of the following is needed in order for liquid water to be formed from the ice in glaciers?**

- Energy input
- A chemical reaction
- Sunlight
- Global warming

***39. Which of the following correctly describes the evaporation of water? Evaporation only occurs when:**

- water's surface area is large.
- water boils.
- water changes from a liquid to a gas.
- water transforms into air.

***40. The primary reason scientists are concerned about ocean acidification is:**

- structures in organisms such as coral will dissolve.
- calcium carbonate structures will not form easily.
- ocean oxygen levels will decrease.
- ocean temperature will increase.

TEACHER SCIENCE CONTENT ASSESSMENT

MODULE 3: BIOLOGICAL AQUATIC SCIENCE

Kanesa Duncan Seraphin, Joanna Philippoff, Lauren J. Kaupp, and George M. Harrison

Teacher Science Content Assessment

Module 3: Biological Aquatic Science

These questions assess your knowledge of some of the content addressed in Module 3 of the TSI Aquatic project. Your responses will serve as useful information for the project team's planning and for measuring the project's effect on teachers' content knowledge.

This assessment will take about 30-40 minutes to complete. You need to submit all of your answers in one sitting.

Directions:
Please answer each of the questions to the best of your ability. For each question, *select the single **best** answer*. Be sure to read the entire question and all possible answers.

Thanks!
TSI Aquatic Research Team

*1. An expedition to Mars has returned with a sample of microscopic particles. Which of the following criteria is the best for determining if the particles are alive? The particles:

- can self-replicate.
- can store hereditary information.
- move in response to stimulus.
- contain carbon or silicon.

*2. All of the following are considered alive by most scientists *except*:

- a brine shrimp cyst.
- a pinto bean.
- dry yeast.
- DNA.

***3. Some scientists do not consider viruses to be alive because they:**

- can only replicate inside other organisms.
- have small genomes.
- do not evolve by natural selection.
- do not have a cellular structure.

***4. Which of the following is the most accurate statement about scientific laws?**

- They are general descriptions explaining events that occur under a broad range of conditions.
- They can change based on the rulings of the scientific authority.
- They can incorporate facts, theories, and tested hypotheses.
- They mathematically predict the behavior of natural phenomena.

***5. Which of the following represents a *scientifically correct* use of the word *theory*?**

- The scientist proved her theory about ocean pH in an experiment.
- It is a well-known theory that shaving your hair makes it grow back thicker.
- Gene theory describes how hereditary information is transmitted.
- Newton had a theory that force is proportional to acceleration or F = ma.

***6. Which word describes an observation that has been repeatedly confirmed?**

- theory
- fact
- law
- prediction

***7. Which of the following statements best distinguishes hypotheses from theories in science?**

- A theory is an initial idea that can be rewritten as a hypothesis.
- Hypotheses are tentative, but theories are proven to be true.
- Theories are supported by evidence from multiple hypothesis-testing.
- Hypotheses and theories are both predictive statements that offer possible explanations.

***8. Why is the law of gravity not considered a theory?**

- There is not enough experimental evidence to elevate it to a theory.
- One person alone, Newton, cannot establish a theory.
- It is concrete and well-supported by evidence.
- It predicts or describes events rather than explaining them.

*9. In what statement is the bolded word used *correctly*?

- My **hypothesis** is that if I hear creaking sounds at night, my house is haunted.
- In my **opinion**, if I make both vanilla and chocolate cupcakes, more people will eat the chocolate cupcakes.
- My **theory** is that it was the salad at the party that caused everyone to get sick.
- Newton's **law** of inertia causes you to keep moving forward a bit if the car you are riding in stops moving.

*10. Which of the following is true about this statement: "When a new species of fish is discovered, it will be made of cells."

- It is a best guess, based on the researcher's knowledge of fish.
- It is a prediction, based on the researcher's hypothesis about the structure of living organisms.
- It is a law, based on what we know about cell theory.
- It is a hypothesis, based on the researcher's knowledge of cell theory.

*11. Of the following statements, which is most correct in explaining why evolution by natural selection is considered a theory?

- It is the best-supported explanation of the world based on evidence.
- It incorporates a number of scientific laws.
- It is the prevailing hypothesis among scientists.
- It has been tested and observed to the point that it no longer needs testing.

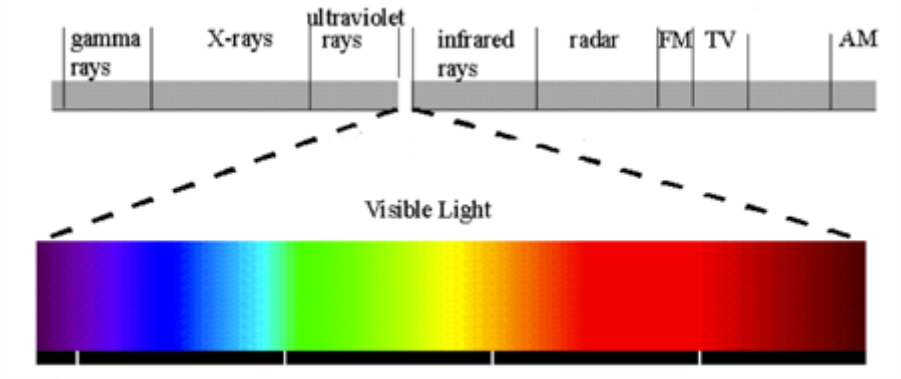
*12. Photosynthesis produces oxygen. Where does this oxygen come from?

- breakdown of H20
- breakdown of C02
- consumption of carbohydrates
- evaporation of H20

*13. Photosynthetic organisms tend to be green because they:

- reflect green light.
- transmit green light.
- absorb green light.
- excite electrons that produce green light.

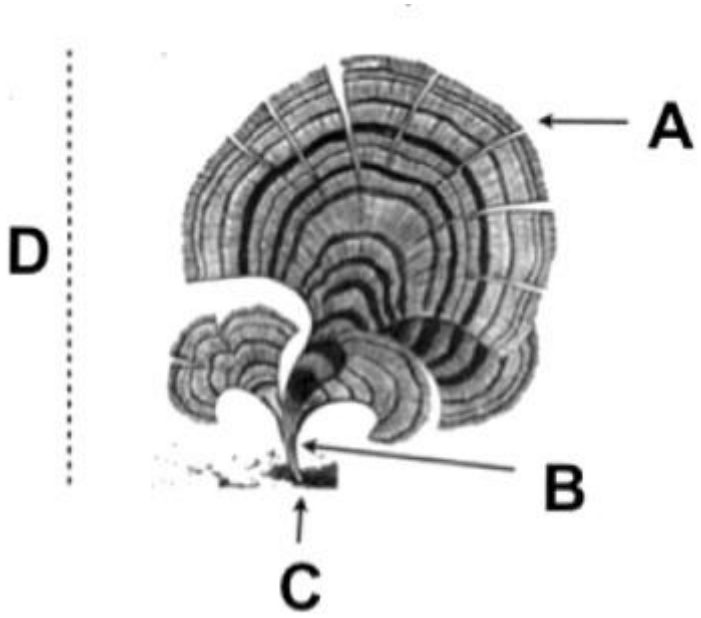
Use the diagram directly below to answer question #14.



***14. In the visible electromagnetic spectrum, the color red has the ___ wavelength and thus the ____ energy.**

- shortest | lowest
- shortest | highest
- longest | highest
- longest | lowest

Use the picture directly below to answer question #15.



***15. Which portion of the algae labeled directly above is known as the stipe?**

- A
- B
- C
- D

***16. What is one of the reasons algae are not considered to be plants? Most algae:**

- do not use the photosynthetic pigment *chlorophyll a*.
- do not have vascular tissues to internally transport water and nutrients.
- can live in a wider variety of ecosystems than most plants.
- do not share a common ancestor with plants.

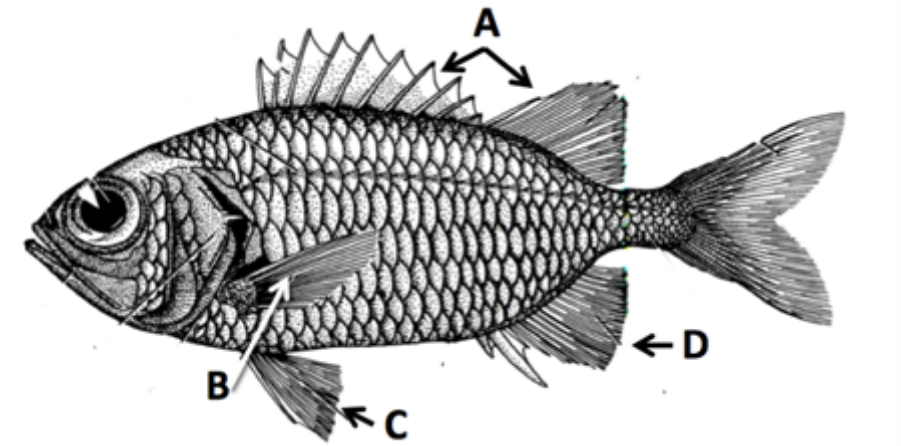
***17. Algae phyla are classified based on their:**

- color.
- pigments.
- morphology.
- distribution.

***18. The role of the fish operculum is to:**

- protect the gills.
- help the fish detect water movement.
- help the fish maintain neutral buoyancy.
- help filter-feeding fish consume plankton.

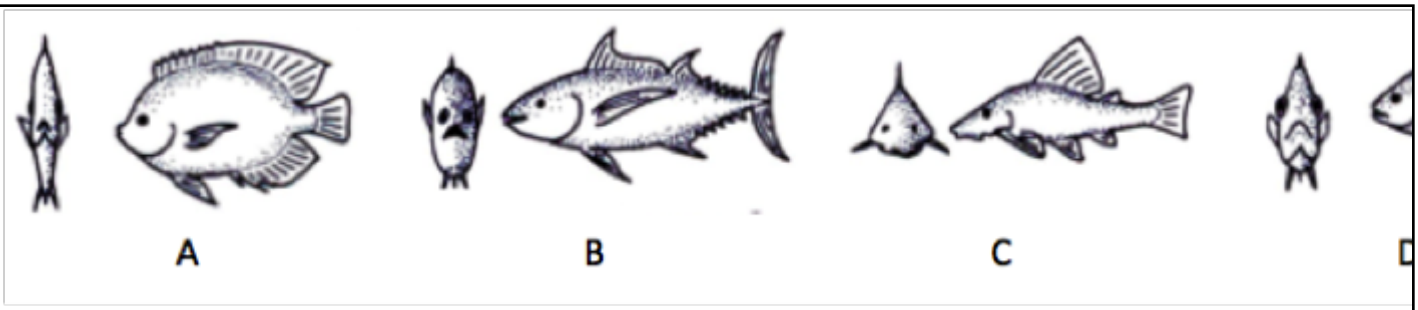
Use the picture directly below to answer question #19.



***19. Which of the fin(s) in the figure directly above is/are *not* positioned farther forward (towards the fish's head) in more evolutionarily advanced fishes?**

- A
- B
- C
- D

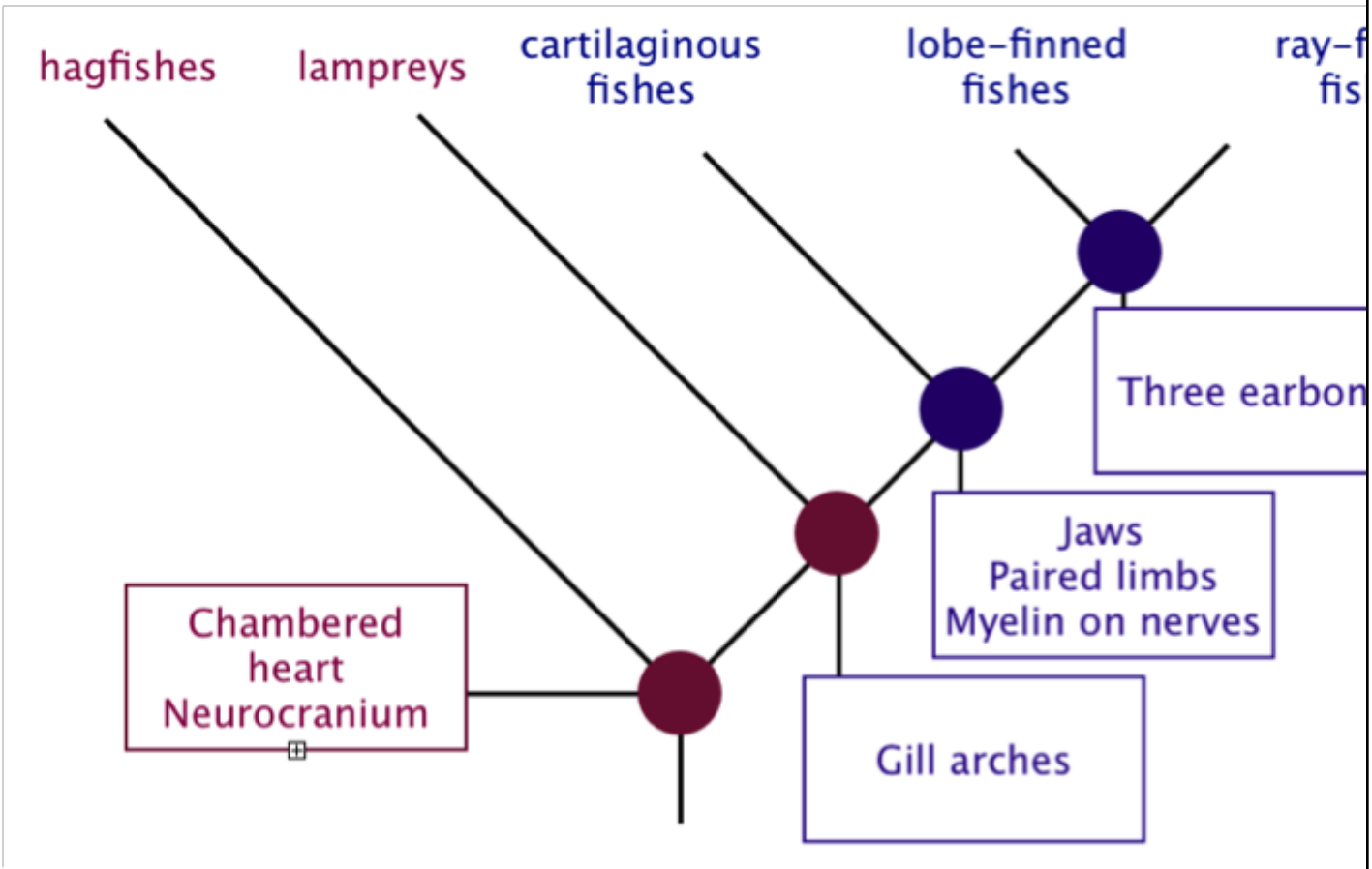
Use the picture directly below to answer question #20.



***20. Which fish in the figure directly above would be *best* suited for living among branches of coral?**

- A
- B
- C
- D

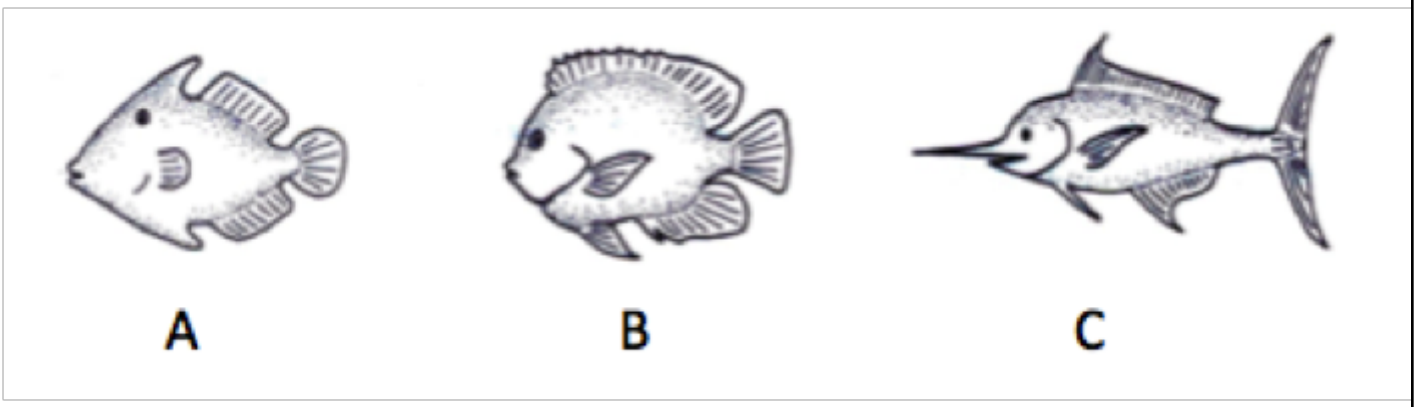
Use the figure directly below to answer question #21.



***21. A phylogenetic tree (such as the one directly above) shows:**

- cartilaginous fish are central in the evolution of fish.
- common ancestry.
- kingdom classification.
- shared ecological niches.

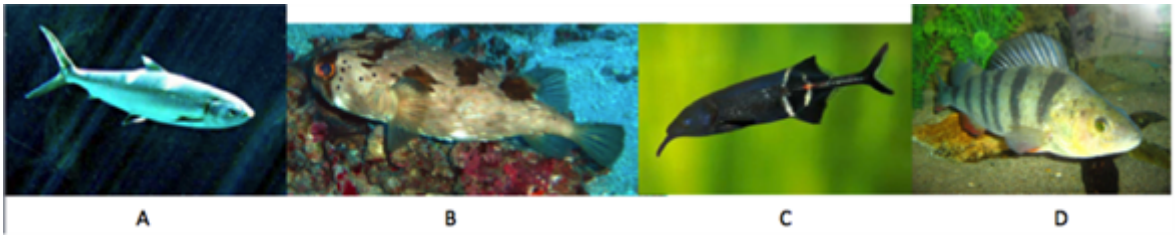
Use the figure directly below to answer question #22.



***22. Based on its anatomy, which fish in the figure above is probably the fastest swimmer?**

- A
- B
- C
- D

Use the figure directly below to answer question #23.



***23. Which of the teleost fish, show in the figure directly above, is the most evolutionarily advanced?**

- A
- B
- C
- D

***24. In the best scientific definition of a fish, which of the following would most likely be included?**

- gets oxygen from the water
- is cold blooded
- has jaws
- has gills

***25. The DNA code is universal. This means that if the triplet UUU codes for the amino acid phenylalanine in cholera bacteria, it codes for phenylalanine in:**

- all bacteria, but not necessarily in all other organisms.
- all species of cholera bacteria.
- all other organisms.
- all organisms in the domains Bacteria and Archaea but not Eucaryota.

***26. What is the relationship between DNA, genes, and chromosomes?**

- DNA contains hundreds of genes, which are composed of chromosomes.
- A chromosome contains hundreds of genes, which are composed of DNA.
- A gene contains hundreds of chromosomes, which are composed of DNA.
- Chromosomes contain hundreds of DNA molecules, which are composed of genes.

***27. Fish species "X" lives in Hanalei Bay, Kaua'i. It has a small upturned mouth that allows it to efficiently capture and eat plankton. Species "X" probably has this type of mouth because:**

- fish in this species needed this mouth shape because other mouth shapes were less efficient at capturing plankton.
- fish with mouth shapes that could eat plankton survived, reproduced, and passed along their DNA to their offspring.
- the mouth muscles of fish in this species became strengthened over time as they reached upward to feed on plankton.
- Individuals in this fish species with more downturned mouths migrated to areas with other food sources.

Use the figure directly below to answer question #28.

Lake Malawi Cichlids

***28. Lake Malawi is a lake that has many different species of cichlids (see picture directly above). This is an example of:**

- changing adaptations.
- population interbreeding.
- species radiation.
- gene regulation.

***29. Variation in populations arises through:**

- replication.
- mutation.
- environmental pressure.
- geologic change.

***30. Natural selection favors organism phenotypes that:**

- are chosen by individuals to enhance their survival.
- allow the organism to adapt to many different environments.
- enhance reproductive success.
- allow the organism to resist diseases.

***31. Whales, like fish, have body appendages modified into fins because:**

- organisms need fin-like structures to live in the water.
- whales and fish share a recent common ancestor.
- whales have adapted similar structures to fish in order to easily move through water.
- whales and fish have adapted at the same evolutionary rate.

***32. In Hawaiian stream gobies, large pelvic disks are selected for. This means that gobies:**

- try to grow larger pelvic disks so they can be more successful.
- with large pelvic disks are more likely to be eaten by predators.
- with large pelvic disks have a higher reproductive rate.
- with large pelvic disks live the longest.

***33. Microevolution is:**

- change within a population.
- change within an individual.
- the evolution of a new species.
- the evolution of small changes.

***34. Natural selection:**

- creates perfectly adapted organisms.
- enhances reproductive success.
- always takes place over long time periods.
- requires variation.

Use the picture directly below to answer question #35.

***35. The invertebrate shown directly above is called *Calcinus seurati*. *Calcinus* refers to the organism's:**

- phylum.
- order.
- family.
- genus.
- species.

***36. Echinodermata, Arthropoda, and Mollusca are all:**

- phylum.
- classes.
- orders.
- families.
- genuses.

***37. All the following are Cnidaria *except*:**

- sea anemones.
- coral.
- jelly medusa.
- sponges.

TEACHER SCIENCE CONTENT ASSESSMENT

MODULE 4: ECOLOGICAL AQUATIC SCIENCE

Joanna Philippoff, Kanesa Duncan Seraphin, and George M. Harrison

A product of Curriculum Research & Development Group (CRDG) College of Education, University of Hawai'i at Mānoa

Teacher Science Content Assessment

Module 4: Ecological Aquatic Science

These questions assess your knowledge of some of the content addressed in Module 4 of the TSI Aquatic project. Your responses will serve as useful information for the project team's planning and for measuring the project's effect on teachers' content knowledge.

This assessment will take about 30-40 minutes to complete. You need to submit all of your answers in one sitting.

Directions:
Please answer each of the questions to the best of your ability. For each question, *select the single **best** answer*. Be sure to read the entire question and all possible answers.

Thanks!
TSI Aquatic Research Team

***1. Lenni wants to know the percentage of each color of candy in a bag of candy, but she doesn't want to count all of the candy in the bag. To answer her question, Lenni closes her eyes, opens the bag, and takes out the first ten pieces of candy she touches. Six of the candy pieces are green, two are red, and two are yellow. What can Lenni infer?**

- 80% of the candy pieces in the bag are green, 10% are red, and 10% are yellow.
- Most of the candy pieces in the bag are green, but there is not enough information to say anything about the other colors.
- There are at least three colors of candy in the bag.
- The bag of candy was not well-mixed. If it were, there would be more colors in the sample.

***2. Even when you use a reliable random sampling method and have a good sample size, your data might not represent that of the whole population. For this reason, scientists generally:**

- prefer to conduct a census where all individuals are represented.
- disregard samples that are unrepresentative due to random variation.
- take multiple samples and calculate the probability of accuracy.
- modify sampling techniques for each data point collected to ensure representative sampling.

***3. Which of the following is true of systematic sampling?**

- It is not a valid way to survey an area when random sampling is possible.
- It characterizes an environment but does not allow us to generalize beyond the specific sample.
- It is an appropriate way of characterizing an environment, depending on the survey goal.
- It is used to collect information about every item you are interested in studying in an area.

***4. Which of the following would *not* result in a random selection?**

- choosing a card from a deck of shuffled cards
- rolling a dice
- throwing a dart
- flipping a coin

***5. Clancy wants to describe the fish population in a pond. Which of the following is the most important issue in designing his sampling procedure?**

- Taking as many fish samples as possible
- Making sure the study design allows him to answer his study questions
- Making sure he measures the number of fish with at least three different sampling strategies
- Making sure sampling locations within the pond are randomly chosen

***6. Jordan does an experiment on his students. He places a handful of carrots in the middle of the room and the entire bag of chocolate kisses in the corner of the room in identical glass bowls. At the end of the day, there are no carrots left but there are lots of chocolate kisses remaining, so Jordan thinks his students like carrots better than chocolate. What is the *biggest* mistake in Jordan's experiment?**

- Jordan did not repeat the procedure multiple times.
- Jordan does not have a control variable for this experiment.
- Jordan did not standardize enough variables to be able to compare preferences.
- Jordan chose variables that are not comparable—chocolate and vegetables.

***7. Mia is studying 15 different Marine Protected Areas (MPAs). She wants to compare these MPAs in terms of the proportion of fish (in a single species) that are of reproductive size. To make this comparison, Mia realizes she needs to develop a sampling procedure that will allow her to accurately estimate the proportion in each MPA. What is the *best* sampling design for Mia's study?**

- Take samples of 10 fish from each MPA until the average reproductive size of the fish reaches pre-determined cut-off points.
- Take samples of 10 fish from one MPA until the running proportion of reproductive fish stabilizes. Then, sample each subsequent MPA this same number of times.
- Take samples of 10 fish from every MPA until the running proportion of reproductive fish stabilizes for that MPA. The number of samples may vary between MPAs.
- Sample each MPA 10 times. Randomly choose the sample-size number using a random-number generator to ensure the study is as unbiased as possible.

***8. Which of the following is the most appropriate strategy for sampling highly mobile organisms like fish?**

- transect point intercept
- quadrat point intercept
- quadrat percent cover
- timed visual estimate

***9. Which of the following techniques would be best if you needed to sample a relatively small area with many small, well-camouflaged species and you wanted to be sure to record as many species as possible?**

- transect point intercept
- quadrat point intercept
- quadrat percent cover
- timed visual estimate

***10. Which of the following is the most appropriate sampling strategy for quickly studying the substrate in a large area (such the deep ocean floor) that is dominated by a few species?**

- transect point intercept
- quadrat point intercept
- quadrat percent cover
- timed visual estimate

***11. Organisms that live close to, or are attached to, the substrate are known as _____ organisms.**

- benthic
- sedentary
- detritivore
- autotroph

***12. In areas like the intertidal, groups of organisms are often found in distinct bands. This phenomenon is known as:**

- succession.
- segregation.
- natural selection.
- zonation.

***13. The transect point intercept sampling method would work best in:**

- a complex high relief area, like a coral reef.
- an area with many active mobile organisms, like a forest canopy.
- a large uniform area, like a field or sandy beach.
- a location with many small cryptic organisms, like a tidepool.

***14. Which of the following types of data are you able to collect with percent cover sampling that you cannot collect using a point intercept type of sampling method?**

- distribution of species over an area
- species diversity and richness
- identity of individual species
- relative area occupied

***15. Where organisms live is partially determined by abiotic factors. Which of the following is an abiotic factor?**

- competition
- temperature
- parasitism
- predation

***16. The measure of biodiversity that describes the relative proportion of species is known as species _____.**

- abundance
- evenness
- ratio
- richness

***17. A kelp forest has been altered through predation by a population of sea urchins. There are still many species, but the numbers of individuals of most species were depleted. Despite predataion, this area still has high species:**

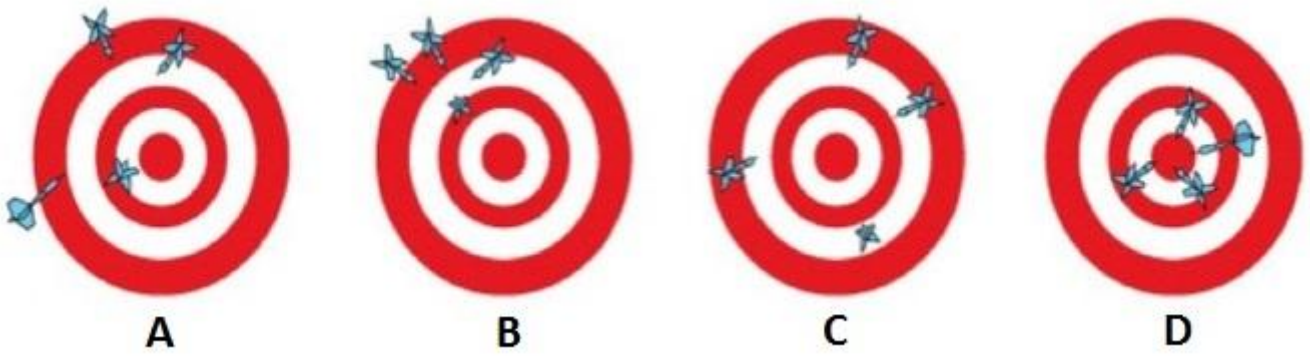
- biodiversity.
- abundance.
- evenness.
- richness.

***18. Which of the following fish tanks has the highest species evenness?**

Tank A: 3 brittle stars, 2 sea cucumbers, 15 urchins, 1 cichlid, 6 oysters, 64 snails, and 40 mussels
Tank B: 6 shrimp, 5 flatworms, 4 crabs, 5 sea slugs, 6 wrasse
Tank C: 964 blennies, 321 gobies
Tank D: 4 dolphins, 1 great white shark, 1 humpback whale

- Tank A
- Tank B
- Tank C
- Tank D

Use the image directly below to answer Question 19.



***19. Which of the dartboards demonstrates a scenario that is accurate but not precise?**

- A
- B
- C
- D

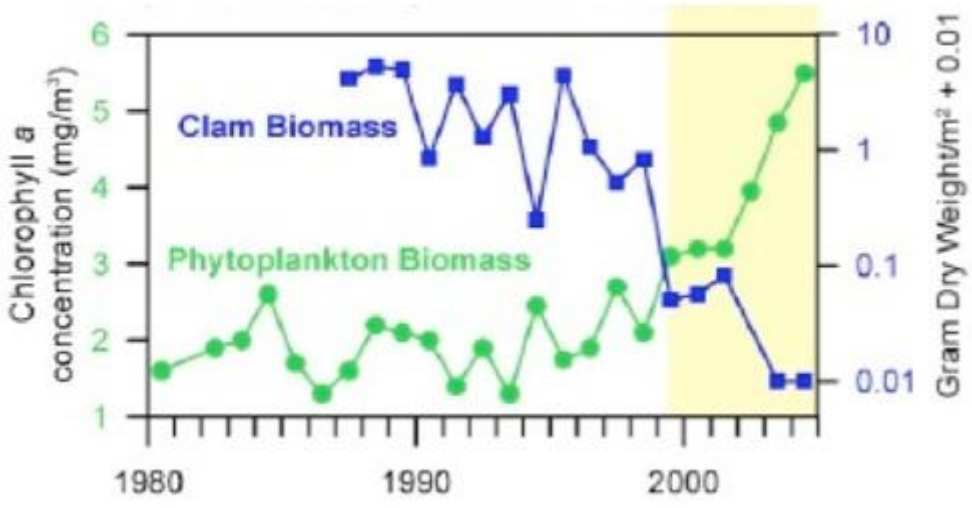
***20. An oceanographer needs to go out in a boat to retrieve an important temperature-and-salinity data logger that is attached to an underwater stake on a coral reef. When the oceanographer's Global Positioning System (GPS) indicates that she is at the location of the stake, she anchors the boat and jumps in the water to collect the data logger. However, she can't find the stake. The other GPS units belonging to her colleagues on the boat also indicate that they are at the correct location. After an extensive search, the oceanographer finds the stake 50 meters (m) from the boat. Assuming the stake was at its assigned location, the GPS units in this scenario were:**

- accurate but not precise.
- precise but not accurate.
- accurate and precise.
- neither accurate nor precise.

***21. Systematic scientific error**

- is nearly always the result of sloppy work and mistakes—it can be eliminated if scientists are careful.
- becomes insignificant when scientists replicate their studies many times.
- is nearly always the result of limitations in instrumentation or procedures.
- can nearly always be accounted for with the use of appropriate mathematical formulas.

Use the diagram directly below to answer Question 22.



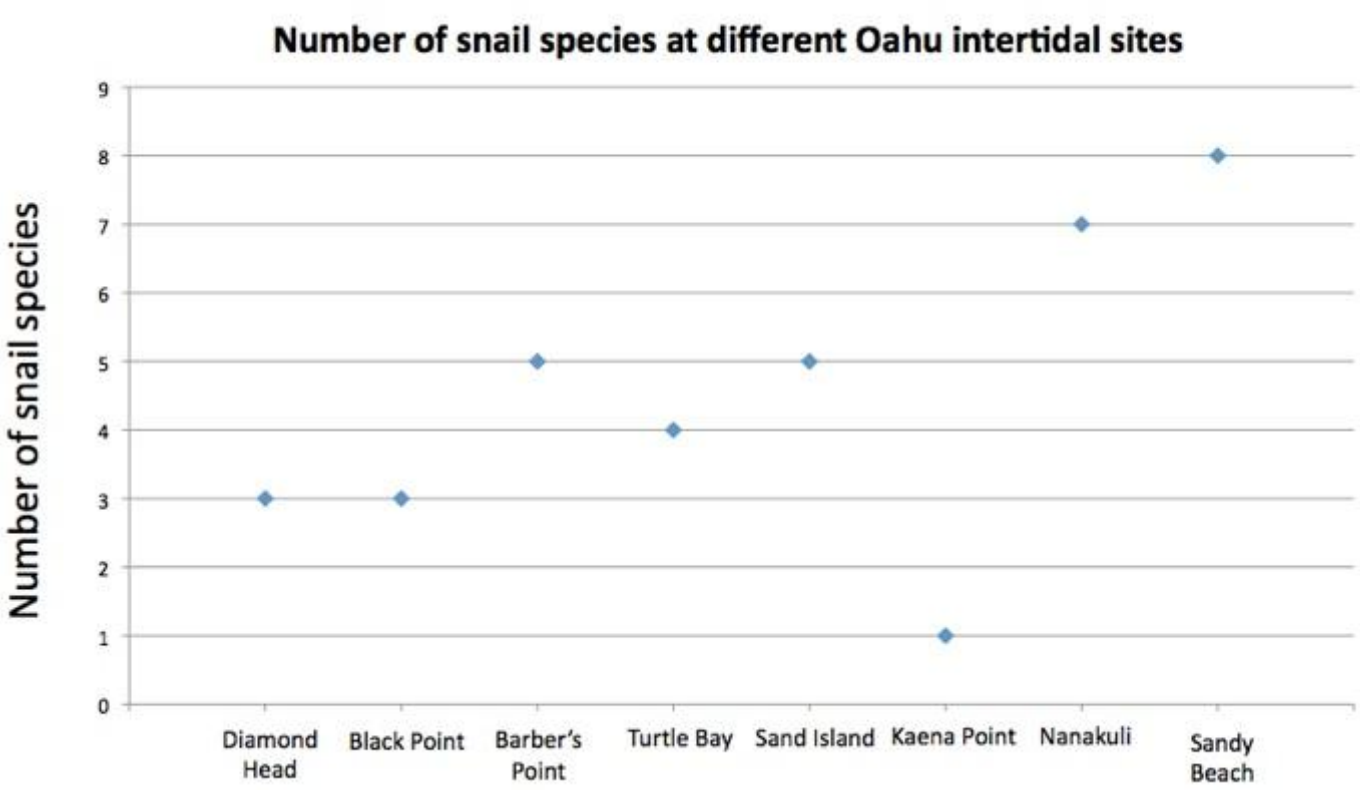
***22. Which of the following terms is best used when describing the way the two variables, phytoplankton biomass and clam biomass, change together in the area highlighted in yellow?**

- causation
- interdependence
- correlation
- explanation

***23. In your study of intertidal organisms, you discovered that lots of *Ulva*, a genera of algae, was found near freshwater puddles. Very little *Ulva* was found near the ocean shoreline. *Ulva* population growth appears to be:**

- more rapid in areas of low salinity.
- stimulated by low salinity water.
- positively correlated with salinity.
- negatively correlated with salinity.

Use the diagram directly below to answer Question 24.



***24. When graphing your data, you see the results in the image shown directly above. What should you do?**

- Keep the data point outlier but only draw a trendline through the other data points.
- Connect all of the points to make a line graph.
- Discard the data point outlier and draw a trendline through the rest of the data points.
- Represent your data in a different way.

Use the table directly below to answer Question 25.

Month	Temperature (°C)	Dissolved Oxygen (mg/l)
Jan	1	7.0
Feb	7	6.7
Mar	7	2.9
Apr	12	3.2
May	14	5.5
Jun	21	2.4
Jul	24	3.3
Aug	17	4.3
Sep	26	6.0
Oct	19	7.6
Nov	14	6.6
Dec	4	7.1

***25. The table directly above shows the mean monthly dissolved oxygen concentration and water temperature for a lake in Japan. What is the best way to represent your data?**

- scatter plot
- line graph
- pie chart
- bar graph

Use the table directly below to answer Question 26.

Algae	Percent Cover (%)
Padina	9
Ulva	3
Turbinaria	8
Sargassum	15
Wrangelia	1
Acanthophora	10
Dictyosphaeria	8
Dictyota	21
Microdictyon	3
Laurencia	2
Gracilaria	13
Halimeda	5
Hypnea	2

***26. The table directly above shows the percent cover of different types of algae at one intertidal site. What is the *best* way to represent this data?**

- scatter plot
- line graph
- pie chart
- bar graph

***27. You surveyed three intertidal sites, and found that they had similar numbers of algae species but that these sites differed in their species composition. What is the best way to represent your results to allow your audience to easily make comparisons across sites?**

- scatter plot
- line graph
- pie chart
- raw data (data table)

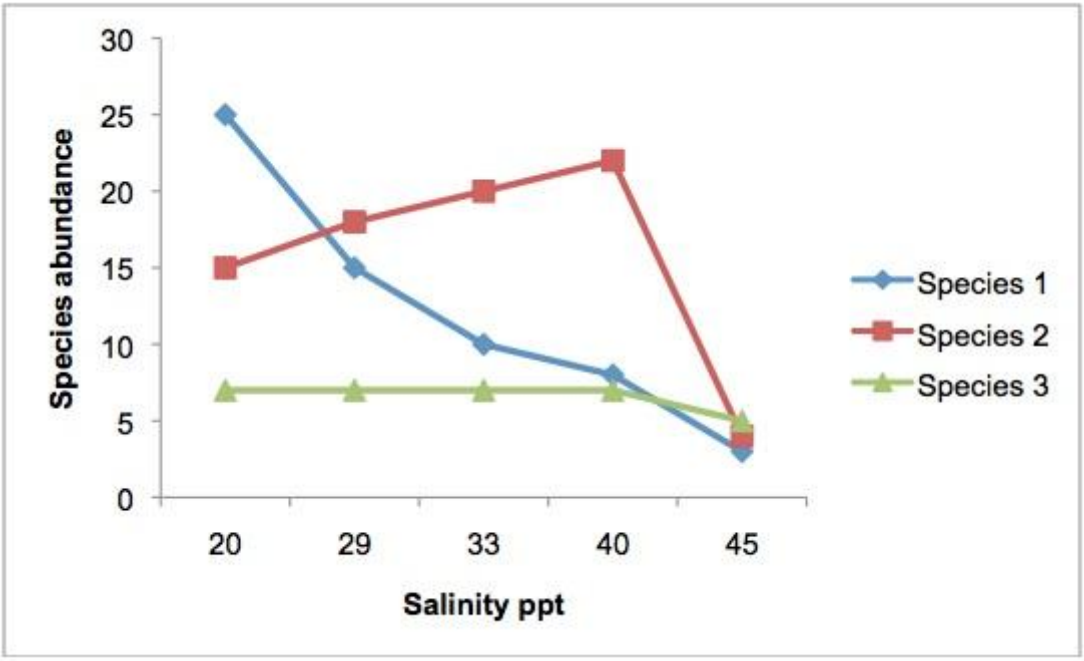
Use the table directly below to answer Question 28.

Coastal area	Average slope of shoreline (°)
A	3
B	6
C	10
D	13
E	18
F	21
G	27
H	34

***28. The table directly above shows the average slope of the shoreline for eight coastal areas labeled *A* through *H*. What is the best way to represent your data?**

- scatter plot with trendline
- line graph
- pie chart
- bar graph

Use the graph directly below to answer Question 29.



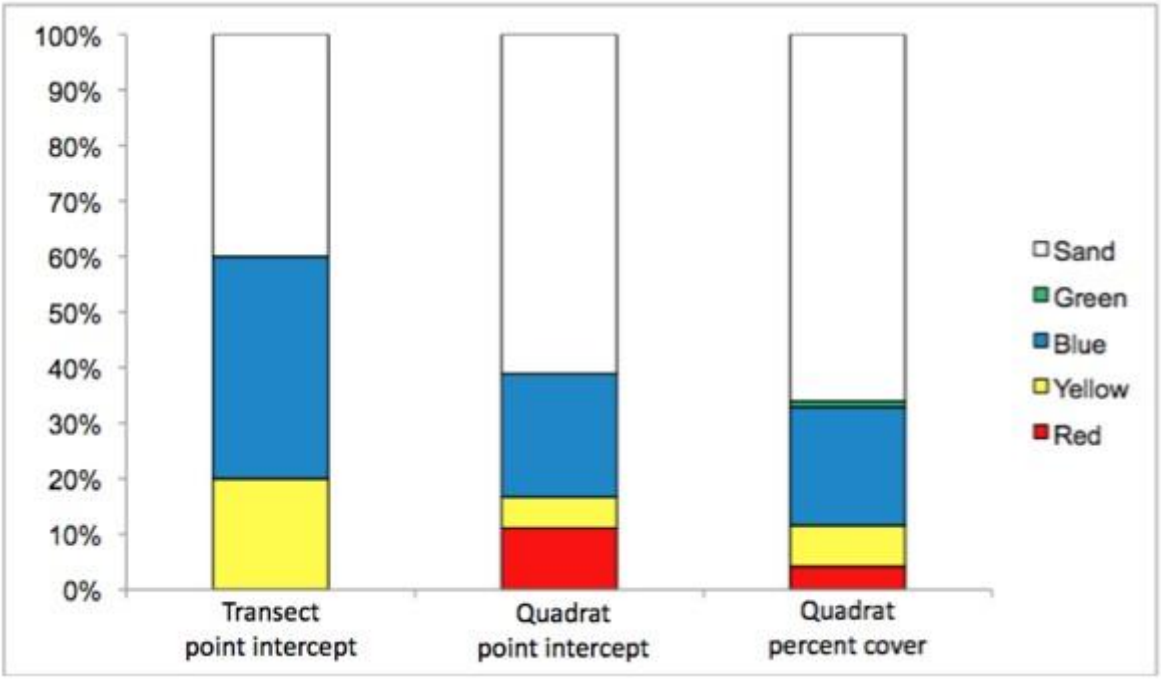
***29. The graph directly above is a:**

- scatter plot.
- scatter plot with trendline.
- time series graph.
- line graph.

***30. You have a grant to identify as many species as you can that live on a newly discovered hydrothermal vent. You spend a week identifying organisms and surveying the area with a remote operated vehicle (ROV). Of the following, which would best communicate your data?**

- descriptive statistics
- descriptive text
- a graph
- raw data

Use the graph directly below to answer Question 31.



***31. The above graph shows the results of three different methods of measuring the percent cover of several species (green, blue, yellow, and red) and of the sand substrate of one area. What can you conclude from the graph?**

- The transect point intercept method is inferior to the other methods.
- The quadrat percent cover method captured the most species in the area.
- You can calculate the true percent cover of the blue species by averaging percent covers across methods.
- The quadrat percent cover method is the most accurate for determining percent cover.

***32. Plankton are scientifically described by all of the following *except*:**

- size.
- life history.
- trophic level.
- locomotion.

***33. _____ are plankton that spend their entire life drifting.**

- Phytoplankton
- Zooplankton
- Holoplankton
- Meroplankton

***34. Plankton can have several adaptations to slow their sinking rate. An adaptation that plankton do *not* have is:**

- flattened bodies.
- spiny projections.
- oil filled structures.
- density less than water.

POST WORKSHOP QUESTIONNAIRE

(This questionnaire was repeated after each of the four modules.)

Curriculum Research & Development Group (CRDG)

Post Workshop Questionnaire

We would like to know about your thoughts and reflections of the TSI Aquatic workshop. Since we are striving to deliver an educational yet enjoyable PD experience, your feedback is crucial in letting us know what things seems to be working and what things we still need to improve. Please take a moment to complete this questionnaire. Thank you for providing us with this important information!

TSI Aquatic Research Team

1. Select the response for each item (ranging from strongly disagree to strongly agree) that best represents your opinion. Note that some of the items are stated in the negative. All responses are anonymous.

	Strongly disagree	Somewhat disagree	Slightly disagree	Slightly agree	Somewhat agree	Strongly agree
The institute provided adequate feedback and coaching.	○	○	○	○	○	○
The institute included applicable theory.	○	○	○	○	○	○
The institute did *not* include helpful demonstrations.	○	○	○	○	○	○
The institute included opportunities for practice.	○	○	○	○	○	○
The goals and objectives of this institute module were clearly stated.	○	○	○	○	○	○
The institute's learning climate was respectful.	○	○	○	○	○	○
The institute improved my capability to provide challenging aquatic science classes.	○	○	○	○	○	○
The institute improved my capability to provide developmentally appropriate introductory aquatic science instruction.	○	○	○	○	○	○
The institute included helpful demonstrations of teaching science as inquiry.	○	○	○	○	○	○
The institute did *not* deepen my subject-matter knowledge.	○	○	○	○	○	○
The institute deepened my pedagogical knowledge.	○	○	○	○	○	○
Sufficient time was provided for completing tasks during the institute.	○	○	○	○	○	○
The institute instructors were knowledgeable and helpful.	○	○	○	○	○	○
The institute activities were *not* well organized.	○	○	○	○	○	○
The institute's professional practice reflections provided adequate time for discussion and reflection.	○	○	○	○	○	○
New practices were modeled well and thoroughly explained.	○	○	○	○	○	○
The institute adequately modeled the Phases of Inquiry (i.e., Initiation, Invention, Investigation, Interpretation, and Instruction).	○	○	○	○	○	○
The institute adequately modeled the Modes of Inquiry used in the PD (e.g., deduction, induction, curiosity, replication).	○	○	○	○	○	○
I was encouraged to try new practices or strategies.	○	○	○	○	○	○
The institute provided content and pedagogy that will be useful in the classroom.	○	○	○	○	○	○
The institute content and pedagogy were *difficult* to grasp.	○	○	○	○	○	○

TSI-A POST WORKSHOP QUESTIONNAIRE

2. What did you learn from this workshop?

3. What do you still want to learn?

4. What were the murkiest points?

TEACHER REFLECTION

(This questionnaire was repeated after each of the four modules and modified for appropriate content.)

Joanna Philippoff, Kanesa Duncan Seraphin, and Brian E. Lawton

Teacher Reflection

Module 4: Ecological

Sampling Design Target Activity

The purpose of the TSI lesson reflection is to help you reflect on your implementation of this activity and to collect information about how you conducted the activity. Please have your lesson plan and the Exploring Our Fluid Earth (EOFE) activity with you when completing this reflection to help you answer the items.

In addition to allowing you to reflect on this lesson, the TSI lesson reflection allows us to see how closely teachers are following the EOFE curriculum. We will use this information for possible modifications to the professional development and curriculum and for reporting project implementation to the funding agency.

Be assured that there are no right or wrong responses.

The items below that you have to complete are shown with asterisks. Others are optional. Please answer all the items in one sitting. After you have submitted your answers, you will not be able to return to this reflection.

Thank you for your time.
TSI Aquatic Research Team

***1. Enter your *first* name:**

***2. Enter your *last* name:**

***3. You are required to implement three activities from this module in your classroom. This activity was the _____ you implemented in this module.**

- First activity
- Second activity
- Third activity

Activity Implementation

*4. To what extent did you have your students follow the Exploring Our Fluid Earth (EOFE) procedures for this activity?

Not at all	A little	Somewhat	Mostly	Fully
(1)	(2)	(3)	(4)	(5)
○	○	○	○	○

Optional. Please explain your answer.

*5. For what reasons, if any, did you have to modify any part of the activity's procedures? (Check all that apply.)

- ☐ No modifications made
- ☐ Age of students
- ☐ Number of students
- ☐ Classroom constraints
- ☐ Class time
- ☐ Student characteristics (SPED, etc.)
- ☐ Management issues
- ☐ Supplies
- ☐ Other

If you modified the activity, briefly explain how you modified the procedures for your class:

*6. How many class periods did this activity require?

Enter the number of class periods here:

*7. How did you incorporate this activity into your curriculum?

- Used this TSI activity instead of a different lesson or activity that covered similar concepts (e.g. you swapped in this TSI activity for a different activity in your curriculum)
- Implemented this TSI activity as a "fun" activity (e.g. before a holiday or weekend)
- Built a new lesson progression around this TSI activity
- Used this activity in the same lesson progression presented in the workshop
- Other

Please explain your answer.

*8. Which activity questions did you have your students address? (Check all that apply.)

- [ ] 1. What did you learn about the composition of the bag by collecting data on your individual sample?
- [ ] 2. What did you learn about the composition of the bag by compiling and averaging class data?
- [ ] 3. How did your individual data, the first three points of class data, and the entire set of class data compare? Explain.
- [ ] 4. Ask your teacher to share the known proportion of each color of object in the bag. How did the averaged class data proportion of colors compare to the known proportion of colors? Explain why you think this occurred.
- [ ] 5. What would result in your sample data if you picked your favorite colors out of the bag when sampling?
- [ ] 6. What situations in nature might cause individual samples not to reflect the larger area?
- [ ] 7. What would happen to your sample data if there were just one or two objects of a particular color in the bag?
- [ ] 8. Read Practices of Science: Scientific Error. a) What are the sources of error in this sampling activity? b) How well do you think your sampling procedure controlled for bias? Explain.

*9. To what extent did you connect the activity to the ocean (as you described in #7 of your TSI lesson plan)?

Not at all (1)	(2)	(3)	(4)	A lot (5)	N/A
○	○	○	○	○	○

Optional. Please explain your answer, especially if you connected the activity to the ocean in a different way than you planned.

*10. To what extent do you think connecting the activity to the ocean helped engage your students?

Not at all helpful (1)	(2)	(3)	(4)	Very helpful (5)	N/A
○	○	○	○	○	○

Optional. Please explain your answer.

***11. Overall, how much do you think this activity helped improve *your students'* science content knowledge?**

Not at all (1)	(2)	(3)	(4)	Very much (5)	Not sure
○	○	○	○	○	○

Optional: What is the evidence for your answer?

***12. To what extent did you read the teacher text for this activity?**

Not at all (1)	A little (2)	Somewhat (3)	Mostly (4)	Fully (5)
○	○	○	○	○

Optional. Please explain your answer.

***13. To what extent did you use the PDF slides from the workshop for this activity?**

Not at all (1)	A little (2)	Somewhat (3)	Mostly (4)	Fully (5)
○	○	○	○	○

Optional. Please explain your answer.

14. *Optional:* If you taught this activity to more classes than your focus class, please tell us how many other classes and their grade levels and subject areas.

Use of Inquiry

***15. How *successful* do you think the process of planning using TSI was in improving your understanding of TSI?**

Not useful (1)	(2)	(3)	(4)	Very useful (5)
○	○	○	○	○

Optional: Please explain your answer

***16. To what extent did you explicitly address the components of TSI with your students during this activity (this includes simply using the phases or mode words with your students when teaching the activity).**

	Not at all (1)	(2)	(3)	(4)	Very much (5)
Phases of Inquiry	☐	☐	☐	☐	☐
Modes of Inquiry	☐	☐	☐	☐	☐
Demeanors of scientists	☐	☐	☐	☐	☐
Practices of scientists	☐	☐	☐	☐	☐
Metacognition	☐	☐	☐	☐	☐

Optional. Please explain your answer.

***17. Overall, how *successful* do you think you were in carrying out your planned TSI inquiry questioning strategies for this activity?**

Not successful (1)	(2)	(3)	(4)	Very successful (5)
○	○	○	○	○

Optional. Please explain your answer.

***18. Overall, how *useful* do you think your questioning strategies were in helping you guide your students through the TSI phases and assessing their progress?**

Not useful (1)	(2)	(3)	(4)	Very useful (5)
○	○	○	○	○

Optional. Please explain your answer.

***19. Overall, how *successful* do you think you were in implementng your planned *assessment strategies* for this activity?**

Poorly (1)	(2)	(3)	(4)	Very well (5)	Not sure
○	○	○	○	○	○

Optional. Please explain your answer.

***20. Overall, how *useful* do you think planning which TSI Practices of Inquiry Teaching strategies you would focus on helped you meet your learning goals?**

Poorly (1)	(2)	(3)	(4)	Very well (5)	Not sure
○	○	○	○	○	○

Optional. Please explain your answer.

***21. To what extent has implementing this activity enhanced *your* understanding of teaching science as inquiry?**

Not at all (1)	(2)	(3)	(4)	Very much (5)	Not sure
○	○	○	○	○	○

Optional: please explain your answer (e.g. did you try something new?)

Effect of Professional Development

*22. Effect of professional development on content knowledge

	No understanding of activty's content (1)	(2)	(3)	(4)	High level of understanding of activity's content (5)
What was your level of understanding of this activity's content *before* the professional development?	○	○	○	○	○
What was your level of understanding of this activity's content *after* the professional development?	○	○	○	○	○
What is your level of understanding of this activity's content *now that you have implemented the activity*?	○	○	○	○	○

*23. Overall, how well do you think the professional development covered the content needed to teach this activity?

Not at all well (1)	(2)	(3)	(4)	Very well (5)
○	○	○	○	○

Other (please specify)

*24. Effect of professional development on confidence

	Not at all confident (1)	(2)	(3)	(4)	Very confident (5)
How confident were you with teaching this content *before* the professional development?	○	○	○	○	○
How confident were you with teaching this content *after* the professional development?	○	○	○	○	○
How confident are you with teaching this content *now that you have implemented the activity?*	○	○	○	○	○

Student Engagement in the Phases of Inquiry

***25. How well do you think you guided your students through the TSI *Phases of Inquiry* for this activity? (Please refer to the descriptions of the phases in your binder if necessary).**

	Poorly (1)	(2)	(3)	(4)	Very well (5)	Not sure	Did not address
Initiation	○	○	○	○	○	○	○
Invention	○	○	○	○	○	○	○
Investigation	○	○	○	○	○	○	○
Interpretation	○	○	○	○	○	○	○
Instruction	○	○	○	○	○	○	○

Optional: please explain your answer.

***26. Estimate about how much *time* your students were engaged in the different Phases of Inquiry. (For example, 10% on Initiation, 0% on Invention, 50% on Investigation, 15% on Interpretation, and 25% on Instruction).**

Remember that there are no right or wrong answers. Sometimes your students may not have been engaged in a phase due to the design of the activity.

***The total amount of time students were engaged across all the phases should add up to 100.* Please enter the phases and corresponding numbers in the following text box *without* the "%" sign.**

For example, your response in the text box might look at follows:

Initiation: 10
Invention: 0
Investigation: 50
Interpretation: 15
Instruction: 25

27. Which Phase of Inquiry did your students engage in the *most*? *(this phase should align with your answer from #25)

- Initiation
- Invention
- Investigation
- Interpretation
- Instruction

Why do you think your students engaged in this phase the most? What might this indicate about their thought processes?

28. What Phase of Inquiry did your students engage in the *least*? *(this phase should align with your answer from #25)

- Initiation
- Invention
- Investigation
- Interpretation
- Instruction

Why do you think your students engaged in this phase the least? What might this indicate about their thought processes?

***29. What might the Phases of Inquiry your students engaged in the most and least indicate about the way *you* planned and implemented the activity?**

30. What could you have done differently during the activity (in planning or implementation) to guide your students more effectively through the phases of inquiry? *(this question is asking about your planning and implementation, not if you used the phase words with your students).*

Student Engagement in the Modes of Inquiry

***31. How well do you think you guided your students through the TSI *Modes of Inquiry* for this activity? (Please refer to the descriptions of the modes in your binder if necessary).**

	Poorly (1)	(2)	(3)	(4)	Very well (5)	Not sure	Did not address
Curiosity	○	○	○	○	○	○	○
Description	○	○	○	○	○	○	○
Authoritative knowledge	○	○	○	○	○	○	○
Experimentation	○	○	○	○	○	○	○
Product evaluation	○	○	○	○	○	○	○
Technology	○	○	○	○	○	○	○
Replication	○	○	○	○	○	○	○
Induction	○	○	○	○	○	○	○
Deduction	○	○	○	○	○	○	○
Transitive knowledge	○	○	○	○	○	○	○

Optional: please explain your answer.

***32. Reflecting on your activity, what were the *overarching mode(s)* that your students engaged in? (Check all that apply)**

Note that the modes your students engaged in may not be the same ones you planned for.

- ☐ Curiosity
- ☐ Description
- ☐ Authoritative Knowledge
- ☐ Experimentation
- ☐ Product Evaluation
- ☐ Technology
- ☐ Replication
- ☐ Induction
- ☐ Deduction
- ☐ Transitive Knowledge

Explain how your students engaged in these mode(s) the most, especially if the modes that occurred during the activity were different that the modes you planned to implement. What might this indicate about your students thought processes?

***33. Think about the mode(s) that your students engaged in the most. What might this mode or modes indicate about the way *you* planned and implemented the activity?**

34. What could you have done during the activity to engage your students more effectively in the Modes of Inquiry or to bring more modes into the activity?** ***(This question is asking about your planning and implementation, not if you used the mode words with your students).

Final Comments

***35. Would you do this activity again?**

- ○ Yes
- ○ No

If yes: what, if anything, would you change?

36. Please provide any additional comments about your experience with this activity. For example, were there any unexpected or unintended consequences?

Please go to the EOFE website to share any suggestions, recommendations, or advice for other teachers doing this activity. EOFE website http://tsi.dcdcgroup.org/

POST-COHORT QUESTIONNAIRE

Curriculum Research & Development Group (CRDG)

Post-Cohort Questionnaire

Spring 2013

The purpose of this questionnaire is to find out about your experience in the project. We will use the results to learn about your opinions about several aspects of the TSI Aquatic project and about how fully you implemented aspects of TSI in the classroom. The results will help us modify the project and provide findings for us to report to the project funders.

This questionnaire will take about 30 minutes to complete. Please carefully read each question. ***You will need to submit all of your answers in one sitting.***

Thanks!
TSI Aquatic Research Team

Part 1.

These questions ask about the value and relevance of aspects of the TSI PD series. For each item, select the response (ranging from *Not true at all* to *Completely true*) that best represents your opinion.

	Not true at all (1)	(2)	(3)	(4)	(5)	Completely true (6)
1. The ***TSI PD series as a whole*** was valuable for my teaching practice.	○	○	○	○	○	○
2. The ***workshops*** were valuable for my teaching practice.	○	○	○	○	○	○
3. The ***in-person follow-ups*** were valuable for my teaching practice.	○	○	○	○	○	○
4. The ***online Blackboard sessions*** were valuable for my teaching practice.	○	○	○	○	○	○
5. The ***website*** was valuable for my teaching practice.	○	○	○	○	○	○
6. The TSI ***approach*** to teaching science as inquiry was valuable for my teaching practice.	○	○	○	○	○	○
7. The training in the inquiry ***phases*** was valuable for my teaching practice.	○	○	○	○	○	○
8. The training in the inquiry ***modes*** was valuable for my teaching practice.	○	○	○	○	○	○
9. I will ***continue to use*** what I learned in the TSI PD series.	○	○	○	○	○	○
10. The TSI PD series provided science ***content that was relevant*** to my teaching context.	○	○	○	○	○	○
11. The TSI ***pedagogical approaches were relevant*** to my teaching context.	○	○	○	○	○	○

Part 2.

These questions ask about the effect of the TSI PD series on your focus class and on your teaching. For each item, select the response (ranging from *Not true at all* to *Completely true*) that best represents your opinion.

	Not true at all (1)	(2)	(3)	(4)	(5)	Completely true (6)
12. The TSI PD series helped me to improve my teaching practice.	○	○	○	○	○	○
13. The target activities engaged the students in my focus class.	○	○	○	○	○	○
14. The target activities of Module 1 (physical) were successful in my focus class.	○	○	○	○	○	○
15. The target activities of Module 2 (chemical) were successful in my focus class.	○	○	○	○	○	○
16. The target activities of Module 3 (biological) were successful in my focus class.	○	○	○	○	○	○
17. The target activities of Module 4 (ecological) were successful in my focus class.	○	○	○	○	○	○
18. The target activities of Module 1 (physical) helped me to teach inquiry-based science.	○	○	○	○	○	○
19. The target activities of Module 2 (chemical) helped me to teach inquiry-based science.	○	○	○	○	○	○
20. The target activities of Module 3 (biological) helped me to teach inquiry-based science.	○	○	○	○	○	○
21. The target activities of Module 4 (ecological) helped me to teach inquiry-based science.	○	○	○	○	○	○
22. The TSI PD series met my expectations of learning how to teach inquiry-based science.	○	○	○	○	○	○

Part 3.

How comfortable were you in implementing each of the following TSI activities *with your focus class*? For each, select a response, ranging from *Not comfortable at all* to *Very comfortable*.

	Not comfortable at all (1)	(2)	(3)	(4)	(5)	Very comfortable (6)
23. Teaching aquatic science content	○	○	○	○	○	○
24. Implementing the Module 1 (physical) target activities	○	○	○	○	○	○
25. Implementing the Module 2 (chemical) target activities	○	○	○	○	○	○
26. Implementing the Module 3 (biological) target activities	○	○	○	○	○	○
27. Implementing the Module 4 (ecological) target activities	○	○	○	○	○	○
28. Using a variety of ***modes*** of inquiry	○	○	○	○	○	○
29. Guiding students through the ***phases*** of inquiry	○	○	○	○	○	○

Part 4.

Please consider the focus-class students that have been in your class since you started the TSI PD. Give your best estimate of your focus-class students as they are now, at the end of the project, in each of the following:

	Very low comfort level (1)	(2)	(3)	(4)	(5)	Very high comfort level (6)
30. My students' comfort level in thinking like a scientist	○	○	○	○	○	○
31. My students' comfort level in participating in inquiry-based science	○	○	○	○	○	○

	Not interested at all (1)	(2)	(3)	(4)	(5)	Very interested (6)
32. My students' interest in science	○	○	○	○	○	○

	Very little belief in relevance (1)	(2)	(3)	(4)	(5)	Strong belief in relevance (6)
33. My students' beliefs about the relevance of science to their daily lives	○	○	○	○	○	○

	Very negative (1)	(2)	(3)	(4)	(5)	Very positive (6)
34. My students' attitudes toward science	○	○	○	○	○	○

Part 5.

To what extent did you implement all the steps of the target activities in each of the following modules? For each, select a response, ranging from *Not at all* to *Completely*.

	Not at all (1)	(2)	(3)	(4)	(5)	Completely (6)
35. Module 1 (physical)	○	○	○	○	○	○
36. Module 2 (chemical)	○	○	○	○	○	○
37. Module 3 (biological)	○	○	○	○	○	○
38. Module 4 (ecological)	○	○	○	○	○	○

Information for Part 6.

The next set of the questions asks about the modes of inquiry. Here are the modes and their descriptions.

Curiosity: The search for new knowledge in external environments through informal or spontaneous probes into the unknown or predictable

Description: The search for new knowledge through creation of accurate and adequate representation of things or events

Authoritative Knowledge: The search for new knowledge through discovery and evaluation of established knowledge via artifacts or expert testimony

Experimentation: The search for new knowledge through testing predictions derived from hypotheses

Product Evaluation: The search for new knowledge about the capacity of products of technology to meet valuing criteria

Technology: The search for new knowledge in satisfaction of a need through construction, production and testing of artifacts, systems, and techniques

Replication: The search for new knowledge by validating inquiry through duplication; testing the repeatability of something seen or described

Induction: The search for new knowledge in data patterns and generalizable relationships in data association – a hypothesis finding process

Deduction: The search for new knowledge in logical synthesis of ideas and evidence – a hypothesis making process

Transitive knowledge: The search for new knowledge in one field by applying knowledge from another field in a novel way

Part 6.

How often did you include this mode in your instruction with your focus class?

	Not at all (1)	A few times (2)	About once a month (3)	Two or three times a month (4)	About once a week (5)	More than once a week (6)
39. Curiosity	○	○	○	○	○	○
40. Description	○	○	○	○	○	○
41. Authoritative knowledge	○	○	○	○	○	○
42. Experimentation	○	○	○	○	○	○
43. Product Evaluation	○	○	○	○	○	○
44. Technology	○	○	○	○	○	○
45. Replication	○	○	○	○	○	○
46. Induction	○	○	○	○	○	○
47. Deduction	○	○	○	○	○	○
48. Transitive knowledge	○	○	○	○	○	○

Information for Part 7.

These descriptions of the modes are here for your convenience in answering the questions in Part 7. These descriptions are the same as those shown on the previous page.

Curiosity: The search for new knowledge in external environments through informal or spontaneous probes into the unknown or predictable

Description: The search for new knowledge through creation of accurate and adequate representation of things or events

Authoritative Knowledge: The search for new knowledge through discovery and evaluation of established knowledge via artifacts or expert testimony

Experimentation: The search for new knowledge through testing predictions derived from hypotheses

Product Evaluation: The search for new knowledge about the capacity of products of technology to meet valuing criteria

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Deduction: The search for new knowledge in logical synthesis of ideas and evidence – a hypothesis making process

Transitive knowledge: The search for new knowledge in one field by applying knowledge from another field in a novel way

Part 7.

To what degree do you value this mode in your instruction?

	Do not value at all (1)	(2)	(3)	(4)	(5)	Value very highly (6)
49. Curiosity	○	○	○	○	○	○
50. Description	○	○	○	○	○	○
51. Authoritative knowledge	○	○	○	○	○	○
52. Experimentation	○	○	○	○	○	○
53. Product Evaluation	○	○	○	○	○	○
54. Technology	○	○	○	○	○	○
55. Replication	○	○	○	○	○	○
56. Induction	○	○	○	○	○	○
57. Deduction	○	○	○	○	○	○
58. Transitive knowledge	○	○	○	○	○	○

Information for Part 8.

These descriptions of the modes are here for your convenience in answering the questions in Part 8. These descriptions are the same as those shown on the previous page.

Curiosity: The search for new knowledge in external environments through informal or spontaneous probes into the unknown or predictable

Description: The search for new knowledge through creation of accurate and adequate representation of things or events

Authoritative Knowledge: The search for new knowledge through discovery and evaluation of established knowledge via artifacts or expert testimony

Experimentation: The search for new knowledge through testing predictions derived from hypotheses

Product Evaluation: The search for new knowledge about the capacity of products of technology to meet valuing criteria

Technology: The search for new knowledge in satisfaction of a need through construction, production and testing of artifacts, systems, and techniques

Replication: The search for new knowledge by validating inquiry through duplication; testing the repeatability of something seen or described

Induction: The search for new knowledge in data patterns and generalizable relationships in data association – a hypothesis finding process

Deduction: The search for new knowledge in logical synthesis of ideas and evidence – a hypothesis making process

Transitive knowledge: The search for new knowledge in one field by applying knowledge from another field in a novel way

Part 8.

How comfortable are you in using each of the following modes in your instruction *now that you have completed all four modules* ?

	Not comfortable at all (1)	(2)	(3)	(4)	(5)	Very comfortable (6)
59. Curiosity	○	○	○	○	○	○
60. Description	○	○	○	○	○	○
61. Authoritative knowledge	○	○	○	○	○	○
62. Experimentation	○	○	○	○	○	○
63. Product Evaluation	○	○	○	○	○	○
64. Technology	○	○	○	○	○	○
65. Replication	○	○	○	○	○	○
66. Induction	○	○	○	○	○	○
67. Deduction	○	○	○	○	○	○
68. Transitive knowledge	○	○	○	○	○	○

Information for Part 9.

These descriptions of the modes are here for your convenience in answering the questions in Part 9. These descriptions are the same as those shown on the previous page.

Curiosity: The search for new knowledge in external environments through informal or spontaneous probes into the unknown or predictable

Description: The search for new knowledge through creation of accurate and adequate representation of things or events

Authoritative Knowledge: The search for new knowledge through discovery and evaluation of established knowledge via artifacts or expert testimony

Experimentation: The search for new knowledge through testing predictions derived from hypotheses

Product Evaluation: The search for new knowledge about the capacity of products of technology to meet valuing criteria

Technology: The search for new knowledge in satisfaction of a need through construction, production and testing of artifacts, systems, and techniques

Replication: The search for new knowledge by validating inquiry through duplication; testing the repeatability of something seen or described

Induction: The search for new knowledge in data patterns and generalizable relationships in data association – a hypothesis finding process

Deduction: The search for new knowledge in logical synthesis of ideas and evidence – a hypothesis making process

Transitive knowledge: The search for new knowledge in one field by applying knowledge from another field in a novel way

Part 9.

How comfortable *were* you in using each of the following modes in your instruction ***before*** *you participated in the PD*?

	Not comfortable at all (1)	(2)	(3)	(4)	(5)	Very comfortable (6)
69. Curiosity	○	○	○	○	○	○
70. Description	○	○	○	○	○	○
71. Authoritative knowledge	○	○	○	○	○	○
72. Experimentation	○	○	○	○	○	○
73. Product Evaluation	○	○	○	○	○	○
74. Technology	○	○	○	○	○	○
75. Replication	○	○	○	○	○	○
76. Induction	○	○	○	○	○	○
77. Deduction	○	○	○	○	○	○
78. Transitive knowledge	○	○	○	○	○	○

Part 10.

To what extent were each of the following TSI toolbox components useful in helping you teach science as inquiry?

	Not useful (1)	(2)	(3)	(4)	(5)	Very useful (6)
79. Metacognition	○	○	○	○	○	○
80. Themes (e.g., classroom as a scientific community, modeling science)	○	○	○	○	○	○
81. Science as a discipline	○	○	○	○	○	○
82. Scientific demeanors	○	○	○	○	○	○
83. Practices of scientists	○	○	○	○	○	○
84. Questioning strategies	○	○	○	○	○	○
85. Teacher as research director	○	○	○	○	○	○

Part 11.

How often will you *use* each of the following TSI toolbox components with your future students?

	Never (1)	(2)	(3)	(4)	(5)	Very frequently (6)
86. Metacognition	○	○	○	○	○	○
87. Themes (e.g., classroom as a scientific community, modeling science)	○	○	○	○	○	○
88. Science as a discipline	○	○	○	○	○	○
89. Scientific demeanors	○	○	○	○	○	○
90. Practices of scientists	○	○	○	○	○	○
91. Questioning strategies	○	○	○	○	○	○
92. Teacher as research director	○	○	○	○	○	○

Part 12.

How frequently will you use the TSI phases in your future instruction to do each of the following?

	Never (1)	(2)	(3)	(4)	(5)	Very frequently (6)
93. Plan classroom activities	○	○	○	○	○	○
94. Reflect on classroom activities	○	○	○	○	○	○
95. Demonstrate to your students that the scientific process is nonlinear	○	○	○	○	○	○

Part 13.

96. How familiar are you with the Ocean Literacy Principles?

Not at all familiar (1)	(2)	(3)	(4)	Very familiar (5)
○	○	○	○	○

Part 14.

To what extent did each of these PD requirements help you improve your understanding of inquiry?

	Not at all (1)	(2)	(3)	(4)	(5)	Very much (6)
97. Implementation of TSI activities	○	○	○	○	○	○
98. Preparation of Blackboard presentations	○	○	○	○	○	○
99. Completion of TSI lesson plans and reflections	○	○	○	○	○	○
100. Completion of post-module surveys	○	○	○	○	○	○

—Thank you!—

Click "Done" to submit your responses

POST-COHORT INTERVIEW GUIDE

Lisa M. Vallin, George M. Harrison, Brian E. Lawton, and Paul R. Brandon

Post-Cohort Interview Guide

1. ***Before the interview***
    a. Log onto the TSI Blackboard virtual office and make sure the note taker logs on as well.
        1) Set the maximum cameras and audio functions to three (interviewee, interviewer and note-taker).
        2) Upload the interview script presentation, and make sure all of the questions are in order.
        3) Set the slide presentation to the welcome page.
    b. Send the Blackboard guest URL link to the teacher via email 10-15 minutes before the interview is scheduled to being.
        1) Once the teacher has logged on spend a few minutes making sure that any technical issues are resolved before the interview beings.
        2) The interviews will collect information about the participant's experiences in the professional development project and teaching science as inquiry
            a) Inform the teacher that although there are a lot of questions regarding the use and understanding of teaching science as inquiry, the purpose of the interview it is not to evaluate the teacher's performance or understandings of teaching science as inquiry.
    c. Confidentiality
        1) Tell the teacher that the interview is confidential, and that the original data from the interview will only be shared by members of the research team. After the data have been analyzed and any identifying characteristics have been removed, the findings will be shared with the members of the project team.
    d. Conducting the interview
        1) Follow the interview script as closely as possible.
    f. If you find ways of improving the interview questions, record these in writing and meet with the research team to discuss the improvements before conducting the next interview.
    g. At the beginning of the interview
        1) Begin the interview by establishing rapport with the interviewee.
            a) Spend a few minutes on introductions and remind them the interview is confidential and is not an evaluation of their use and understanding of teaching science as inquiry.
            b) Ask if the participant has any questions before the interview begins.

Interview Script

Thank you for taking the time to do this interview. We appreciate it. As you know, I am here to gather some information from you about your experiences with the TSI Aquatic professional development project. The topics we will address include:

1. your overall experience with the TSI Aquatic PD,
2. the value and relevance of the TSI Aquatic PD to your ongoing teaching practice, and
3. the implementation and future use of the TSI Aquatic curriculum and pedagogy.

We want to emphasize that the purpose of this interview is ***not*** to evaluate you, but to gather information and gain understanding of the value and use of the TSI Aquatic PD.

We are videoing and voice recording this interview so that we maintain accuracy of what you say. No one will hear this interview except for the people on the TSI research team. Neither Kanesa, Joanna, or any of the other project team members will hear this interview. And of course all your answers to my questions today, as well as the other information that we collect about you, will be reported anonymously.

1. Your overall experience of the TSI Aquatic PD

a. I'd like to ask a few questions about your overall experience of the TSI Aquatic professional development.
   1) What do you think about the way the PD was structured, a year-long PD with four modules containing the workshops, follow-ups, and Blackboard sessions?
   2) What do you think about the Online Learning Community, including the online interactions, the sharing etc.?
   3) What can you say about the TSI Aquatic content; in other words, the physical, chemical, biological, and ecological content?
   4) What did you think about the TSI pedagogy, including the phases and modes of inquiry?
   5) Can you give us any feedback about the research instruments, such as the teacher logs, student questionnaires, PD questionnaires, assessments about your content knowledge, and assessments about your understanding of inquiry?

2. The value and relevance of the TSI Aquatic PD to your ongoing teaching practice

a. Now I want to ask you about the value and relevance of the TSI Aquatic PD to your teaching practices.
   1) On a scale from 1 to 10, where 1 is not at all valuable and 10 is very valuable, how *valuable* has the TSI Aquatic PD been to your practice, and can you explain your rating?
   2) And, on a scale from 1 to 10, how *relevant* has the TSI Aquatic PD been to your practice, and can you explain your rating?
   3) Please describe any experiences you have had or any lessons you have learned that reflect the value and relevance of the TSI PD to your practice?

4) To what extent, if any, have you been able to transfer and apply what you learned in the TSI-PD to your other, non-TSI, classroom activities? What features of the TSI curriculum and pedagogy, if any, have been transferable?

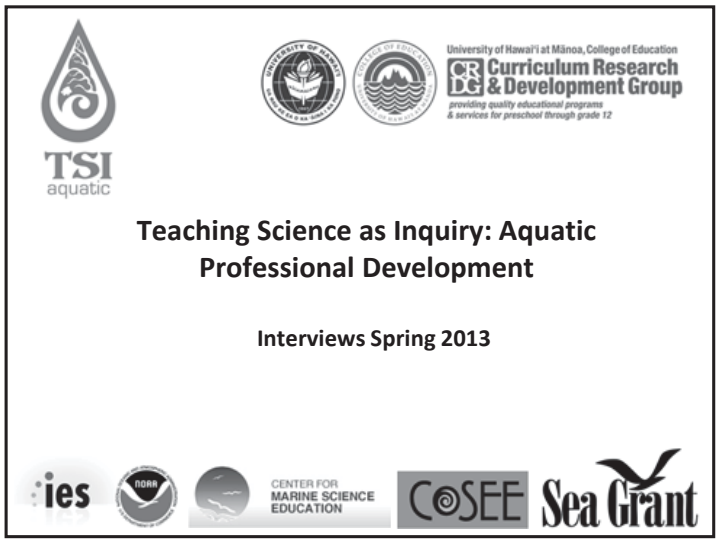
3. Implementation and future use of the TSI Aquatic curriculum and pedagogy

a. Now think about your experience in implementing the TSI Aquatic curriculum and pedagogical strategies in your classes. To what degree do you believe you were able to successfully implement the TSI Aquatic curriculum and pedagogy?
   1) Please describe any experiences that stand out or any lessons you have learned?
   2) What classroom and contextual features hindered or helped the implementation?
   3) What has been your experience with implementing TSI Aquatic in the context of your school—for example, its curriculum, administration, grade-level demands, and so forth?
   4) Now please describe the struggles or challenges, if any, that you experienced? What did you do to deal with or adapt to these challenges? Do you have any recommendations for overcoming these implementation barriers?
   5) Were there any unexpected consequences for you, positive or negative, from participating in the TSI Aquatic project?
   6) Will you be using TSI in your future teaching? Why or why not.
   7) Would you recommend this PD to a colleague? Why or why not.

4. Do you have any questions for me or any final comments/anything you would like to add to the interview?

a. Thank you very much for your time and your insights!

Interview Questions Presented to the Teachers as Slides in Blackboard Collaborate



TSI Interview:
Introduction

- Anonymous, confidential, only will be shared with research team.
- Not an evaluation of you.
- Your chance to be forthright and honest about your experiences.

TSI Interview:
Overall Experience with the TSI PD

- What do you think about the way the PD was *structured*? That is, a year-long PD with four modules containing the
  - workshops,
  - follow-ups,
  - blackboard sessions, and
  - Website

TSI Interview:
Overall Experience with the TSI PD (cont'd.)

- What can you say about the TSI content?
  - physical,
  - chemical,
  - biological, and
  - ecological

TSI Interview:
Overall Experience with the TSI PD (cont'd.)

- What did you think about the TSI pedagogy?
  - Phases of inquiry
  - Modes of inquiry
  - Demeanors
  - Practices
  - Metacognition
  - TSI questioning strategies
  - TSI practices of inquiry teaching

TSI Interview:
Overall Experience with the TSI PD (cont'd.)

- Please provide feedback about the research instruments:
  - activity reflections, lesson plans, & implementation checklist;
  - student questionnaires;
  - PD questionnaires;
  - assessments about your content knowledge; and
  - assessments about your understanding of inquiry
  - in-class observations

TSI Interview:
The Value and Relevance of the TSI PD to Your Ongoing Teaching Practice

How would you rate how ***valuable*** the TSI PD has been to your teaching practice?

Not at all valuable									Very valuable
1	2	3	4	5	6	7	8	9	10

- Please explain your rating.
  - your experiences
  - lessons learned

TSI Interview:
The Value and Relevance of the TSI PD to Your Ongoing Teaching Practice (cont'd)

How would you rate how ***relevant*** the TSI PD has been to your teaching practice?

Not at all relevant									Very relevant
1	2	3	4	5	6	7	8	9	10

- Please explain your rating.
  - your experiences
  - lessons learned

TSI Interview:
The Value and Relevance of the TSI PD to Your Ongoing Teaching Practice (cont'd.)

- To what extent, if any, have you been able to transfer and apply the TSI content and pedagogy to your other, non-TSI, classroom activities?
- Please describe how you have transferred and applied TSI to other classroom activities.

TSI Interview:
Implementation and Future Use of the TSI Content and Pedagogy

How would you rate how ***successful*** you were in implementing the TSI ***content***?

Not at all successful									Very successful
1	2	3	4	5	6	7	8	9	10

- Please explain your rating.
  - your experiences
  - lessons learned

TSI Interview:
Implementation and Future Use of the TSI Content and Pedagogy (cont'd.)

How would you rate how ***successful*** you were in implementing the TSI ***pedagogy***?

Not at all successful									Very successful
1	2	3	4	5	6	7	8	9	10

- Please explain your rating.
  - your experiences
  - lessons learned

TSI Interview:
Implementation and Future Use of the TSI Content and Pedagogy

How would you rate how ***successful*** you were in implementing the m&m sampling design activity (thinking about content and pedagogy)?

Not at all successful									Very successful
1	2	3	4	5	6	7	8	9	10

Please explain your rating.

If you were to do it again, would you do it the same?

TSI Interview:
Implementation and Future Use of the TSI content and Pedagogy (cont'd.)

- What has been your experience with implementing TSI in the context of your school?
  - school's curriculum,
  - administration,
  - grade-level demands, and
  - so forth…

TSI Interview:
Implementation and Future Use of the TSI content and Pedagogy (cont'd.)

- Please describe the struggles and/or challenges , if any, that you experienced with TSI?
- How did you deal with, or adapt to, these challenges?
- Do you have any recommendations for others that might face similar challenges?

TSI Interview:
Implementation and Future Use of the TSI content and Pedagogy (cont'd.)

- Were there any unintended or unexpected consequences for you from participating in the TSI project?
  - Positive?
  - Negative?

TSI Interview:
Implementation and Future Use of the TSI content and Pedagogy (cont'd.)

To what extent did the TSI PD series **meet your expectations** of teaching inquiry-based science?

Not at all									Very much
1	2	3	4	5	6	7	8	9	10

Please explain your rating.

TSI Interview:
Implementation and Future Use of the TSI content and Pedagogy (cont'd.)

To what extent did the TSI PD series **affect your understanding** of inquiry-based science?

Not at all									Very much
1	2	3	4	5	6	7	8	9	10

Please explain your rating.

TSI Interview:
Implementation and Future Use of the TSI content and Pedagogy (cont'd.)

To what extent did the TSI PD *target activities* (e.g., electrolysis) **help you to teach** inquiry-based science?

Not at all									Very much
1	2	3	4	5	6	7	8	9	10

Please explain your rating.

TSI Interview:
Implementation and Future Use of the TSI content and Pedagogy (cont'd.)

- Do you intend to apply what you learned in TSI in your future teaching?
  - Why or why not?
- Effect of supplies?
- Would you recommend the TSI program to a colleague?
  - Why or why not?

TSI Interview:
Parting Comments

Do you have any questions for me or any final comments you would like to make?

Thank you for your time!!!

Please remember to mail us back your headset.

POST-COHORT INTERVIEW WRITTEN RESPONSE ASYNCHRONOUS VERSION

Brian E. Lawton, Lisa M. Vallin, George M. Harrison, and Paul R. Brandon

A product of Curriculum Research & Development Group (CRDG) College of Education, University of Hawai'i at Mānoa

Post-Cohort Interview Written Asynchronous Version

The purpose of this questionnaire is to find out how well the TSI professional development project worked for you. This is *not* to evaluate you in anyway; rather, it is to gain critical understanding of the value and use of the TSI PD series.

The questions will ask for your written responses. The topics that you will be asked about include

a) your overall experience with the TSI PD,
b) the value and relevance of the TSI PD to your ongoing teaching practice, and
c) the implementation and future use of the TSI curriculum and pedagogy.

Your responses will be confidential. That is, the connection between your identity and your responses will only be known by the project researchers and will be kept secret. No one else will have access to what you write here (that is, Kanesa, Joanna, and other project developers will *not* have access). Results that the research team does report (in order to help the project improve) will *not* identify you, and where possible, the research team will aggregate your responses along with the responses from the other teachers.

We highly value your forthright responses so we can provide feedback to the project team about ways they can improve the activities for future participants. Please be honest and do not be afraid to provide critical feedback.

We appreciate your time in filling this out. If you have any questions, please contact us, the research team (George, Lisa, Brian and Paul) at tsistudy@hawaii.edu.

This questionnaire will take about 30 minutes to complete. Please carefully read each question. ***You will need to submit all of your answers in one sitting.***

Sincerely,
TSI Aquatic Research Team

Your overall experience of the TSI-A PD

*1. What do you think about the way the PD was structured?

The PD was structured as a year-long PD with four modules containing the workshops, follow-ups, and Blackboard sessions. You may wish to discuss, among other things, how the structure affected your learning of the PD material; whether there were practical issues with things like timing, time-commitment, curriculum alignment, etc.; and how the structure may have helped or hindered your collaboration with other teachers.

*2. What do you think about the TSI website?

The TSI website included online interactions, sharing of lessons, and other website activities. You may wish to discuss, among other things, the TSI website's applicability to your teaching practice and any difficulties you experienced.

*3. What do you think about the TSI content?

***Content* refers to the physical, chemical, biological, and ecological content components. You may wish to discuss, among other things, the applicability of the TSI content to your teaching practice and any difficulties you experienced.**

*4. What do you think about the TSI pedagogy, including the *phases* and *modes* of inquiry?

The phases are *Initiation, Invention, Investigation, Interpretation and Instruction*. The modes are *Curiosity, Description, Authoritative knowledge, Experimentation, Product Evaluation, Technology, Replication, Induction, Deduction*, and *Transitive knowledge*.

***5. Please provide feedback about the research instruments. That is, what do you think could be changed, if anything?**

These instruments included the lesson plans, lesson reflections, student content surveys, student science questionnaire (SSQ), the questionnaires after the workshops and followups, assessments of your content knowledge, the assessment of your understanding of inquiry, and the questionnaire about your teaching practice.

The value and relevance of the TSI-A PD to your ongoing teaching practice

***6a. How valuable has the TSI PD been for your practice?**

Not at all valuable (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	Very valuable (10)
○	○	○	○	○	○	○	○	○	○

***6b. Please explain your rating in Question 6a.**

***7a. How relevant has the TSI PD been to your teaching practice?**

Not at all relevant (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	Very relevant (10)
○	○	○	○	○	○	○	○	○	○

***7b. Please explain your rating in Question 7a.**

***8. Please describe any experiences you have had or any lessons you have learned that reflect the value and relevance of the TSI PD to your teaching practice.**

***9a. To what extent, if any, have you been able to transfer and apply what you learned in the TSI PD to your other, *non-TSI*, classroom activities?**

9b. Please describe how (if at all) you have transferred and applied TSI to other classroom activities.

Implementation and future use of the TSI-A curriculum and pedagogy

***10a. How would you rate how *successful* you were in implementing the TSI *curriculum*?**

Not at all successful									Very successful
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
○	○	○	○	○	○	○	○	○	○

***10b. Please explain your rating in Question 10a.**

***11a. How would you rate how *successful* you were in implementing the TSI *pedagogy*?**

Not at all successful									Very successful
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
○	○	○	○	○	○	○	○	○	○

***11b. Please explain your rating in Question 11a.**

***12. Please describe any experiences that stand out or any lessons you have learned as a result of implementing the TSI PD.**

***13. What has been your experience with implementing the TSI activities in the context of your school?**

Consider, for example, your school's curriculum, administration, grade-level demands, and so forth.

14a. Please describe the struggles or challenges, if any, that you experienced when implementing the project activities.

14b. What did you do to deal with or adapt to these challenges?

Consider, for example, what suggestions you could give to other TSI teachers.

15. Were there any unintended or unexpected consequences for you (positive or negative), from participating in the TSI project?

***16a. Please rate the extent to which the TSI PD series *met your expectations* of teaching inquiry-based science.**

Not at all (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	Very much (10)
○	○	○	○	○	○	○	○	○	○

***16b. Please explain your rating in Question 16a.**

***17a. Please rate the extent to which the TSI PD series *affected your understanding* of teaching inquiry-based science.**

Not at all (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	Very much (10)
○	○	○	○	○	○	○	○	○	○

***17b. Please explain your rating to Question 17a.**

***18a. Please rate the extent to which the TSI PD series *helped you to teach* inquiry-based science.**

Not at all (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	Very much (10)
○	○	○	○	○	○	○	○	○	○

***18b. Please explain your rating in Question 18a.**

***19a. Do you intend to apply what you learned in TSI in your future teaching?**

- ○ Yes
- ○ No
- ○ Maybe

Please explain why or why not.

***19b. To what extent will your access to supplies contribute to whether you apply TSI in your future teaching?**

***20. Would you recommend the TSI PD series to a colleague?**

- Yes
- No
- Maybe

Please explain why or why not.

Additional Comments

21. Do you have any questions or any final comments about the TSI PD that have not been covered in this questionnaire that you think would help in improving the PD for future participants?

—Thank you!—

Click "Done" to submit your responses

INSTRUCTIONS TO TEACHERS FOR ADMINISTERING THE STUDENT SCIENCE QUESTIONNAIRE

George M. Harrison, Lisa M. Vallin, and Paul R. Brandon

A product of Curriculum Research & Development Group (CRDG) College of Education, University of Hawai'i at Mānoa

Instructions to Teachers for Administering the Student Science Questionnaire
Spring 2013

These are instructions for administering the Student Science Questionnaire to your focus class. To keep this questionnaire secure, please do *not* make copies and please return *all* questionnaires. Additionally, do *not* study these questions and please do *not* use these questions in your instruction. *Before you administer the questionnaires, please read these instructions carefully*.

Complete Numbers 1 through 4 in the box below before administering the questionnaire to your class. Complete Numbers 5 through 10 while you administer the questionnaire.

1. Teacher name *(your name)*:	
2. Your estimate of the achievement level of the class as a whole *(check one)*:	Very low ☐ low ☐ medium ☐ high ☐ very high ☐
3. Grade of the class:	
4. Class period:	
5. Number of students present who have given consent *(those with both sides of the form signed)*:	
6. Number of questionnaires handed out *(should be the same as the number of consenting students)*:	
7. Number of blank questionnaires:	
8. Time the students started the questionnaire:	
9. Time the last student finished the questionnaire:	
10. Number of completed questionnaires *(should be the same number as the number handed out)*:	

When you administer the questionnaire to consenting students, make sure students are seated and that nothing is on their desks except for writing utensils. Ensure everyone has a pen or pencil on their desk.

Open the envelope containing the questionnaires. Before distributing the questionnaires, say the following:

> **This is a questionnaire to find out what you know about science. It will take about 45 minutes to complete. Do not open this until I tell you to do so.**

Each questionnaire has a coversheet with the student's name already printed on it**.** Hand out the questionnaires to ***only*** those students who have returned the consent forms with ***both*** sides of the form signed. Please do ***not*** give the questionnaire to students who have ***not*** given their consent (return these blank questionnaires back to us). Ask the students who do not have questionnaires to do something quietly such as read or study.

After all participating students have their questionnaires and are settled, say

> **Please gently tear the cover sheet off of your questionnaire and leave it on your desk. I will pick up these cover sheets in a minute.**

Make sure everyone has torn off the cover sheet. Then say,

> **There are two parts to this questionnaire. Please answer both parts. Now read the instructions to Part 1 silently while I read them aloud:**
>
> **This is a questionnaire about your knowledge and beliefs about science. You will not be graded on your answers but it is important that you answer each of the questions to the best of your knowledge. For each question, there may be more than one possible answer. *Select the single best answer* and circle the letter for the answer. If you do not know the answer to a question, make your best guess. Be sure to read the whole question and *all* the possible answers.**
>
> **Read the instructions to Parts 2 and 3 on your own when you get there. When you are done, please turn over the questionnaire so it is face down. You may quietly take out something to read or study.**
>
> **Does anyone have any questions?**

Respond to questions. Tell students to begin.

Complete Numbers 5 through 8 in the box above (the number of consenting students, the number of questionnaires you have handed out, the number of blank questionnaires, and the time students started).

Pick up the cover sheets. Place the cover sheets and the blank questionnaires in the envelope provided.

Monitor the class. If students ask what a question means or anything else about the question's content, tell them that you are not supposed to explain anything and that they should give their best answer. Take notes below about any questions students ask that indicate a potentially confusing item.

When all the students are finished, note the time and complete Number 9 in the box.

Collect the questionnaires, count them, and complete Number 10 in the box. Then conclude the questionnaire, saying

Thank you for your help. Your answers will be very useful to the science project.

Notes about any disruptions or unusual events that occurred during the test

Enclose the following in the provided pre-paid envelope, seal it, and mail it back to us :

- this green sheet
- all questionnaires (both completed and blank)
- the torn-off cover sheets (You may destroy the cover sheets rather than returning them.)
- all consent forms (both completed and blank)

Thanks!

STUDENT SCIENCE QUESTIONNAIRE

Curriculum Research & Development Group (CRDG)

Part 2, was adapted from Ayala (2003).

Please do ***not*** duplicate.

Student Science Questionnaire

Part 1

Directions: This is a questionnaire about your knowledge and beliefs about science. You will not be graded on your answers but it is important that you answer each of the questions to the best of your knowledge. For each question, there may be more than one possible answer. ***Select the single best answer*** and circle the letter for the answer. If you do not know the answer to a question, make your best guess. Be sure to read the whole question and *all* the possible answers.

1. Two students independently tested the boiling point of a liquid. They used liquid from the same source and followed the same procedure, but they got different results. Which of the following do you think is the ***best*** explanation for the difference in their results?

    a. They have different results because they did not conduct the experiment at the same time.
    b. The results of scientific tests are sometimes different because of human or instrument error.
    c. One of the students probably has more experience conducting scientific experiments than the other.

2. You are unsure whether one of the scales you used to weigh clams was accurate. You cannot repeat the measurements because the clams have been put back in the ocean. What is the best way to deal with the data from the questionable scale?

    a. Remove it from your analysis and report only the part of your data that you are sure is accurate.
    b. Report it with the rest of your data, but explain which values might be inaccurate and why.
    c. Include it in your analysis because the inaccurate values will average out.

3. Accepted scientific explanations change over time because:

    a. scientists conduct experiments more carefully.
    b. scientists share new findings and new information.
    c. scientists vote on the correct explanations.

4. Which of the following sentences best describes the distribution of saltwater on Earth?

    a. There is one ocean.
    b. There are five oceans.
    c. There are seven oceans.

5. When scientists make careful measurements many times, they expect that:

    a. they will have to repeat the measurements until the results are identical each time.
    b. most of the measurements will be identical.
    c. most of the measurements will be close but not exactly the same.

6. Scientists today are able to study small parts of living cells with electron microscopes. The invention of the electron microscope is an example of:

    a. how scientists are getting more intelligent over the years.
    b. how technology helps to advance scientific knowledge.
    c. how scientific findings are becoming more accurate.

7. A science teacher tells her class to "think and act like a scientist." What do you think she means?

    a. In every investigation, follow the scientific method by going from hypothesis to procedure to results and then to the conclusion.
    b. Ask questions, invent procedures, and revise your questions and procedures when you discover better ways to do the investigation.
    c. Revise your questions and procedures until you show that your hypothesis is correct.

8. What do you expect will happen when the warm Amazon River flows into the warm Atlantic Ocean basin?

    a. The river and ocean water will mix evenly.
    b. The river water will sink to the bottom of the ocean.
    c. The river water will float on the ocean water.

9. Thinking and acting like a scientist is useful for:

    a. students in all classes.
    b. students who want to become scientists.
    c. students in a science class.

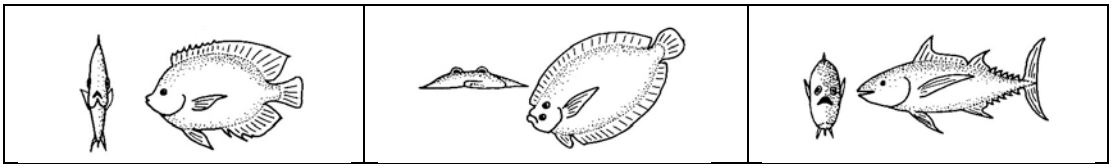
10. Malia has conducted the same experiment many times, but her data did ***not*** give her the results she expected. What should she do?

    a. Conduct the experiment again.
    b. Report the results she should have gotten.
    c. Revise her research question and procedures and conduct a new experiment.

11. Imagine that you are reading about a scientific study. You need to decide how well the study was conducted. Select the ***best*** question to ask about the study.

    a. Did the study's methods include an experiment?
    b. Were the study's methods appropriate for the study?
    c. Was the study conducted by well-known scientists?

12. Which fish in the figure below would be best adapted for moving around coral in a reef environment?



Fish A Fish B Fish C

    a. Fish A
    b. Fish B
    c. Fish C

13. Emma is a young friend. She wants to know if basketballs bounce higher when they are fully inflated with air. What is the ***best*** thing to do to help Emma learn?

    a. Draw a picture that shows how high two different basketballs will bounce when they have different amounts of air in them. Use your picture when you explain the results to Emma.
    b. With Emma, fully inflate one basketball and partially inflate another basketball. Drop the two balls from the same height. Help Emma explain the results.
    c. Show Emma where the information is in a good science book and have her read it. Later, ask her to explain to you what she learned from the book.

14. Kai had a hypothesis. He tested the hypothesis by doing an experiment. Based on the results of the experiment, Kai changed his hypothesis. Which of the following best describes Kai's actions?

    a. Kai was practicing good science because scientists revise their hypotheses based on experimental results.
    b. Kai was practicing good science because he conducted an experiment.
    c. Kai was ***not*** practicing good science because the scientific method goes from hypothesis to procedure to results to conclusion.

15. What causes genetic variation in a population?

    a. Mutation
    b. Replication
    c. Translation

16. Alex has been studying a gumball machine for two hours. He says he has a theory that the next gumball to come out of the machine will be green. Why is Alex's idea ***not*** a scientific theory?

    a. Alex has only used his own observations to explain why the next gumball will be green. He needs to do an experiment to test his idea.
    b. Alex does not describe a large set of observations and explain those observations. He needs to consider scientific facts, laws, and previous studies.
    c. Alex has not shared his idea with others. He needs to present his observations and idea to others before it can be called a scientific theory.

17. Elena is conducting an experiment and finds that her procedure ***cannot*** help her answer her research question. After reviewing her experiment, she develops a new set of procedures for answering the question. What should she do?

    a. Repeat the experiment but use the new set of procedures.
    b. Repeat the experiment with the procedures she used the first time.
    c. Record her current results and finish the investigation.

18. After you take a shower, your hair remains wet for some time. The property of water that ***best*** explains why your hair remains wet for some time is:

    a. Adhesion
    b. Cohesion
    c. Holding Capacity

19. Kiana has a hypothesis that bananas will ripen faster when placed in a plastic bowl than when placed on the counter. She places some bananas in a plastic bowl and some bananas on the counter and observes the bananas for a week. Kiana's data show that the bananas in the plastic bowl did not ripen faster. What can Kiana conclude?

    a. Her investigation has failed.
    b. Her hypothesis was not supported.
    c. Her hypothesis cannot be answered using the scientific process.

20. Lisa's science teacher asked her class to work in groups and to record observations of fish behavior. One group's findings are very different from the others. Select the ***best*** way for Lisa's class to address the differences in the data.

    a. Compare the groups' procedures to see if this explains different results.
    b. Conduct the observations again but make sure each group's findings are the same.
    c. Have the class vote on which group's data should be accepted.

21. There is a new brand of toothpaste called Smile. Which of the following sources of information would be the best for deciding if Smile is a good brand of toothpaste?

    a. A study you found on the Smile website that concludes that four out of five of dentists say Smile works best
    b. Your own study in which you ask four people with shiny teeth what they think about Smile
    c. A government study that compared the ingredients of Smile with other toothpastes

22. Scientific knowledge is determined from:

    a. the votes of knowledgeable individuals.
    b. information that is written in books.
    c. explanations that are supported by evidence.

23. Your cat, Frisky, is a vegetarian. Based on this, you hypothesized that cats prefer vegetables to meat. However, the data you gathered show that most cats prefer to eat meat instead of vegetables. This means that:

    a. you conducted a poor experiment because your data did not support your hypothesis.
    b. you showed that your hypothesis about cats was not supported.
    c. your hypothesis was poor because most people already know that cats prefer meat.

24. Last week, you noticed that your pet fish swam to the top of its fishbowl when the sun came up. You decided to watch your fish every morning for a week to see if the fish always swims to the top of the fishbowl at sunrise. You are:

    a. doing science because you are repeatedly making careful observations.
    b. doing sloppy science because you are only observing at sunrise.
    c. ***not*** doing science because your observations are too informal.

25. How would a scientist explain the presence of the hard, outer shell in lobsters?

    a. Lobsters inherit the genetic blueprint for their shell, which evolved over many generations.
    b. Lobsters discovered how to grow an outer shell and passed that on to their offspring.
    c. Lobsters prefer an outer shell to an internal skeleton.

26. Water molecules form hydrogen bonds because of the _____ sharing of electrons in the O-H bond. (*Select the best word to fill in the blank.*)

    a. unequal
    b. ionic
    c. nuclear

27. Water in the ocean depths is generally _____ the water at the ocean surface. (*Select the best choice to fill in the blank.*)

    a. colder than
    b. colder and saltier than
    c. the same temperature and salinity as

28. There are 1000 students at Mikayla's school. Which of the following represents the best way for Mikayla to sample the students at her school to see if they like cats or dogs better?

    a. Ask all of the students in her school.
    b. Ask the first 50 students she meets in the hallway.
    c. Ask all of her friends.

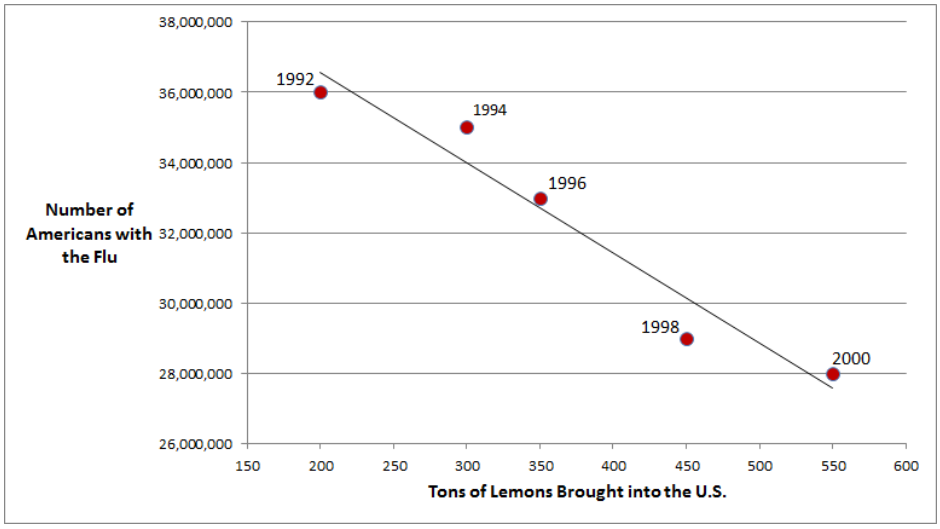
29. Mr. Lai does an experiment on his students. He places apple slices in the middle of the room and candy bars in the corner of the room. At the end of the day, there are no apples left but there are lots of candy bars remaining. The experiment appears to show that students like apples better than candy bars. To be sure of his results, what should Mr. Lai do when he repeats the experiment?

    a. Make sure he uses the same procedure.
    b. Improve the procedure by putting both kinds of food in the same location.
    c. Use marshmallows in another corner as a control.

30. Which of the following is the densest water?

    a. Cold salty water
    b. Warm salty water
    c. Cold fresh water

31. The following graph compares the number of Americans who had the flu with the number of lemons brought into the U.S. from 1992 through 2000. What can you conclude from the graph?

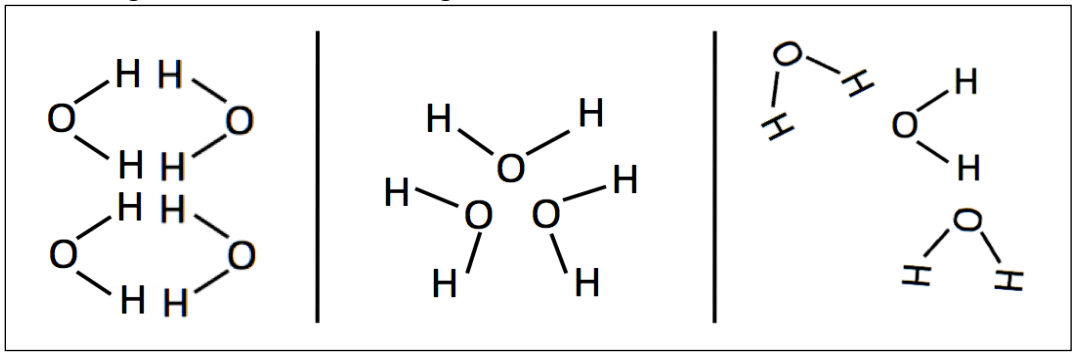


a. Americans should eat more lemons because they decrease your chance of getting the flu.
b. People who get the flu buy more lemons than people who do not get the flu.
c. There is not enough evidence to show that the number of people who get the flu is affected by the number of lemons.

32. There are red, green, blue, and yellow Legos in a box. Kim wants to know the percentage of red Legos. Kim shakes the box so that all of the Legos are well mixed. She then closes her eyes and picks up the first ten Lego pieces she touches. Nine of the Lego pieces are red and one is blue. What should Kim do next?

a. Report the results as she found them, showing that most of the Legos in the box are red.
b. Repeat her procedure a few more times to get an average value for each color.
c. Repeat her procedure, but keep her eyes open to be sure that at least one of each Lego color will be chosen.

Use the figure below for answering Questions 33 and 34.



Position A **Position B** **Position C**

33. Which of the positions of molecules in the figure above shows the most likely position of water molecules in pure liquid water?

    a. Position A
    b. Position B
    c. Position C

34. In the figure above, what do the lines between the *O*s and *H*s represent?

    a. Hydrogen bonds
    b. Ionic bonds
    c. Covalent bonds

35. What can you conclude based simply on your observation of this photo?

    a. The shrimp is cleaning the eel's mouth.
    b. The eel is getting ready to eat the shrimp.
    c. The shrimp is almost fully inside the eel's mouth.

Part 2

Directions: Please tell us how true you believe these statements are about science. For each question below, circle the number on the scale that matches how true you think the statement is. *Circle **only one number** for each question.* The scale numbers are defined as:

Not at all true					Very true
0	1	2	3	4	5

	Not at all true					Very true
36. Many different kinds of people can be good scientists.	0	1	2	3	4	5
37. Scientific knowledge is neither good nor bad.	0	1	2	3	4	5
38. Scientific knowledge can be useful away from school.	0	1	2	3	4	5
39. All good scientists work in the same way.	0	1	2	3	4	5
40. Scientific knowledge is only useful to scientists.	0	1	2	3	4	5
41. Scientists never try to show that other scientists are wrong.	0	1	2	3	4	5
42. Sometimes things that scientists thought were right turn out to be wrong.	0	1	2	3	4	5
43. Scientists always get the same results.	0	1	2	3	4	5
44. There are many different ways to do science.	0	1	2	3	4	5
45. Scientific knowledge can change over time.	0	1	2	3	4	5
46. Scientists are always right.	0	1	2	3	4	5
47. When you follow the scientific way of doing something, you get the right answer.	0	1	2	3	4	5

Reference

Ayala, C. C. (2005, October). *Development and validation of an inquiry science student achievement*. Paper presented at the annual meeting of the American Evaluation Association, Toronto, Canada.

APPENDIX D

SUMMARY OF THE POST-COHORT INTERVIEW RESULTS

POST-COHORT INTERVIEW SUMMARY

Lisa M. Vallin, George M. Harrison, and Paul R. Brandon

Post-Cohort Interview Summary

All 28 Cohort 4 and 5 teachers who completed the project were interviewed towards the end of the project, during the final weeks of May 2013. To ensure careful use of time and financial resources, the research team conducted the interviews online using software the teachers had already been familiar with through participation in the PD.[11] The initial plan was to randomly sample half of the 28 teachers for face-to-face synchronous online interviews and to conduct the remaining interviews using asynchronous software (as was done in Year 2 of the project with Cohorts 1–3). Because, however, one of the interviewers had devoted extra time to the data collection activities for the Oahu II cohort (for conducting dissertation research), all 15 Cohort 4 teachers were synchronously interviewed. Half of the teachers in Cohort 5 (7 of the 13 teachers) were randomly selected for the face-to-face synchronous interviews. All face-to-face synchronous sessions were conducted via Blackboard Collaborate virtual office. The remaining six teachers from the Kauai cohort completed the interview asynchronously online in a written-response format via SurveyMonkey. The face-to-face interviews lasted between 25 and 45 minutes, with an approximate mean completion time of 30 minutes; the median time of the six asynchronous responses was 1 hr. 20 minutes.

After logging on to the Blackboard virtual office, the teacher was greeted by two members of the research team. Before the interview began, a few technical procedures were noted to ensure the software was functioning properly; then, one member of the research team introduced themselves as the interviewer while a second member of the research team took a backseat, focusing on note taking. After some minutes of checking-in, the interviewer began by letting the teacher know that the purpose of the interview was to collect information about the participant's experiences in the PD project and with teaching science as inquiry. The teacher was also informed that although there would be a lot of questions regarding the use and understanding of teaching science as inquiry, the purpose of the interview was not to evaluate the teacher's performance or understanding of teaching science as inquiry. Next, the teacher was told that the interview was confidential and that the original data from the interview would only be shared with and reviewed by members of the research team. Teachers were told that the findings would be shared with the members of the project team after identifying information was removed and the data were analyzed. For the SurveyMonkey interviews, the same information was presented at the start of the interview. After prompting for and addressing any questions the teacher had, the interviewer started the interview, with the first question addressing the PD structure.

PD Structure

The PD was structured to be distributed throughout an entire academic year. It included an initial orientation meeting and four modules, each lasting about two months. Each module comprised a two-day in-person workshop, an in-person three-hour follow-up meeting, an online virtual meeting, and interactions on a website. With this structure, the teachers met on thirteen occasions throughout the year: nine times in-person and four times online.

[11] Conducting interviews at teachers' schools would have been more expensive because of travel time and the need to work around other logistics such as securing interview locations.

Of the 28 teachers, 15 stated that the structure worked very well for them. In response to the question "what do you think about the way the PD was structured," one teacher, for example, lauded the effect of the scheduling and PD planning on their practice: "The structure of the [PD], although time consuming, was well organized and executed. It certainly contributed to my own learning and my ability to build stronger and more relevant lessons in my classroom." Another teacher commented on the growth they experienced with the year-long structure: "I really liked the set-up and the fact that it was spread out over an entire year allowed us to grow. If you cram it shorter I don't think it would have been as useful." Similarly, another teacher addressed the effect of the PD on their own learning and practice, saying, "I learned so much from each module and then developed my understanding and excitement by running the activities with my students. I feel very fortunate to have had this opportunity especially being a first-year middle school science teacher." Another teacher presented a perspective from the eyes of their students: "My students were always excited when I told them I was going to a new workshop, [because] I would bring back more activities." These, and other similar responses, suggested that the structure facilitated teachers' professional development.

Two teachers added that having the PD stretched out over a school-year allowed for the development of professional relationships within the cohort. One teacher said "The yearlong PD was good. I liked the fact that it was [completed] over a year so I got to develop friendships with[in] my cohort." Another teacher said, "I was really impressed by the structure; I liked the interactions." The extended PD exposure likely provided multiple opportunities for teachers to interact with each other.

Even though the PD was spread out over an entire year, each of the four modules included a large number of activities compressed in a short period of time, an issue which at least one teacher addressed: "The workshops were really good, but some of the information was a bit fast. It was a bit difficult to transfer the activities we learned in the workshop to our classes because it was so much information. I think it would have been better if we had focused on less material so I could have had a chance to flesh out some stuff with the other teachers." Although teachers learned a lot, there still may have been a lot of material they were unable to fully engage in.

There was other constructive feedback about the structure. One teacher simply stated that the PD was too long. This person (who added that they had taken a number of PDs prior to TSI) wanted a structure providing a "spurt" of learning rather than one stretched out over the school year. Two other teachers mentioned that the structure worked well, but wished that the workshop series would have started earlier in the school year so that the PD could have been completed sooner, alleviating some of the end-of-school-year stress: "By the time the last module rolled around, it was the very hectic two-thirds of [the way through] the 4th quarter. For almost any teacher, this is a very tight time of the year." Thus, there were some perceptions that the PD should have been scheduled to be more compact or more heavily front-loaded.

The follow-up sessions were much appreciated, but a few teachers mentioned that the logistics of fitting it into their schedules was sometimes challenging. One teacher said, "the follow-ups were okay, but some days it was just hard to get there after a long day. If they could have shortened it somehow that would be great." Even though, the virtual meetings did not require transportation to a meeting location, teachers for the most part perceived these as being less successful than the in-person meetings. At least three

teachers reported that these online sessions were not useful to their learning; one teacher said it felt like "homework" and two other stated that they were "boring."

One of the main critiques of the PD structure was the issue of time. Nearly all teachers expressed concerns about time issues and many said they felt under pressure with the many deadlines. One teacher explained that the commitment required careful planning because of the need to schedule their classroom lessons to accommodate the Friday workshops. This teacher was concerned with "tell[ing] the students that I had to miss class because I was going to class myself." Another teacher stated, "The time commitment was far greater than initially expected. This [was] due to the lengthy out-of-workshop tasks such as PowerPoint creation, lengthy lesson plan outlines that were new to us in format, and classroom time commitment." Some teachers also talked about the activities they learned in the workshops and made the point that these activities took longer to implement in their own classrooms. A different teacher added, "time has been the biggest struggle. Nearly all the activities took longer than planned—from two to three times as long—which then changed up the pacing for the whole year." Another person talked about ways to overcome these challenges around time. "To adapt, I cut the time [allotted] to discussion [within the TSI lesson], I cut some of the activities, and focused on the main idea." The issues with time were expected, and these responses were not surprising given the multiple requirements teachers faced outside of the PD.

There were some comments from a few teachers about non-scheduling aspects of the PD structure. Two teachers commented about the grouping of participants in workshop activities; they said they experienced challenges while working in a single group during one part of the workshop. And one of the teachers explained, "I had a hard time with some other participants being negative or condescending. So the seating or table groups were hard for me for one module in particular." Another teacher made the point that the video camera was intrusive. Most of the workshops in this cohort were held in a relatively small room, with some of the space allocated to the video camera.

Overall, the responses to questions about PD structure suggested that although the teachers reported experiencing challenges with finding the time to fully implement the activities in their classes and there were a few participants wanting a more front-loaded schedule, the structure overall was perceived as a beneficial feature of the PD. The teachers were able to observe their own growth and build rapport with each other.

Perceptions of the Value of the PD

All of the teachers found the PD to be valuable to their learning and teaching about science as inquiry. In response to the question, "on a scale from one to ten, how would you rate how valuable the TSI PD has been to your teaching practice, and could you please explain your rating," several teachers praised it as the best PD experience they had ever had. One teacher offered this: "I think it was extremely valuable in every way, I feel more comfortable teaching other subjects too as a result. I feel that I have gained a lot, and believe that every science teacher should have access to this PD." When asked about the value of the PD, many teachers talked about what they were able to apply in their classrooms. A teacher stated, "I learned so much from this PD that was immediately applicable to the classroom setting. Of the PDs I have participated in, this one gave me the most directly useful and usable information. I am so glad that I got to be a participant, not only for myself and my learning of new information, but for what it has done for the ability to engage my students." Another teacher said, "I will say that this PD is the sole

reason for the growth of my teaching this year. I could have easily started cruising at this point in my teaching, but the PD really pushed me to learn and to grow was a teacher. It was extremely valuable, I learned tremendously."

An important component of the PD was to establish community building among the teachers. Six teachers brought this up in their interviews as something they valued, and talked about newfound friendships, "I was not expecting to make such great friendships with the cohort as I did, so that was very positive." Another teacher said, "I made a lot of connections with people, and exchanged some phone numbers and built friendships that I did not expect to do." It is clear that the PD was very successful in establishing value for its participants by offering substantive professional development and community building.

Experiences with the TSI Content

One of the main components of this PD was the TSI content. This was organized by module, with Modules 1–4 addressing physical science, chemistry, biology, and ecology, respectively. All content was presented in the context of aquatic science. The teachers expressed appreciation for this, and many of them talked about the positive effect it seemed to have on their students. "The biggest thing [that] stands out to me is how the students could get such a thrill out of discovering and doing some of the activities we did. I thought that some of the students would have been "too cool" to do them, but it turns out they were extremely excited and enthusiastic about doing all the activities." Overall the teachers' comments suggested that the physical and the chemical content were regarded as more valuable than the biological and the ecological content. Some mentioned that the last two modules' content, on biology and ecology, seemed less rigorous and less in-depth. This may have been because more focus was placed on pedagogy than content in these modules. Many teachers also talked about spending significant time cutting and modifying lessons to make them "fit" their classrooms, which may have contributed to valuing some modules and/or activities less. Although the TSI Aquatic curriculum was designed to be modifiable to different content areas and grade levels, teachers' comments suggested that they felt most successful when their content area matched the TSI Aquatic curriculum and when they taught 8–12 graders. When asked about their experience with the TSI content, one teacher stated, "It was great! I loved all of it. The problem with it was that when you are trying to use it in the classroom, really any other than a Marine Biology one, you are stretching it. I lost students in the Ecological and the Biological, like when we did the fish printing activity in an honors Chemistry class, the students just didn't see the connection." Another teacher talked about the many modifications that needed to be done to fit their grade level and said, "all four modules had decent things, and if one lacked some it was the Ecological one. I think it still needs some work. There is no Life Science in sixth grade so I had to justify spending time with some aspects of the curriculum to tie it to the Standards. I had to modify the activities a lot due to vocabulary and other difficulties due to the grade level I teach." Though the content was viewed as valuable, it was not as highly valued when it did not align with the curricula the teacher was expected to follow by their grade level.

During each of the four PD workshops, the teachers participated in a number of TSI lessons, or activities, in which they took on the role of students and engaged in reflective discussions on the pedagogy and content. For each module, there were three target

activities that the teachers were required to implement in their classes after completing the workshop. (Teachers were asked to select one of their regular teaching classes to serve as a *focus class* in which these three mandatory target activities were to be implemented; nothing precluded implementation in non-focus classes.) The target activities were well received by the teachers, although some of them mentioned that certain activities were a better fit than others depending on the alignment of the content to their curriculum. Several teachers mentioned that although they did not fully implement the activities this year most often due to time constraints, they would review the TSI curriculum in time for the next school year and include it in their practice. "I think next year for sure I will definitely apply the TSI content, but this year I only did it with the activity where we had to do it with our own lesson, but next year I am definitely going to look over my activities and see how I can incorporate more TSI content and definitely the pedagogy." Many of the teachers reported using the TSI curriculum and pedagogy with their non-focus-class students. One teacher shared how they adapted the TSI activities for use in another class: "Just adapting some of the lessons, like the chemistry lesson with the envelopes, I used the same idea in my anatomy class. I teach a number of biology classes, and I used the TSI lessons in all of them, not just in my focus class."

With the target activities, teachers were provided with supplies, which they could keep for future use. The teachers expressed appreciation for these. In one teacher's words, "the supplies were very valuable; having the things ready to go was hugely beneficial. Especially the ecology module and having access to the transects were great. I would not have taught that activity otherwise." Another teacher said, "supplies were awesome! A lot of times that is the thing that stops you from implementing an activity, so that was a really great aspect of the PD because it made it easy to do the activities." Although the target activities were very structured (the teachers were taught the activities in the workshops and asked to implement them with as few modifications as possible) many of the teachers were thankful for this. Providing lesson plans and the activity supplies appeared to facilitate teachers' target-activity implementation.

Experiences with the TSI Aquatic Pedagogy

Compared to the TSI Aquatic content, the TSI Aquatic pedagogy was perceived as more difficult to apply in the classroom. There were three questions that solicited information on this: (a) "On a scale from one to ten, how would you rate how *valuable* the TSI PD has been to your teaching practice, and could you please explain your rating?"; (b) "On a scale from one to ten, how would you rate how *relevant* the TSI PD has been to your teaching practice, and could you please explain your rating?"; and, (c) "How would you rate how *successful* you were in implementing the TSI pedagogy, please explain your rating?". Some of the teachers' responses suggested that they greatly appreciated the pedagogy whereas others were critical and hesitant to use it. The teachers' responses indicated that, for the majority of the teachers, the pedagogy was not an issue when they encountered it during the TSI Aquatic workshops, but once they were expected to use the pedagogy themselves and teach the TSI framework and language to their students, several of them struggled. The pedagogy was presented to the teachers as a *toolbox*, with several different components including *phases*, *modes*, *metacognition*, *questioning strategies*, *practices of science*, *demeanors of science*, and *practices of inquiry teaching*. The core emphasis of the pedagogy was on the TSI Aquatic phases and modes of inquiry, with the other components tying into these. The teachers seemed most

comfortable with these central components. “I really really like the phases and the modes of inquiry—it really caught my attention and my students’ attention. I keep telling them that science is not linear, so that is why I like the phases because I am able to relate the information to my students. It was very meaningful because we have always taught science to be linear, especially through the scientific method and the scientific process, through science experiments, so it was nice for me to learn and also nice for my students.”

Although some of the teachers really seemed to appreciate the TSI Aquatic pedagogy, most of them were critical of it. “I think the modes and the phases are unnecessary layers to the teaching—it is too complex. But I can see the value in using a common language around TSI; still, it is too complex.” Another teacher said, “The phases and the modes, even though I understand them, to me, to have that be a big part of what you teach students—it takes more time than what you get out of it. It is an alternate way of teaching the scientific method, but the vocabulary and the context of it, I am not just sure it is worth the time to teach it. I am not sure that it is that important for the students to know about the difference between investigation and invention, it takes a lot of effort.” Several of the teachers talked at length about issues around the time it took to teach the TSI pedagogy to their students and saw that as a main barrier to implementation. “I looked at how much time I had with my students and how much time I had to get things done, and decided that they would not get the pedagogy, as I prioritized the content. I wanted them to get the science first and did not focus on the pedagogy. Maybe it would have been different if I taught science all year long. My students did not learn the TSI language; they still refer to the scientific method. But I would say that I personally used the TSI pedagogy when implementing, but the students themselves did not really learn it.” Another teacher echoed similar struggles with time and said, “My students would not have a good grasp about the TSI phases and modes because I did not really go over it very much. We have a certain amount of time and there are things that we have to cover and the vocabulary and the ideas about the phases are complex, so for them to learn it, it would be too challenging.” Another teacher questioned the relevance of the TSI pedagogy, adding that students were frustrated with explicit instruction on the modes and phases: “There is way too much emphasis on these phases and modes it is just not the way teenagers learn. It really frustrated the students when they had to think about what mode or phase they were using. Especially because the language was so confusing all starting with “in” (initiation, invention, investigation, interpretation), and it was hard to remember what the modes were all about. Because the terminology of the phases and the modes are not intuitive, it becomes confusing, so they lose the value of what they are supposed to be about. If the language was different [they] would have been able to absorb it better.”

Other comments, however, suggested that although the TSI pedagogy might have been tricky to internalize, it was rewarding for both teaching and learning. “The pedagogy is just phenomenal. I think the students really responded to it, they used to think science was boring and just about finding an answer, but now when we did the microevolution activity; they loved it! We had some really great discussions and they really enjoyed learning about evolution.” Another teacher said, “I am comfortable and confident with TSI. This is not to say I have it all figured out. I look forward to developing this pedagogy in my teaching in the future. I have used a similar form of this

pedagogy, 'the 5 E Method' in the past, but I find TSI to be a richer teaching and learning method." The teachers' comments suggest the TSI Aquatic pedagogy was challenging and that teachers varied among each other in their perceptions of its value and relevance.

Perceptions of the PD's Effect on Understanding of Scientific Inquiry

When asked about the PD's effect on the teachers' understanding of inquiry, 25 of the 28 teachers reported that they believed the PD had had a significant impact on their inquiry understanding. These teachers frequently attributed their increase in understanding to both the content and the pedagogy components of the PD. One teacher said, "I remember when I first wrote down my definition of inquiry, and now after the PD when we were asked to write it again I could really see the difference. I really liked that you guys stressed the fact that there are different ways and methods of inquiry—that inquiry doesn't always have to be open-ended." Another teacher stated, "[the PD] helped me crystallize or focus my ideas about science teaching, and now I realize it has a name; inquiry based science. I knew how I wanted to do what I want to do, but now I have a better idea of how to [teach inquiry]." Although most teachers had ideas about what it would mean to teach science as inquiry, their definitions of inquiry became more nuanced throughout the project. The remaining three teachers who did not believe that the PD really affected their understanding of inquiry explained that their existing beliefs were rather confirmed than changed. Since these teachers had knowledge of inquiry prior to this PD, perhaps these teachers may have entered with an already solidified definition of inquiry.

In most of the interviews, the teachers' responses suggested that their PD experience exceeded their initial expectations, especially in terms of learning about inquiry. Several teachers expressed that they did not expect to learn about inquiry "in so many different forms" and felt fortunate to now being able to "explain inquiry" better due to newfound language around the topic. In the words of one teacher, "I was never really sure about what inquiry-based science was. These modules helped give me a better sense of what that is." Another teacher stated, "I would say that this PD course exceeded my expectations of inquiry-based science. I took away much more from the course than I expected." Many teachers also said they were surprised about what they learned about the content and the pedagogy. One teacher stated, "I did not expect the content for TSI to be what it is, but it has been a positive experience for me to learn and implement the models, and take the curriculum and pedagogy with me into other classrooms and with other teachers that I co-teach with."

Many of the teachers discussed the positive aspects of the PD and several credited the PD as having helped them grow professionally. One teacher explicitly related their experience to their professional growth, "I did not anticipate growing as much as a teacher, I have a lot of new tools and knowledge that I can now use, so that is great. I will attribute TSI to being able to further myself in my career because I taught a TSI lesson for my future job, and I got it, so they must really like what I did." This individual attributed success in landing a new position to what they learned from the PD.

The Online Learning Community

In addition to the in-person and online meetings, teachers were expected to interact with each other on the Exploring our Fluid Earth website by posting lesson plans and commenting on each other's work. Teachers were required to access the curriculum and engage in this online community. The teachers had mixed comments about the use of the

website. Only one out of the 28 teachers expressed complete satisfaction with the website and stated, "I really liked the website, I was able to share some of the stuff on the site with some of the teachers at my school. I think one of our cohort members had the best lesson plans on earth, so it was really nice to be able to see those online." Most other teachers were only somewhat satisfied with the website and mentioned that the site needs updating and modifications to improve its use. "I liked the website although it was hard to navigate, and I didn't really download a lot of worksheets et cetera, because I had to modify them for my grade level. The website got better, but still needs some work." Most of the dissatisfaction with the website seemed to be about the layout and the navigation. Several teachers commented on this, with one person saying, "I used the website to introduce lessons and enrich lessons. I did however, find the teacher community portion on the site to be very cumbersome. I don't think in order to file my website comment that I should have to dig so deep to find the 'blue bubble'. The current font color choice is a disaster. It is VERY difficult to read. I expect to use the website in the future with my classes and hope it will be easier to read." Another teacher said, "The website still needs work, I didn't find it useful. Like I could not do a search and it was difficult to navigate and know where to post." Significant resources were spent on constructing and maintaining the website, and with continued improvements, teachers seemed hopeful to be able utilize the site more for both professional growth and teaching.

Professional Development Credits

In addition to the regular PD course, teachers had the opportunity to participate in more activities to earn PDE3 credits (continuing education credits for in-service teachers). Each module offered three PDE3 credits. Out of the 28 teachers, 22 of them (79%) completed PDE3 credits for all four modules. The remaining six teachers did not participate in the PDE3 credit option. Comments about the PDE3 were mostly positive, with teachers expressing appreciation that they could earn these credits. One teacher stated, "I think for me, I really liked the fact that you could earn so many credits during the whole year. Even though it was a lot of work, I liked the fact that we could earn 12 credits in one year. I think the set-up was pretty logical, with the workshops then the follow-ups and the Blackboard [Collaborate sessions]." Two other teachers struggled with committing enough time to meet the requirements of earning the PDE3 credits. One teacher made the point that the PDE3 component required a strong commitment and a lot of effort: "The negative was that it was a 12 credit course that required a commit[ment] and effort to participate in it and to get it done. It did require good energy to meet course expectations." The other teacher pointed out that the requirements of the PDE3 were less than optimally aligned to those of the PD: "The portfolio template was a challenge to work with when inputting student work as it did not allow this action to take place easily, adding [to] the amount of time it took to do this task. This was the worst part of this PD." This extra effort is not surprising, however, because the PDE3 credit component of the training was intended to be beyond that of the regular course structure.

Recommendations and Future Use of TSI Aquatic

Toward the end of each interview, the teachers were asked to offer any additional thoughts on how to improve any aspects of the PD. Since several teachers had expressed struggles with learning the pedagogy some of them suggested that the TSI pedagogy and language be introduced earlier in the PD; one teacher said, "I would recommend introducing the vocabulary early and keep reinforce it throughout." Another teacher

echoed this: “I would adopt the TSI terminology earlier in the year. I would recommend incorporating the TSI toolbox earlier in the year so we won’t have to adopt as much later on.” Two teachers pointed out that there is a difference in learning as an adult teacher in a PD and the process of using that knowledge to teach students. One person had this to say: “I think it is a little different when you do a workshop with adults and then you are supposed to teach it with kids. The transfer is a bit different. What happens in the workshop does not always happen in the classroom. But this is the reality you have workshops with adults and all goes smooth and then when you do it with your kids then it is very different.” Related to this, two other teachers mentioned that more face-to-face time would have been beneficial for discussing possible modifications to the target activities to make the lessons a better fit for individual classrooms; in one teacher’s words, “I think it would have been better if we had focused on less material so that I could have had a chance to flesh out some stuff with other teachers. For me it was [hard to] imagine how the lessons we learned in the workshops would translate into our classrooms. It was great that we did them in the workshop, but I don’t think we had enough time to flesh out some of the ideas about how to implement them in the workshop. I would have wanted to plan the lessons more with the help of my cohort members.”

Of the 28 teachers 27 found the PD to be useful overall and expressed great satisfaction with their experiences. The one teacher who did not find the overall experience satisfying still found parts of the PD to be useful. All teachers stated that they plan to continue to use parts of what they have learned. “I definitely intend to implement TSI in my future teaching because I think it creates a more authentic science experience that helps students learn on a deeper level.” Another teacher said, “I will definitely use what I have learned in the future. This is the direction that science teaching needs to go in.” Teachers, for the most part, characterized their experience as meaningful and enjoyable. “[the PD] was a great experience, I got the chance to connect to great and knowledgeable expertise in the field, and [it] allowed us to collaborate and gain feedback from our peers.” Another teacher said, “This PD allowed me to grow as a teacher; it was invaluable. Thank you all so very much!”

Conclusion

The Post-Cohort PD Interview responses suggest that, overall, the TSI Aquatic PD was perceived as a success, particularly in the way it was structured and in its provision of aquatic content activities that teachers could use in their classes. Although some of the teachers did not fully embrace the pedagogy in their practice, others adopted it and applied it to teaching contexts outside of those identified for the project. The teachers’ observations of their own growth in their understanding of inquiry, their knowledge of the content, and their reports of how they developed collaborative relationships with their peers, suggest the project achieved what it had set out to do.

APPENDIX E

FORMATIVE EVALUATION INSTRUMENTS

POST-MODULE QUESTIONNAIRE

(This questionnaire was repeated after each of the four modules and modified for appropriate content.)

Joanna Philippoff, Kanesa Duncan Seraphin, and Lauren J. Kaupp

A product of Curriculum Research & Development Group (CRDG) College of Education, University of Hawai'i at Mānoa

Post-Module Questionnaire

Module 4: Ecological Aquatic Science

This questionnaire asks about your experiences with the *Module 4 Blackboard Session*, and it asks you to review and reflect on your work in the module. We value your feedback, as we are striving to further this professional development experience!

This questionnaire will take about 30 minutes to complete. Please make sure you submit all of your answers in one sitting.

Thanks!
TSI Research Team

***1. Instructions: Please give us your opinions about the online Blackboard session that you recently attended. Select the response for each item (ranging from strongly disagree to strongly agree) that best represents your opinion.**

	Strongly disagree	Somewhat disagree	Slightly disagree	Slightly agree	Somewhat agree	Strongly agree
Sharing my lesson helped me to clarify my understanding of teaching science as inquiry.	☐	☐	☐	☐	☐	☐
The feedback given to me about my lesson was useful.	☐	☐	☐	☐	☐	☐
Observing my peers' lessons improved my understanding of teaching science as inquiry.	☐	☐	☐	☐	☐	☐
I was encouraged to try new practices or strategies.	☐	☐	☐	☐	☐	☐
Overall, I found the online session to be useful.	☐	☐	☐	☐	☐	☐
Preparing and sharing my lesson helped me to understand the Phases of Inquiry.	☐	☐	☐	☐	☐	☐
Preparing and sharing my lesson helped me to understand the Modes of Inquiry	☐	☐	☐	☐	☐	☐
Preparing and sharing my lesson helped me to understand TSI inquiry questioning strategies.	☐	☐	☐	☐	☐	☐
Preparing and sharing my lesson helped me to become more metacognitive.	☐	☐	☐	☐	☐	☐
Preparing and sharing my lesson furthered my understanding of TSI pedagogy.	☐	☐	☐	☐	☐	☐

2. Please provide any comments you have about the *Blackboard* session.

Module 4 Review

*3. To what extent do you think the ocean theme was evident in this module (e.g. workshop and follow-up)?

Not evident (1)	(2)	(3)	(4)	Very evident (5)
○	○	○	○	○

Optional: Please explain your answer

*4. To what extent do you think this module improved *your* understanding of ocean processes?

No change in understanding (1)	(2)	(3)	(4)	Much greater understanding (5)
○	○	○	○	○

Optional: Please explain your answer

*5. To what extent do you think you were *aware of and purposefully use* the TSI practices of inquiry and teaching strategies?

	Not at all (1)	(2)	(3)	(4)	A lot (5)
before the Module 4 workshop?	○	○	○	○	○
in your **TSI** activities for this module?	○	○	○	○	○
in your **non-TSI** activities during this module?	○	○	○	○	○

Optional: Please explain your answer

*6. How *successful* do think you were when implementing the TSI practices of inquiry and teaching strategies?

	Not at all (1)	(2)	(3)	(4)	A lot (5)
before the Module 4 workshop?	○	○	○	○	○
during your **TSI** activities for this module?	○	○	○	○	○
during your **non-TSI** activities during this module?	○	○	○	○	○

Optional: Please explain your answer

***7. *In your own words*, briefly define each of the TSI Phases on Inquiry**

Initiation	
Invention	
Investigation	
Interpretation	
Instruction	

***8. *In your own words*, describe what the TSI Phases of Inquiry demonstrate.**

***9. How do you think the TSI phases of Inquiry are different than the traditional scientific method?**

***10. *In your own words,* describe what the TSI Modes of Inquiry demonstrate.**

***11. Which TSI mode(s) do you think you utilize *the most* in your teaching? Why?**

***12. Which TSI mode(s) do you think you utilize *the least* in your teaching? Why?**

***13. TSI advocates the teaching of disciplinary inquiry, teaching inquiry through the authentic practice of science. To replicate this process in the classroom, in TSI students are scientists, the teacher is the research director, and the classroom is the scientific community.**

	Not a lot (1)	(2)	(3)	(4)	A lot (5)
To what extent do you think you teach disciplinary inquiry when doing TSI activities?	○	○	○	○	○
To what extent to you think you teach disciplinary inquiry when doing non-TSI activities?	○	○	○	○	○

Optional. Please explain your answer.

***14. To what extent do you think your overall understanding of inquiry has changed over the course of this module?**

Not at all (1)	(2)	(3)	(4)	Very much (5)
○	○	○	○	○

Optional. Please explain your answer.

Module 4 Review

15.** ***Use of TSI Terminology.

To what extent are you using TSI terminology with your students when you do *TSI* activities?

	Not useful (1)	(2)	(3)	(4)	Very useful (5)	N/A
Phases of Inquiry	○	○	○	○	○	○
Modes of Inquiry	○	○	○	○	○	○
Demeanors of scientists	○	○	○	○	○	○
Practices of scientists	○	○	○	○	○	○
Metacognition	○	○	○	○	○	○

Optional. Please explain any of your answers.

16.** ***Use of TSI Terminology.

To what extent are you using TSI terminology with your students when you do *non-TSI* activities?

	Not useful (1)	(2)	(3)	(4)	Very useful (5)	N/A
Phases of Inquiry	○	○	○	○	○	○
Modes of Inquiry	○	○	○	○	○	○
Demeanors of scientists	○	○	○	○	○	○
Practices of scientists	○	○	○	○	○	○
Metacognition	○	○	○	○	○	○

Optional. Please explain any of your answers.

17.** ***Explicitly Addressing TSI.

If you are explicitly addressing (e.g. defining and using terms) any of the following TSI pedagogy components with your students, how useful do you think they are in helping your students understand the process of science?

	Not useful (1)	(2)	(3)	(4)	Very useful (5)	N/A
Phases of Inquiry	○	○	○	○	○	○
Modes of Inquiry	○	○	○	○	○	○
Demeanors of scientists	○	○	○	○	○	○
Practices of scientists	○	○	○	○	○	○
Metacognition	○	○	○	○	○	○

Optional. Please explain any of your answers.

18.** ***Implementing TSI activities.

To what extent are you taking into consideration the following TSI pedagogy components when planning and implementing TSI activities?

	Not at all (1)	(2)	(3)	(4)	A lot (5)
Phases of Inquiry	○	○	○	○	○
Modes of Inquiry	○	○	○	○	○
Demeanors of scientists	○	○	○	○	○
Practices of scientists	○	○	○	○	○
Metacognition	○	○	○	○	○
TSI Inquiry Questioning Strategies	○	○	○	○	○
TSI Themes	○	○	○	○	○
TSI Practices of Inquiry Teaching	○	○	○	○	○

Optional. Please explain any of your answers.

19.** ***Implementing non-TSI activities.

To what extent are you taking into consideration the following TSI pedagogy components when planning and implementing non-TSI activities?

	Not at all (1)	(2)	(3)	(4)	A lot (5)
Phases of Inquiry	○	○	○	○	○
Modes of Inquiry	○	○	○	○	○
Demeanors of scientists	○	○	○	○	○
Practices of scientists	○	○	○	○	○
Metacognition	○	○	○	○	○
TSI Inquiry Questioning Strategies	○	○	○	○	○
TSI Themes	○	○	○	○	○
TSI Practices of Inquiry Teaching	○	○	○	○	○

Optional. Please explain any of your answers.

20.** ***Communication of TSI.

To what extent do you think each of the following TSI pedagogy components helps *you* communicate the process of science to your students?

	Not useful (1)	(2)	(3)	(4)	Very useful (5)
Phases of Inquiry	○	○	○	○	○
Modes of Inquiry	○	○	○	○	○
Demeanors of scientists	○	○	○	○	○
Practices of scientists	○	○	○	○	○
Metacognition	○	○	○	○	○
TSI Inquiry Questioning Strategies	○	○	○	○	○
TSI Themes	○	○	○	○	○
TSI Practices of Inquiry Teaching	○	○	○	○	○

Optional. Please explain any of your answers.

Module 4 Student Impact

***21. How does the *level of engagement* of your students when doing TSI activities compare, on average, to other non-TSI activities?**

	Less engaged (1)	(2)	(3)	(4)	More engaged (5)	N/A
Overall class	○	○	○	○	○	○
ELL students	○	○	○	○	○	○
SPED students	○	○	○	○	○	○
Gifted students	○	○	○	○	○	○

Optional. Please explain any of your answers.

***22. How does the *level of behavioral problems* in your class when doing TSI activities compare, on average, to behavior problems of your class when doing non-TSI activities?**

	Less behavioral problems (1)	(2)	(3)	(4)	More behavioral problems (5)	N/A
Overall class	○	○	○	○	○	○
ELL students	○	○	○	○	○	○
SPED students	○	○	○	○	○	○
Gifted students	○	○	○	○	○	○

Optional. Please explain any of your answers.

***23. How does the *level of perseverance* of your students when doing TSI activities compare, on average, to the perseverance of your students when doing non-TSI activities?**

	Less perseverance (1)	(2)	(3)	(4)	More perseverance (5)	N/A
Overall class	○	○	○	○	○	○
ELL students	○	○	○	○	○	○
SPED students	○	○	○	○	○	○
Gifted students	○	○	○	○	○	○

Optional. Please explain any of your answers.

***24. How does *the number of scientifically oriented questions* posed by your students when doing TSI activities compare, on average, to the number of questions posed by your students when doing non-TSI activities?**

	Less questions (1)	(2)	(3)	(4)	More questions (5)	N/A
Overall class	○	○	○	○	○	○
ELL students	○	○	○	○	○	○
SPED students	○	○	○	○	○	○
Gifted students	○	○	○	○	○	○

Optional. Please explain any of your answers.

***25. How does the number of times students came into your class voluntarily (e.g. during lunch or after school) to do *further investigations* on TSI activities compare, on average, to the number times students came in voluntarily when doing non-TSI activities?**

	Less further investigations (1)	(2)	(3)	(4)	More further investigations (5)	N/A
Overall class	○	○	○	○	○	○
ELL students	○	○	○	○	○	○
SPED students	○	○	○	○	○	○
Gifted students	○	○	○	○	○	○

Optional. Please explain any of your answers.

***26. How does the *level of homework completion* when doing TSI activities compare, on average, to the level of homework completion when doing non-TSI activities?**

	Less homework completion (1)	(2)	(3)	(4)	More homework completion (5)	N/A
Overall class	○	○	○	○	○	○
ELL students	○	○	○	○	○	○
SPED students	○	○	○	○	○	○
Gifted students	○	○	○	○	○	○

Optional. Please explain any of your answers.

27. *Optional:* **Did you notice any other student impacts when implementing the TSI activities (e.g. confidence, physical or emotional well-being, achievement on assessments)?**

28. *Optional.* **Please provide any additional comments about your experiences in this module.**

OPPORTUNITY TO LEARN SURVEY

(This questionnaire was repeated after each of the four modules and modified for appropriate content.)

Joanna Philippoff, and Brian E. Lawton

Module 4: Ecological - Opportunity to Learn Survey

Opportunity to Learn Questionnaire

Module 4: Ecological Aquatic Science

This questionnaire asks you rate, for each quiz question, how much exposure your students had to the content in the question. In other words, think about the degree to which your students had the opportunity to learn this content when they experienced the TSI lessons in your classroom and then provide a rating from 0 to 5, where 0 = they did not have any exposure to this content, and 5 = they had a lot of exposure to this content.

The purpose of this questionnaire is primarily to assess the Exploring Our Fluid Earth curriculum and secondarily to collect information about how you are implementing activities. This questionnaire is based on the student content questions for this module. How well your students did on their surveys is not a reflection of you or your teaching.

Be assured that there are no right or wrong responses. *Please do not complete this survey until you have finished all of the activities for this module and have given your students the Post Content Survey.*

This assessment will take about 10 minutes to complete. You will need to submit all of your answers in one sitting.

Thanks!

TSI Research Team

***1. Enter your *first* name:**

***2. Enter your *last* name:**

Module 4: Ecological - Opportunity to Learn Questionnaire

This questionnaire asks you rate, for each quiz question, how much exposure your students had to the content in the question. In other words, think about the degree to which your students had the opportunity to learn this content when they experienced the TSI lessons in your classroom and then provide a rating from 0 to 5, where 0 = they did not have any exposure to this content, and 5 = they had a lot of exposure to this content.

***3. From this sample of pizza, what can you say about the pizza? The pizza:**

a. does not have olives.
b. has more pepperoni than mushrooms.
c. has mushrooms, peppers, and pepperoni.
d. is in the shape of a square.

They did not have any exposure to this content. (0)	(1)	(2)	(3)	(4)	They had a lot of exposure to this content (5)
○	○	○	○	○	○

***4. Which of the following would give you the most accurate sample of the biodiversity in a coastal area?**

a. a group of the most common organisms
b. at least one of each organism, including those that are rare
c. a representative portion of the organisms
d. all of the organisms in the area

They did not have any exposure to this content. (0)	(1)	(2)	(3)	(4)	They had a lot of exposure to this content (5)
○	○	○	○	○	○

***5. An individual sample taken during the study of an environment:**

a. should be analyzed in the same way as every other sample.
b. should have the same results as all other samples.
c. can give you a complete description of the environment.
d. has to be large enough to capture all of the variety in the environment.

They did not have any exposure to this content. (0)	(1)	(2)	(3)	(4)	They had a lot of exposure to this content (5)
○	○	○	○	○	○

***6. Andrea set up a mouse maze, She put carrots at one end and tomatoes at the other end. Andrea put a mouse in the middle of her maze. The mouse went to the end of the maze with the carrots. What can Andrea say about mice?**

a. Mice like carrots more than tomatoes.
b. This mouse likes carrots more than tomatoes, but that might not be true of all mice.
c. There is not enough evidence to say anything about mice, carrots, or tomatoes.
d. Mice are good at completing mazes if there are carrots at the end.

They did not have any exposure to this content. (0)	(1)	(2)	(3)	(4)	They had a lot of exposure to this content (5)
○	○	○	○	○	○

***7. When sampling the water in a tidepool, each sample might not be representative of the whole tidepool. For this reason, you should take several different water samples and then:**

a. mix them together before testing.
b. remove samples that do not seem to represent the tidepool.
c. calculate an average after testing each sample.
d. go back for new samples if you do not get the results you expect.

They did not have any exposure to this content. (0)	(1)	(2)	(3)	(4)	They had a lot of exposure to this content (5)
○	○	○	○	○	○

***8. Leilani is going to very carefully examine and describe a coastal area. She is going to be doing a scientific _____.**

a. survey
b. experiment
c. sampling
d. evaluation

They did not have any exposure to this content. (0)	(1)	(2)	(3)	(4)	They had a lot of exposure to this content (5)
○	○	○	○	○	○

***9. One technique that scientists use to help them sample is to count whatever they find under a specific point along a line. This is known as the _____ method.**

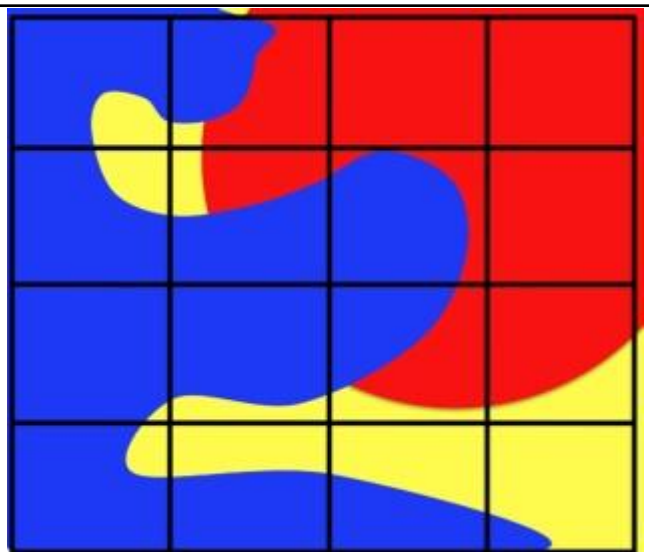
a. transect point intercept
b. quadrat point intercept
c. transect percent cover
d. band transect

They did not have any exposure to this content. (0)	(1)	(2)	(3)	(4)	They had a lot of exposure to this content (5)
○	○	○	○	○	○

***10. Which of the following scientific tools would you use if you wanted to describe a large uniform area, like a field or a sandy beach?**

a. transect
b. quadrat
c. identification field guide
d. camera

They did not have any exposure to this content. (0)	(1)	(2)	(3)	(4)	They had a lot of exposure to this content (5)
○	○	○	○	○	○



***11. Which of the following scientific tools would you use if you wanted to describe a small area with a lot of small, well-hidden organisms?**

a. transect
b. quadrat
c. identification field guide
d. camera

They did not have any exposure to this content. (0)	(1)	(2)	(3)	(4)	They had a lot of exposure to this content (5)
○	○	○	○	○	○

***12. Which of the colors in the diagram above would be counted the most using the quadrat point intercept method?**

a. blue
b. red
c. yellow
d. black

They did not have any exposure to this content. (0)	(1)	(2)	(3)	(4)	They had a lot of exposure to this content (5)
○	○	○	○	○	○

***13. Responsibility, courtesy, respect for the ideas of others, honesty, and open-mindedness are some of the _____ of scientists.**

a. methods
b. demeanors
c. phases
d. modes

They did not have any exposure to this content. (0)	(1)	(2)	(3)	(4)	They had a lot of exposure to this content (5)
○	○	○	○	○	○

***14. Which of the following is the most accurate representation of scientific practice in real-life?**

a. If the results of multiple scientific experiments are conflicting, then the findings are not useful.
b. Scientists present their research to other scientists so their results can be discussed and replicated.
c. Scientists work on their research independently and in isolation.
d. Scientists all work in the same way because there is only one way to do science.

They did not have any exposure to this content. (0)	(1)	(2)	(3)	(4)	They had a lot of exposure to this content (5)
○	○	○	○	○	○

***15. An awareness of your thought process while you are thinking is:**

a. metacognition.
b. a mode of inquiry.
c. curiosity.
d. concentration.

They did not have any exposure to this content. (0)	(1)	(2)	(3)	(4)	They had a lot of exposure to this content (5)
○	○	○	○	○	○

***16. Scientific inquiry:**

a. always follows the same steps in the same order.
b. is how students imitate doing science.
c. involves continually asking new questions and trying new ideas.
d. requires that you develop and carry out experiments.

They did not have any exposure to this content. (0)	(1)	(2)	(3)	(4)	They had a lot of exposure to this content (5)
○	○	○	○	○	○

***17. The phase of inquiry where you communicate and share information with others is:**

a. Initiation
b. Invention
c. Interpretation
d. Instruction

They did not have any exposure to this content. (0)	(1)	(2)	(3)	(4)	They had a lot of exposure to this content (5)
○	○	○	○	○	○

***18. When you realize an activity is relevant to your life, you are in the _____ phase of inquiry.**

a. Initiation
b. Invention
c. Interpretation
d. Instruction

They did not have any exposure to this content. (0)	(1)	(2)	(3)	(4)	They had a lot of exposure to this content (5)
○	○	○	○	○	○

***19. For your science fair project, you decide to compare two different detergents and how well they remove grass stains from white cotton cloth. This is an example of the ___ mode of inquiry.**

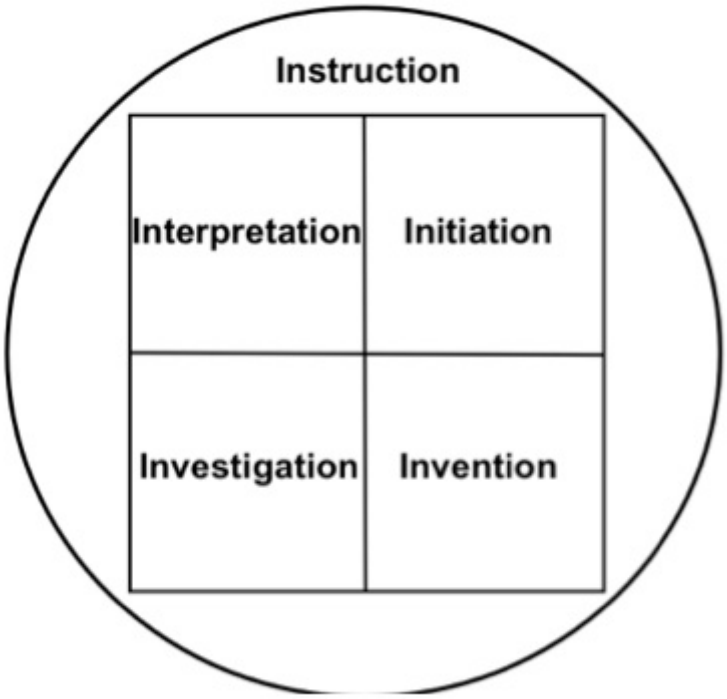
a. transitive knowledge
b. induction
c. product evaluation
d. technology

They did not have any exposure to this content. (0)	(1)	(2)	(3)	(4)	They had a lot of exposure to this content (5)
○	○	○	○	○	○

***20. Scientific inquiry includes authoritative investigations, such as:**

a. careful descriptions of things or events.
b. repeating tests to make sure something happens the same way each time.
c. asking questions of people who have expert knowledge.
d. using information from one field in a different field.

They did not have any exposure to this content. (0)	(1)	(2)	(3)	(4)	They had a lot of exposure to this content (5)
○	○	○	○	○	○



***21. In your own words, explain how the Teaching Science as Inquiry (TSI) phases of inquiry (shown above) describe the process of science.**

They did not have any exposure to this content. (0)	(1)	(2)	(3)	(4)	They had a lot of exposure to this content (5)
○	○	○	○	○	○

Modes of Inquiry: Curiosity, Description, Authoritative Knowledge, De
Technology, Product Evaluation, Experimentation, Replication, Transitiv

***22. In your own words, explain what the Teaching Science as Inquiry (TSI) modes of inquiry (listed above) represent.**

They did not have any exposure to this content. (0)	(1)	(2)	(3)	(4)	They had a lot of exposure to this content (5)
○	○	○	○	○	○

23. Please let us know if you have any comments on this survey or want to explain any of your answers.

INSTRUCTIONS TO TEACHERS FOR ADMINISTERING THE STUDENT SCIENCE CONTENT ASSESSMENT

Joanna Philippoff and Kanesa Duncan Seraphin

Instructions for Administering Module 4 Student Content Surveys

These are instructions for administering the Module 4 Ecological Aquatic Science Student Content Surveys to your focus class.

These content survey questions will eventually be part of the *Exploring Our Fluid Earth* (EOFE) curriculum. Your students' participation is considered coursework because they are using the EOFE curriculum in their class. These surveys are not considered research surveys. The surveys may be administered to students who have not given consent to participate in the research portion of the project. However, we still cannot accept surveys from students who have not given consent.

We are collecting the questions so we can improve the curriculum. In order to know if and how student content knowledge is changing as a result of your implementation of the EOFE curriculum, we need to collect both pre and post surveys.

- Administer the **pre** content survey **before** implementing **any** of the module activities.
- Administer the **post** content survey **after** implementing **all** of the module activities.

Fill out the following table to provide us details about when and how you administered the surveys. Check off which students completed the pre survey and which completed the post survey on your class roster. ***Bring the completed pre and post content surveys to the next workshop.***

Unlike the research student questionnaire, you can use these surveys in your instruction. Although we do not want students to be graded on their answers, you can look at their responses to see where they are in their understanding of the material and talk about the questions with your students. ***Please have these discussions after they answer the post survey***. Please also do not "teach to the survey" as we are interested in your student's authentic responses.

Questions about the Pre Survey
1. What **date** was the pre survey given to students?
2. Explain how the pre survey was given to the students *(e.g. bellwork)*:
3. How long were students given to complete the pre survey?
4. How many students completed the pre survey?
Questions about the Post Survey
5. What **date** was the post survey given to students?
6. Explain how the post survey was given to the students *(e.g. bellwork)*:
7. How long were students given to complete the post survey?
8. How many students completed the post survey?

Use this section to share your thoughts on the questions. Please let us know if and how you used the questions in your instruction.

Mahalo!

STUDENT SCIENCE CONTENT ASSESSMENT

MODULE 1: PHYSICAL AQUATIC SCIENCE

Joanna Philippoff, Kanesa Duncan Seraphin, Lauren J. Kaupp, and George M. Harrison

Physical Science Questions - PRE **Name** _____

Directions: This is a questionnaire about your knowledge and beliefs about science. You will not be graded on your answers, but it is important that you answer each of the questions to the best of your knowledge. For each question, there may be more than one possible answer. ***Select the single best answer*** and circle the letter for the answer. If you do not know the answer to a question, make your best guess. Be sure to read the whole question and *all* the possible answers.

1. The density of ocean water:
   a. is the same everywhere in the world.
   b. varies by location.
   c. varies by depth.
   d. varies by *both* location and depth.

2. Water at the surface of the ocean is _____ water in the deepest parts of the ocean.
   a. warmer than
   b. warmer and less salty than
   c. less salty than
   d. the same as

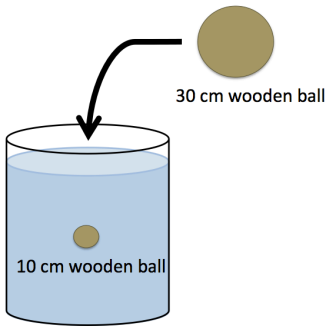
3. Icebergs are composed of freshwater. When an iceberg begin to melt, the melting iceberg water will
   a. mix evenly with the ocean water
   b. sink about one meter below the surface of the ocean
   c. sink below the ocean water
   d. float on top of the ocean water

4. The volume of a metal cube is 4 cm^3. The mass of the same cube is 2 g. How could you determine the density of the cube?
   a. Density = $4cm^3 + 2g$
   b. Density = $4cm^3 – 2g$
   c. Density = $4cm^3$ x 2g
   d. Density = $4cm^3 \div 2g$

5. When the gravitational force on an object is less than the buoyant force, the object will:
   a. sink.
   b. rise.
   c. be neutrally buoyant (subsurface float).
   d. increase in density.

6. To make sugar water, you add 10 grams of sugar to 1 liter of tap water. Compared to the tap water, the sugar water:
   a. is less dense.
   b. is more dense.
   c. is the same density.
   d. has less of water.

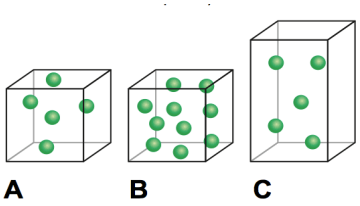
7. You have two wooden balls of the same material. One ball is 10 cm in diameter and the second ball is 30 cm in diameter. When you put the 10 cm ball into a bucket of water, it neither floats to the top nor sinks to the bottom, but subsurface floats at a depth about halfway between the bottom of the bucket and the surface of the water. If you put the 30 cm ball into the bucket, what do you think will happen? The larger ball will:



   a. sink to a depth about 3 times deeper than the smaller ball.
   b. sink all the way to the bottom of the bucket.
   c. subsurface float at the same depth as the smaller ball.
   d. subsurface float closer to surface of the water than the smaller ball.

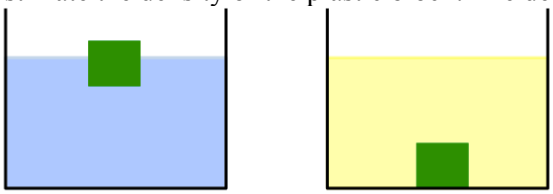
8. In this figure, green circles represent matter. Which of the following is the *least* dense?

   a. Object A
   b. Object B
   c. Object C
   d. They are all of equal density



9. A pebble is dropped into a cup of water and sinks to the bottom of the cup. A solid metal bead of exactly the same size is dropped into the same cup and also sinks to the bottom of the cup. Based on your observations, you can infer that the metal bead and the pebble:
   a. have the same density.
   b. are the same mass.
   c. are both denser than water.
   d. are both as dense as water.

10. The density of water is greater than the density of cooking oil. Erin put a green plastic block into each of the two liquids. The plastic block floated in water but sank in cooking oil. Estimate the density of the plastic block. The density of the plastic block is



Water Cooking Oil

   a. less dense than both the water and cooking oil.
   b. less dense than the water but more dense than the cooking oil.
   c. the same density as the cooking oil.
   d. the same density as the water.

Directions: Please tell us how true you believe these statements are. For each question below, circle the number on the scale that matches how true you think the statement is. Answer based on your ability to *learn*, not on your ability to get a good grade. *Circle **only one number** for each question.* The scale numbers are defined as:

Not at all true	Somewhat true				Very true
0	1	2	3	4	5

11. I use different learning strategies depending on the situation.

Not at all true	Somewhat true				Very true
0	1	2	3	4	5

12. I have control over how well I learn.

Not at all true	Somewhat true				Very true
0	1	2	3	4	5

13. I can motivate myself to learn when I need to.

Not at all true	Somewhat true				Very true
0	1	2	3	4	5

14. I am aware of what strategies I use when I study.

Not at all true	Somewhat true				Very true
0	1	2	3	4	5

15. I reevaluate my assumptions when I get confused

Not at all true	Somewhat true				Very true
0	1	2	3	4	5

STUDENT SCIENCE CONTENT ASSESSMENT

MODULE 2: CHEMICAL AQUATIC SCIENCE

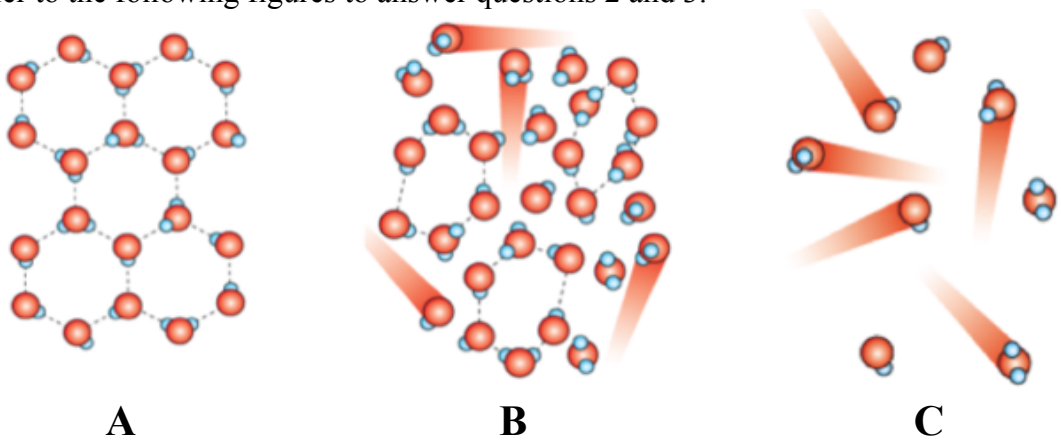
Lauren J. Kaupp, Kanesa Duncan Seraphin, Joanna Philippoff, and George M. Harrison

TSI aquatic Chemical Science Questions - PRE **Name** _____

Directions: This is a questionnaire about your knowledge and beliefs about science. You will not be graded on your answers but it is important that you answer each of the questions to the best of your knowledge. For each question, there may be more than one possible answer. ***Select the single best answer*** and circle the letter for the answer. If you do not know the answer to a question, make your best guess. Be sure to read the whole question and *all* the possible answers.

1. In a covalent bond, electrons are:
   a. shared.
   b. not involved.
   c. transferred.
   d. orbiting.

Refer to the following figures to answer questions 2 and 3.



A **B** **C**

2. In the figures above, the red circles (oxygen) and the blue circles (hydrogen) represent water molecules in liquid water, gas, and solid ice. Which of the figures ***best*** represents what molecules look in liquid water?
   a. Figure A
   b. Figure B
   c. Figure C

3. In figures A and B above, what type of bonds do the dotted lines represent?
   a. Hydrogen bonds
   b. Ionic bonds
   c. Covalent bonds
   d. Atomic bonds

4. After it rains, soil is able to hold water and become wet mud. What is the property of water that helps explain its ability to make soil wet and form mud?
   a. Surface tension
   b. Holding capacity
   c. Adhesion
   d. Cohesion

5. Which of the following is possible because of capillary action?
   a. Water droplets form into bubbles when they are on glass surfaces.
   b. Water can move up small tubes against the pull of gravity.
   c. Water can dissolve substances such as salt and sugar.
   d. Water can move between cells in organisms.

6. In the picture on the left, the water appears to be sticking together even though it is not in a container. Which of the following forces best explains the ability of water to stick together in this way?
   a. Cohesion
   b. Pressure
   c. Adhesion
   d. Holding capacity

7. The force that allows water to be piled high on the penny is called _____.
   a. adhesion
   b. cohesion
   c. capillary action
   d. pressure

8. Hydrogen bonds:
   a. occur when two atoms share electrons equally.
   b. are a weak attraction between molecules.
   c. are strong bonds within a molecule.
   d. are a side effect of ionic bonds.

9. Some small bugs, like the one in the picture on the left, can walk on water due to the surface tension of water. What causes the surface tension of water?
   a. A film on the surface of the water.
   b. Electric interactions between the atoms in water and the atoms in the air.
   c. Attraction between water molecules due to polarity of the molecules.
   d. The water is more dense than the bug, so the bug can walk on water.

10. Pure freshwater is a(n) _____.
    a. atom
    b. compound
    c. mixture
    d. element

STUDENT SCIENCE CONTENT ASSESSMENT

MODULE 3: BIOLOGICAL AQUATIC SCIENCE

Kanesa Duncan Seraphin, Joanna Philippoff, Lauren J. Kaupp, and George M. Harrison

Biological Science Questions - POST **Name** _____

Directions: This is a questionnaire about your knowledge and beliefs about science. You will not be graded on your answers, but it is important that you answer each of the questions to the best of your knowledge. For each question, there may be more than one possible answer. ***Select the single best answer*** and circle the letter for the answer. If you do not know the answer to a question, make your best guess. Be sure to read the whole question and *all* the possible answers.

1. A scientific hypothesis must be about something we can:
   a. see.
   b. predict.
   c. test.
   d. apply to all situations.

2. Which of the following statements best describes the difference between theories and hypotheses in science?
   a. Theories are hypotheses that have been proven to be true.
   b. A hypothesis may not be correct, but a theory has been proven to be true.
   c. Theories are supported by evidence from lots of hypothesis-testing.
   d. Theories and hypotheses are different words for the same thing.

3. A friend tells you that Sparkle laundry detergent is better than Snow Fresh laundry detergent. You know this is an **opinion** because the following statement is true:
   a. There is a mathematical equation predicting that Sparkle is better.
   b. There is scientific evidence supporting the claim that Sparkle is better.
   c. You can scientifically test whether Sparkle is better.
   d. Whether something is better than something else is a personal belief.

4. Select the word that best describes this statement: "John Dalton is one of the most important scientists because he came up with many of the ideas in Atomic Theory."
   a. theory
   b. opinion
   c. idea
   d. hypothesis

5. Your friend says he has a theory that the Gladiators football team will be undefeated this year. Why would you say that your friend's theory is *not* scientific?
   a. A newspaper article has predicted that another football team, the Bears, will go undefeated.
   b. It is *not* an explanation that brings together a well-supported set of observations.
   c. The way it is worded; it cannot be supported with evidence.
   d. It is *not* general enough, it does not predict the record of other teams.

6. Fish that live in the open ocean, like those shown above, look similar because of the process of natural selection. Another way to say this is:
   a. fish that live in the open ocean perfected their bodies to match their environment.
   b. the open ocean changed the fish so that they could live a long time.
   c. fish with characteristics that helped them survive and reproduce in the open ocean passed along their characteristics to their children.
   d. fish that did *not* look like these open-ocean fish died.

7. The flu virus most likely spreads because:
   a. it keeps adapting to new environments.
   b. it wants to infect people everywhere.
   c. it is smarter and stronger than most people.
   d. the virus is made of DNA.

8. Bees and birds have body parts modified into wings because:
   a. nature knew these organisms needed to fly, so nature gave them wings.
   b. bees evolved from birds.
   c. bees and birds adapted similar structures in order to fly.
   d. bees and birds are closely related.

9. Which of the following is an example of genetic variation?
   a. Lisa and Matt have different eye colors.
   b. Lisa is older than Matt.
   c. Lisa has a scar; Matt does not.
   d. Lisa eats meat; Matt is a vegetarian.

10. Over the past several decades, natural selection has caused populations of *Staphylococcus aureus* (a bacteria that can cause infections) to evolve resistance to most antibiotics. If humans stopped using antibiotics, what do you predict would happen to these *S. aureus* bacteria populations?
    a. The bacteria will go extinct without the antibiotic.
    b. The number of bacteria that are resistant to the antibiotic will increase.
    c. The bacteria will begin colonizing new environments.
    d. The number of bacteria *not* resistant to the antibiotic will increase.

STUDENT SCIENCE CONTENT ASSESSMENT

MODULE 4: ECOLOGICAL AQUATIC SCIENCE

Joanna Philippoff, Kanesa Duncan Seraphin, and George M. Harrison

A product of Curriculum Research & Development Group (CRDG) College of Education, University of Hawai'i at Mānoa

Ecological Science Questions - POST **Name** _____

Directions: This is a questionnaire about your knowledge and beliefs about science. You will not be graded on your answers, but it is important that you answer each of the questions to the best of your knowledge. For each question, there may be more than one possible answer. ***Select the single best answer*** and circle the letter for the answer. If you do not know the answer to a question, make your best guess. Be sure to read the whole question and *all* the possible answers.

1. From this *sample* of pizza, what can you say about the pizza? The pizza:
   a. does not have olives.
   b. has more pepperoni than mushrooms.
   c. has mushrooms, peppers, and pepperoni.
   d. is in the shape of a square.

2. Which of the following would give you the most accurate *sample* of the biodiversity in a coastal area?
   a. a group of the most common organisms
   b. at least one of each organism, including those that are rare
   c. a representative portion of the organisms
   d. all of the organisms in the area

3. An individual sample taken during the study of an environment:
   a. should be analyzed in the same way as every other sample.
   b. should have the same results as all other samples.
   c. can give you a complete description of the environment.
   d. has to be large enough to capture all of the variety in the environment.

4. Andrea set up a mouse maze, She put carrots at one end and tomatoes at the other end. Andrea put a mouse in the middle of her maze. The mouse went to the end of the maze with the carrots. What can Andrea say about mice?
   a. Mice like carrots more than tomatoes.
   b. This mouse likes carrots more than tomatoes, but that might not be true of all mice.
   c. There is not enough evidence to say anything about mice, carrots, or tomatoes.
   d. Mice are good at completing mazes if there are carrots at the end.

5. When sampling the water in a tidepool, each sample might not be representative of the whole tidepool. For this reason, you should take several different water samples and then:
   a. mix them together before testing.
   b. remove samples that do not seem to represent the tidepool.
   c. calculate an average after testing each sample.
   d. go back for new samples if you do not get the results you expect.

6. Leilani is going to very carefully examine and describe a coastal area. She is going to be doing a scientific _____.

a. survey
b. experiment
c. sampling
d. evaluation

7. One technique that scientists use to help them sample is to count whatever they find under a specific point along a line. This is known as the _____ method.

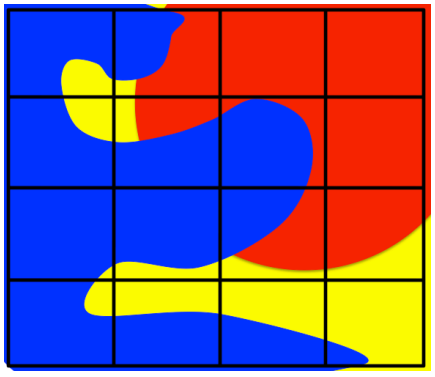
a. transect point intercept
b. quadrat point intercept
c. transect percent cover
d. band transect

8. Which of the following scientific tools would you use if you wanted to describe a large uniform area, like a field or a sandy beach?

a. transect
b. quadrat
c. identification field guide
d. camera

9. Which of the following scientific tools would you use if you wanted to describe a small area with a lot of small, well-hidden organisms?

a. transect
b. quadrat
c. identification field guide
d. camera



10. Which of the colors in the diagram above would be counted the most using the quadrat point intercept method?

a. blue
b. red
c. yellow
d. black

11. Responsibility, courtesy, respect for the ideas of others, honesty, and open-mindedness are some of the _____ of scientists.
    a. methods
    b. demeanors
    c. phases
    d. modes

12. Which of the following is the most accurate representation of scientific practice in real-life?
    a. If the results of multiple scientific experiments are conflicting, then the findings are not useful.
    b. Scientists present their research to other scientists so their results can be discussed and replicated.
    c. Scientists work on their research independently and in isolation.
    d. Scientists all work in the same way because there is only one way to do science.

13. An awareness of your thought process while you are thinking is:
    a. metacognition.
    b. a mode of inquiry.
    c. curiosity.
    d. concentration.

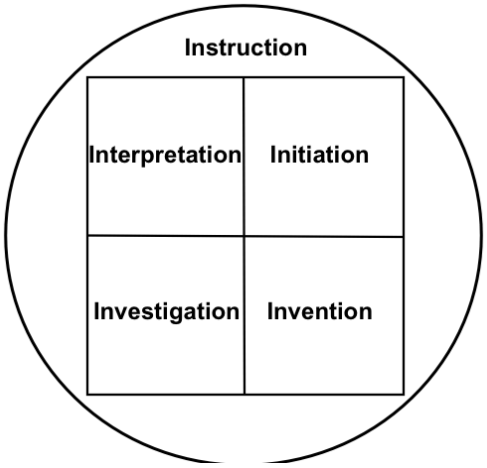
14. Scientific inquiry:
    a. always follows the same steps in the same order.
    b. is how students imitate doing science.
    c. involves continually asking new questions and trying new ideas.
    d. requires that you develop and carry out experiments.

15. The phase of inquiry where you communicate and share information with others is:
    a. Initiation
    b. Invention
    c. Interpretation
    d. Instruction

16. When you realize an activity is relevant to your life, you are in the _____ phase of inquiry.
    a. Initiation
    b. Invention
    c. Interpretation
    d. Instruction

17. For your science fair project, you decide to compare two different detergents and how well they remove grass stains from white cotton cloth. This is an example of the ____ mode of inquiry.
    a. transitive knowledge
    b. induction
    c. product evaluation
    d. technology

18. Scientific inquiry includes authoritative investigations, such as:
    a. careful descriptions of things or events.
    b. repeating tests to make sure something happens the same way each time.
    c. asking questions of people who have expert knowledge.
    d. using information from one field in a different field.



19. In your own words, explain how the Teaching Science as Inquiry (TSI) **phases** of inquiry (shown above) describe the process of science.

Modes of Inquiry: Curiosity, Description, Authoritative Knowledge, Deduction, Induction, Technology, Product Evaluation, Experimentation, Replication, Transitive Knowledge

20. In your own words, explain what the Teaching Science as Inquiry (TSI) **modes** of inquiry (listed above) represent.

Directions: Please tell us how true you believe these statements are. For each question below, circle the number on the scale that matches how true you think the statement is. Answer based on your ability to *learn*, not on your ability to get a good grade. *Circle **only one number** for each question.*

21. I use different learning strategies depending on the situation.

Not at all true	Somewhat true				Very true
0	1	2	3	4	5

22. I have control over how well I learn.

Not at all true	Somewhat true				Very true
0	1	2	3	4	5

23. I can motivate myself to learn when I need to.

Not at all true	Somewhat true				Very true
0	1	2	3	4	5

24. I am aware of what strategies I use when I study.

Not at all true	Somewhat true				Very true
0	1	2	3	4	5

25. I reevaluate my assumptions when I get confused.

Not at all true	Somewhat true				Very true
0	1	2	3	4	5