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Chapter 1

SCIENCE TEACHERS' PROFESSIONAL GROWTH AND THE COMMUNICATION IN SCIENCE INQUIRY PROJECT

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ABSTRACT

The *Communication in Science Inquiry Project* (CISIP) a National Science Foundation-funded, standards-based model of a scientific classroom discourse community (SCDC) was designed to meet the need for highly-qualified teachers and science education reform. The model included: (a) inquiry; (b) oral discourse; (c) written discourse; (d) academic language development, and (e) learning principles. Research and evaluation feedback were mechanisms by which CISIP become self-regulating, promoting instructional change and incorporating more aspects of inquiry-based learning with academic language development strategies. The program underwent a philosophical shift from teachers-as-consumers to teachers-as-producers based on classroom observations using a professional development-aligned classroom observation instrument that showed teachers were not implementing the CISIP model. Research indicated that CISIP was effective in changing how teachers taught science by providing sustained, long-term professional development. Teachers who participated for greater than one year showed the most change in their teaching practices, becoming more aligned with science education standards documents. Current and future directions in science teacher professional development (PD) include: (a) studying how teacher PD affects student learning; (b) building validity arguments for research instruments to be used for generalizing findings from multiple PD contexts, and (c) the need for improving PD

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providers' understanding of how to conduct effective PD and engage in research that contributes to our understanding of 21st century science education reform.

INTRODUCTION TO SCIENCE TEACHER PROFESSIONAL DEVELOPMENT

Teacher professional development, while a relatively new phenomenon beginning in the 1970s (Lieberman, 1992), is important because preservice teacher preparation is limited in scope by its length of time, clinical apprenticeship, and cognitive load for learning demanding tasks and represents just the beginning of teachers' professional development. Novice teachers in particular face a steep learning curve and need supportive induction programs to continue to develop their practice so that it aligns with standards-based teaching (AAAS, 1991; AAAS, 1993; Banilower, Trygstad and Smith, 2015). Teacher professional development activities commonly focus on learning more content, pedagogy, or both. Teachers' learning through professional development (PD) programs often occurs in groups of teachers as they work with both the PD providers and each other as part of a community of practice that supports situated learning (Lave and Wenger, 1991; Wenger, 1998). This chapter mainly focuses on U.S. secondary (grades 7-12) science teacher PD through a standards-aligned (i.e., *National Science Education Standards*, 1996; *Next Generation Science Standards*, 2013) PD program and research on teacher learning and some effects of that learning in the classroom.

Research studies in science teacher PD indicate that teacher PD providers have, until recently, understood little about how science teachers apply what they learn from PD to their classrooms (Hewson, 2007). In the last five to ten years, increasingly more research has been conducted to learn about the effects of science teacher PD (van Driel, Meirink, van Veen, and Zwart, 2012). Recent research has led to a general consensus that there are six aspects of effective and useful PD programs: (a) a clear focus on classroom practice that involves both subject matter and pedagogical knowledge; (b) active and inquiry-based learning; (c) collaborative learning; (d) longer-term duration of PD and sustainability; (e) coherence in its goals and design; and (f) attentions to school organizational conditions (van Driel et al., 2012). Thus, expectations for PD, and indeed the research thereof, have risen and both should strive to determine the degree to which teacher PD has been effective. In the United States, effective teacher PD is a critical issue at state and national levels, especially in light of the *Next Generation Science Standards* and its intent to develop a scientifically literate society.

CONTEXT OF CISIP PROJECT

Proposal Development

The *Communication in Science Inquiry Project* (CISIP) was a five-year teacher professional development program funded by the National Science Foundation (NSF). Michael Lang of the National Center for Teacher Education (NCTE) located at the Maricopa Community College District brought together Dale Baker and graduate students at Arizona

State University, faculty from the Maricopa Community Colleges, and secondary science and language arts teacher leaders in several school districts with large numbers of English Language Learners (ELLs) to work together on a proposal. Multiple meetings were held to determine district needs, the roles of the partners, the design of the PD, and the research focus.

In response to the NSF guidelines, we decided to address communication in science with special attention to the needs of ELLs because of the expertise of the professional development design and provider team. We also agreed that a team approach where English language arts teachers could support science teachers in helping their students communicate in science would strengthen our model. Initial cohorts of teachers were recruited from high schools with subsequent cohorts recruited from both high schools and middle schools.

All partners were involved in the design of the PD program. Faculty from the Maricopa Community Colleges and school district teacher leaders had primary responsibility for the delivery of the PD. The Arizona State University team had primary responsibility for the research component of the project. This included the development of a classroom observation instrument, later named the *Discourse in Inquiry Science Classrooms* (DiISC) that went through multiple iterations of development, including classroom observations and observations of the PD process, feedback from teachers and PD providers and measures of students' and teachers' written scientific explanations and student achievement. The development of the DiISC is detailed in a separate section in this chapter and elsewhere (Özdemir, Lewis, and Baker, 2007).

The model we proposed focused on scientific talking and writing within the context of learning science. As a consequence, the PD was designed to help teachers infuse writing and talking in science through collaboration with English teachers working in school based teams. Special attention was given to the communication needs of ELLs and the instructional strategies their teachers should employ in the classroom. Furthermore, we endeavored to give English teachers the tools to help their science teacher counterparts infuse communication activities in the science classrooms. To do this, the PD for English teachers focused on the development of expository writing skills, especially those associated with writing scientific explanations. These scientific explanations consisted of three parts, claims, evidence and reasoning. Reading scientific texts was also used as an instructional tool to help identify how claims, evidence and reasoning are written by scientists in their own research reports.

As originally conceived by Michael Lang and Dale Baker, the PD emphasized ELL strategies and metacognition. Inquiry (i.e., scientific investigation) was the vehicle to support written and oral scientific discourse, ELL strategies, and metacognition in science instruction. CISIP offered an integrated approach, combining these components to create science classroom discourse communities (SCDC) with the goal of increasing students' science achievement.

Because the research (Kelly, 2014) is so convincing, especially for our target audience of ELLs, the CISIP PD model considers scientific discourse (i.e., talking and writing) and academic language development as central to learning science through inquiry-based lessons. The model also emphasizes learning principles. The CISIP PD program did not separate the learning of content from learning about pedagogy or students' needs and presented content within the context of inquiry. This decision was supported by research that found that knowledge of content alone is not enough preparation for teaching (Feiman-Nemser and Parker, 1990). However, we do acknowledge that content knowledge is critical in the

development of teachers' pedagogical content knowledge (Abell, 2007) and that there are strong correlations between a teacher's background in science and use of a variety of preferred instructional strategies (Abell, 2007) and teaching effectiveness (Druva and Anderson, 1983). The research in science education also has indicated that an effective teacher has well-organized and integrated science content knowledge. Teachers whose content knowledge lacks organization and integration cannot help students' link factual knowledge to larger conceptual frameworks nor help students make connections to the natural world (Fisher and Moody, 2000; Wandersee and Fisher, 2000).

Philosophical and Structural Change in Objectives of Teacher PD

Our initial proposal stated that we would work with high school teachers, but our research indicated that the structure of some high schools and scheduling issues made teaming by English and science teachers difficult in some schools because these teams of teachers did not have the same students in their classes and they did not share the same prep period to be able to meet easily as a team. In addition, we began to receive requests from school districts to expand our grade level focus to include middle school level teachers. Given the teaming issue and the administrative requests, we agreed to include middle school teachers who would also benefit from our professional development model.

As the project progressed, teachers' feedback indicated that the ELL strategies were beneficial for all students. As a consequence, we expanded our instructional strategies to encompass academic language development for all students. In addition, our research with teachers indicated that metacognitive strategies were difficult for teachers to use in the classroom for a variety of reasons. After much discussion, we decided to focus on a broader set of learning strategies that addressed metacognition, but also included strategies such as accessing prior knowledge and modifying instruction. Our formative evaluation of teachers' written scientific explanations found that linking claims and evidence to larger conceptual frameworks through reasoning needed greater emphasis in the PD. This required us to modify our activities and place greater emphasis on the writing of scientific explanations and the content knowledge that supported conceptual frameworks in science. We felt justified in this change of emphasis because research indicated that to be an effective teacher, content knowledge must be well-organized and well-integrated.

Scripted Lessons to Teacher Choice

In its initial development phase (2004-2006) the CISIP program underwent a philosophical shift from teachers-as-consumers to teachers-as-producers. This change was based upon classroom observations that showed teachers were not implementing the CISIP model. We discovered that the scripted lessons we designed as models resulted in limited fidelity of implementation of the model and ultimately, teacher dissatisfaction. There were too many differences among classrooms, teachers, schools, and students for a once-size-fits-all approach. Furthermore, since the scripted lessons were provided, the teacher did not have ownership of the lessons nor did they necessarily build upon, expand, or enhance the teachers' current instructional strategies. Nor did the scripted approach acknowledge the participating teachers as professionals who were able to, and did, make informed decisions daily about the kinds of lessons and support of learning that their students needed as the

school year progressed. This top-down approach, using scripted lessons, made teachers passive recipients of knowledge rather than active creators of their knowledge and pedagogical skills. The use of scripted lessons also violated our philosophical stance of a learner-centered approach. If a learner-centered approach was good for students, it was also good for teachers. After varying the degree to, and the way in which, the lessons were scripted over a two-year time period, we abandoned the scripted lessons in favor of lessons that were developed by teachers to better reflect teachers' knowledge of their students' learning needs. This empowered teachers with the freedom to modify or develop their own lessons based upon the PD principles. Our external evaluator concurred that this was a good decision that would increase teachers' implementation of the CISIP strategies without violating the core elements of the model. With this change, teachers became equal partners and reduced the hierarchical power structure of the PD. Again, we found that this decision was supported by research that indicated that interventions that allow flexibility are more likely to be adopted quickly and be sustained over time (Rogers, 2003). Furthermore, an examination of teacher-created lessons indicated that teachers were indeed capable of creating their own CISP lessons.

Timely research and evaluation feedback by the project's research team and external evaluator were mechanisms by which CISIP became self-regulating; promoting instructional change and incorporation of more aspects of inquiry-based learning with academic language development strategies. Next we present some of the critical literature that informed the development of the CISIP grant proposal and PD program.

Original Proposal and Literature Review of Teacher Professional Development

At the time that the CISIP proposal was submitted to the NSF, teacher PD was based on reform movements and the *National Science Education Standards* (1996) for inquiry since inquiry was viewed as essential to effective science teaching and student learning (National Research Council, 1996). Employing inquiry requires teachers to create an environment within which students engage in a set of complex cognitive processes (Windschitl, 2004). Our project focused on the creation of just such an environment that we called a science classroom discourse community (SCDC). We emphasized the creation of an SCDC because there is little in the PD research that examines teachers' communication skills or their capability to teach communication skills to students. The model emphasized inquiry-based instruction that takes place in a student-centered classroom where students explore the natural world with varying degrees of independence. The notion of inquiry in science education has now been replaced by the focus on scientific practices, crosscutting concepts and core disciplinary concepts in the *Next Generation Science Standards* (NGSS) in the U.S., but as we will demonstrate throughout this chapter, much of the PD we designed foreshadowed this transition.

The CISIP model also emphasized teaching that bridged everyday experiences and scientific discourse to support a SCDC. The PD activities modeled ways for teachers to provide students with opportunities to build scientific vocabulary and engage in peer-to-peer discussions that supported the construction of scientific arguments, as well as ways for students to explore the nature of scientific communication. Based on the work of Moje, Collazo, Carillo, and Marx (2001), we defined scientific discourse in classrooms as knowing,

doing, talking, reading, and writing or as the combination of scientific ways of talking, knowing, doing and using appropriate form of evidences (Lemke, 1990). Newton, Driver, and Osborne (1999) argued that in addition to conceptual understanding, discourse creates a scientific community in classrooms. Thus, scientific discourse provided a vehicle for the social and cultural construction of knowledge (Alexopoulou and Driver, 1996; Kelly and Crawford, 1997; Kelly and Green, 1998; Kittleson and Southerland, 2004) through the negotiation of meanings.

Integral to our work with teachers were the ways in which teachers could provide students with opportunities to pre-write, write, and share writing. These activities support acquiring the language patterns and vocabulary to communicate scientific ideas, use science notebooks, and the development of a SCDC. We determined that writing should be central to our work because several researchers assert that writing is both a reflection of conceptual understanding and a tool to generate understanding (Halliday and Martin, 1993; Lemke, 1990). In his review of the research about writing in science, Rivard (1994) wrote that "students using appropriate writing-to-learn strategies are more aware of language usage, demonstrate better understanding and better recall, and show more complex thinking content" (p.975). Rivard and Straw (2000) investigated the role of talking and writing on learning science. Forty-three students were randomly assigned to four groups stratified for gender and ability. During an instructional unit, three treatment groups received problem tasks to construct scientific explanations about ecological concepts applied to real-world situations. A control group received simpler tasks based on similar content. Findings from this study suggested that talking in science lessons is important for students to share, clarify, and distribute knowledge, while asking questions, hypothesizing, explaining, and formulating ideas are all important activities during discussions. Furthermore, explicit teaching of scientific writing helps students to organize relationships among factual information (Callaghan, Knapp, and Noble, 1999).

Our concern with English language learners led us to also provide teachers with tools to support scientific language development such as visual aids, supplemental resource materials, clear instruction, and lessons that built on students' everyday language and culture in order to provide opportunities for students to acquire scientific vocabulary. We used strategies adapted from Herell and Jorden (2003) such as using visual aids and gestures, and building on students' language and culture, as well as the research in science education that has addressed linguistically diverse students (Fradd and Lee, 1999; Lee and Fradd, 1996).

 Our focus on metacognition involved exploring with teachers strategies that provided opportunities for students to assess prior knowledge, make conceptual connections, and engage in metacognition. However, since we found this focus to be somewhat narrow and difficult to implement in classrooms we expanded our learning strategies beyond metacognition to modeling scientific thinking, establishing community norms, and providing timely and specific feedback as a key element of formative assessment (Black and Williams, 1998). With this expanded focus we hoped to help teachers guide students to develop understanding, and promote an academic focus that supported learning science. Our choice of learning strategies was based upon the cognitive principles outlined in *How People Learn* and *How Students Learn* (National Research Council, 2000; National Research Council, 2005). We still addressed metacognition, as part of self-regulated learning, because students must "develop the ability to take control of their own learning, consciously define learning goals, and monitor their progress in achieving them" (National Research Council, 2005, p.4-10).

The design of the PD took into consideration that changes in teachers' beliefs and practices take time. This decision was well supported by newer research that indicates that multiple year PD increases teachers' use of inquiry-based instruction (Lakshmanan, Heath, Perlmutter and Elder, 2011; Marshall and Alston, 2014). We also built in long-term support and opportunities to collaborate and reflect since these factors have been found to support teachers in enacting reform in their classrooms (Banilower, Heck and Weiss, 2007; Garet, Porter, Desimone, Birman and Kwang, 2001; Supovitz, Mayer, and Kahle, 2000). However, we did not assume that the PD experience would necessarily translate into the implementation of PD instructional strategies in classrooms, and studies at the time of writing this proposal and subsequently have indicated that few teachers implement inquiry-based teaching successfully in their classrooms (Capps and Crawford, 2013; Roehrig, Kruse, and Kern, 2007; Woodbury and Gess-Newsome, 2002). Furthermore, there have been few empirical studies about the impact of PD on teachers' use of inquiry-based instruction (Capps, Crawford and Constas, 2012).

Fidelity of implementation, using instructional strategies to deliver curriculum consistently and accurately as designed by an intervention, is one is of the greatest challenges of PD. Effective implementation is associated with high fidelity and ineffective implementation with low fidelity (Blakely, Mayer, Gottschalk, Schmitt, Davidson, Roitman, and Emshoff, 1987). Higher student outcomes are associated with greater fidelity of implementation (O'Donnell, 2008). However, PD strategies that require less fidelity are more likely to be adopted quickly and be sustained over time (Rogers, 2003). One factor in adoption and fidelity is practicality. Teachers evaluate whether to use and be faithful to PD innovations based mostly on whether such instructional approaches and strategies are practical. From the teachers' point of view, PD is practical if what is being presented can easily be translated into concrete instruction; required changes in pedagogy fit current practices and goals; implementation requires limited investment, and the changes promise numerous benefits (Doyle and Ponder, 1977). Since we were concerned with fidelity of PD implementation, we created a classroom observation instrument called the *Discourse in Inquiry Science Classrooms* (DiISC) to measure teachers' use of the PD (Baker et al., 2008). Though much has been written about fidelity of implementation from a conceptual perspective, there is little research to provide guidance to the education research community as to how fidelity can be measured (O'Donnell, 2008). The challenge of measuring fidelity of implementation, as one measure of the success of PD, was the impetus behind the development of the DiISC.

The use of the DiISC provided challenges for both the teachers and the PD providers as well as for the researchers. We had the teachers and PD providers critique the items on the DiISC and make suggestions for revisions to increase teacher understanding and acceptance of the importance of the classroom observations. This removed some of the mystery of what was being focused upon in the observations and how lessons were being assessed. In analyzing the observation data, we considered the fidelity of PD implantation in terms of teachers' time in the PD to learn and practice CISIP instructional strategies, teachers' need for flexibility, and systemic, structural, and social barriers to change.

van Driel et al. (2012) in their review of 40 studies of teacher PD in science education concluded that most researcher have relied upon teachers' self-reporting about their implementation. Researchers rarely have asked students to describe what their teachers do in terms of instructional strategies, and have neglected to examine school organizational factors.

van Driel and his colleagues also found that knowledge assessments and classroom observations were only part of the design in some studies, but not all. These conclusions make our work with the CISIP PD unique in that we: (a) spent several years developing a classroom observation instrument that we used to measure fidelity of implementation rather than rely on self-reports; (b) developed a student survey called *My Science Classroom* that allowed students to report the CISIP instructional strategies used by their teachers; (c) explored school organizational factors through an assessment of barriers and supports to implementation; (d) embedded our instructional innovations in science content areas allowing us to assess the acquisition of content knowledge facilitated by our PD; and (e) looked at student outcomes as a function of teachers' skills and knowledge acquired from the PD.

Connections to NGSS and Common Core State Standards

Our PD model was prescient. Even though CISIP was created prior to the release of the *Next Generation Science Standards* (NGSS), we addressed ideas found in the practices, crosscutting concepts, and disciplinary core knowledge of *A Framework for K-12 Science Education* (National Research Council, 2012) and NGSS. All of the practices of scientists (i.e., developing and using models, asking questions, planning and carrying out investigations, analyzing and interpreting data, constructing explanations, engaging in argument from evidence, developing models and using mathematics, and obtaining, evaluating and communicating information) promoted in the NGSS were major components of the CISIP PD program.

We also foresaw the need to including crosscutting concepts in our model that the NGSS identified in its framework. These included the crosscutting concepts of systems and system models, and energy and matter. Disciplinary knowledge we addressed in biology (i.e., heritability, matter and energy flow in organisms), physical sciences (i.e., forces and motion) and Earth and space science (i.e., Earth systems) were defined as core ideas in the NGSS. In retrospect, it is easy to explain this congruence. The practices, crosscutting concepts, and disciplinary core ideas were widely written about in the science education research literature before being codified in the NGSS, which enabled us to be at the cutting edge of reform. We were also influenced, as were the writers of the *Next Generation Framework*, by the *National Science Education Standards* (National Research Council, 1996) and the *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993) and the work of Bransford, Brown and Cocking (NRC, 2000) for learning principles.

The reading, writing, crafting scientific arguments, and working with data from laboratory activities also aligned well with the current *Common Core State Standards* (National Governors Association Center for Best Practices and Council of Chief State School Officers, 2010). Specifically, we aligned with the writing and literacy standards for science and technical subjects in that we addressed analysis of technical text; following procedures for experiments and measurements; distinguishing among facts, reasoned judgment based on research findings, and speculation in a text; assessing the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem; writing arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence; attending to the norms and conventions of the discipline in which they are writing. These ideas were also being written

about in the science education literature before they became codified in the *Common Core State Standards*.

RESEARCH APPROACH AND METHODOLOGY

Overall, we adopted a descriptive, exploratory approach to investigating the phenomenon of teachers learning from PD and applying their new understandings of how to teach science to the classroom. At times, our studies used qualitative methods such as case study (e.g., Lewis, 2011) and at other times they used quantitative methods such as structural equation modeling (e.g., Lewis, Baker, and Helding, 2015) to describe the change in teachers' practices over time. Additionally, our research was conducted while the teachers participated in the PD and our formative findings were then used to assist the PD providers in revising and redesigning the CISIP program itself prior to the next PD institute. Thus, there was an element of the approach that could be loosely considered design-based research (Baker et al., 2009). Finally, the last facet of the research approach and objectives that are presented in this chapter concerns the development of the classroom observation instrument (Özdemir, Lewis, and Baker, 2007) that aligned with the five key PD foci of the scientific classroom discourse community model.

CISIP Program Components and Professional Development Activities

After several iterations the CISIP PD institute came to rely upon particular PD activities and instructional approaches to acclimating teachers to its vision of teaching science. A short view of key PD program activities and their connection to the five core elements is presented in Table 1 (taken from Lewis, Baker, and Helding, 2015).

Development of the DiISC

One of the first tasks of the CISIP research group was to develop a classroom observation instrument that was based upon the reform efforts in science education and would provide standardized and reliable evidence that change was occurring in the classrooms of the teachers who were participating in the PD. The process of generating items and field-testing the instrument is described in detail in Özdemir, Lewis, and Baker (2007) and in its user's manual (Baker, et al., 2008). However, a short summary is presented here to provide methodological context for result from particular studies (Lewis, Baker, and Helding, 2015; Lewis, 2009) that were conducted about CISIP. First, we briefly summarize the content of the instrument scales.

**Table 1. Selected CISIP Professional Development Activities for Teachers to
Learn to Build Scientific Classroom Discourse Communities
(from Lewis, Baker, and Helding, 2015)**

SCDC Core Elements	Activity Example
Scientific Inquiry	• *BioLab 1: Human Characteristics:* Inquiry investigation about human characteristics with embedded support for academic language development with modeled strategies to use in the classroom. • *BioLab 2: Gummy Bear Genetics:* Experience and use of academic language development strategies embedded within a CISIP inquiry activity about genetics. • *BioLab 3: DNA Extraction:* Integration of CISIP components within DNA laboratory.
Oral Discourse	• *Nature of Science Communication Card Activity:* Definition of the nature of science and the types of communication that are integral to doing science. Discussion about how scientific writing and talking reflects the nature of science.
Written Discourse	• *Mystery Boxes and the Writing of a Scientific Explanation:* Begin writing process of a scientific explanation with an emphasis on clear performance expectations for writing and the writing of an explanation with claims, evidence, and reasoning. Provide feedback on written scientific arguments and revise arguments based upon writing.
Academic Language Development	• *Opening Doors:* Experience and identification of scaffolding strategies and techniques for teaching academic skills to English Language Learners. • *BICS/CALP:* Explanation of the significance of Basic Interpersonal Communication Skills (BICS) and Cognitive Academic Language Proficiency (CALP) in language acquisition.
Learning Principles	• *Fish is Fish:* Introduction to learning principles and the socio-cultural influences on English Language Learners (ELL) as they relate to "Fish is Fish" story. • *Graphing Motion with Motion Detectors:* Situating of metacognition within an inquiry activity. Development of concepts of graphing of back and forth motion with attention to metacognition.

Instrument Scales

Inquiry Scale

The inquiry scale on the DiISC teacher observation instrument reflects the essential features of inquiry (focusing on one aspect of the scientific endeavor in *scientific practices* in the NGSS while other scales focus on other aspects of scientific practices) and measures the degree to which inquiry-based instruction takes place in a student-centered classroom and how independently students explore the natural world. The major consideration in developing items for this scale was to identify observable teacher behaviors found in inquiry-oriented classrooms.

Oral Discourse Scale

The oral discourse scale measures the degree to which teaching bridges everyday experiences and scientific discourse to create a SCDC. The scale focuses on whether the teacher has provided students with opportunities to build scientific vocabulary and engage in peer-to-peer discussions that support the construction of scientific explanations. It also focuses on whether the teacher has provided opportunities for students to explore the nature of scientific communication.

Writing Scale

The writing scale measures the degree to which students have opportunities to pre-write, write, revise, and share their writing. These activities support acquiring the language patterns and vocabulary to communicate scientific ideas, use science notebooks, and the development of a SCDC.

Academic Language Development Scale

The academic language development scale measures the degree to which teachers support students' scientific language development through the use of gestures, visual aids, supplemental resource materials, and clear instruction. It also measures the degree to which science lessons build on students' everyday language and culture and provide opportunities for students to acquire scientific vocabulary.

Learning Principles Scale

The learning principles scale measures the degree to which teaching provides opportunities for students to assess prior knowledge, make conceptual connections, and engage in metacognition. The scale also measures whether the teacher models scientific thinking, establishes community norms, and promotes an academic focus that supports learning science.

Development and Field-Testing of the DiISC

The initial draft of the DiISC observation instrument was developed by our research group to measure fidelity to the CISIP PD model by identifying critical components of the PD model, as well as evaluating lessons and teachers' instructional behaviors in the classroom. A list of instructional strategies were generated for each scale and discussed by the team. Instructional strategies were either eliminated or combined based on the discussions that included continual reference to the research literature, PD model, and standards. The items on the scales were then discussed with the CISIP team.

Feedback from the team, as well as CISIP's evolving PD vision, and the PD activities were used to revise items. The first draft of the DiISC teacher observation instrument consisted of the aforementioned five scales with each scale consisting of 5-7 items with sub-items describing discrete instructional strategies. The university research group of 2-4 individuals attended the PD days with the teachers to observe the teachers' opportunity to learn aspects of the PD model.

The DiISC was field tested in the second phase of development. A series of classroom observations with debriefing sessions were conducted to the determine ease of use, alignment with PD, and ease of consensus between raters. During the debriefing sessions the research team discussed their observations and how they rated instructional strategies (and implicitly the lessons) item by item. This process helped to establish the alignment of the instrument to the PD, the degree of rater agreement, and a common understanding for each item. We also refined the wording of the items, and added or eliminated items based on shared judgment.

The DiISC was then reframed using these scores and the experience of field observations. First, we re-conceptualized the English Language Learner scale to be more inclusive. We agreed that some ELL instructional strategies were good for all students because all students need to acquire the language forms used in science. In addition, because of how the PD was evolving we felt that our focus should be the development of academic language in science within an SCDC. Therefore, the English Language Learner scale was renamed the *Academic Language Development* scale and items were reviewed to reflect this change. Explicit items regarding the nature of scientific communication were added to the *Academic Language Development* scale to measure the goal of creating a scientific discourse community in the classroom. Second, we asked for more global feedback from district administrators responsible for curriculum and from our outside evaluator of the grant. Finally, the scale that was used to rate observation items was reduced from six-points to a four points to improve observers' agreement with each other. This constituted the second draft.

The third draft was made after a CISIP summer institute in 2006. The focus of the institute was on essential components of the model and teachers were expected to create "signature lesson plans" by integrating CISIP instructional strategies that they selected into their curriculum. The research team met with the teachers and PD providers to determine whether we had a shared understanding of the model and what the SCDC instructional strategies looked like in the classroom. As a consequence of these discussions, some items on the DiISC were rephrased, eliminated, or moved to a different scale; some new items were also added.

The third draft included two modifications. First, a new scale called *Learning Principles* was created replacing a formally-used metacognition scale and the metacognition items were placed on the *Learning Principles* scale with slight changes in wording. The *Learning Principles* scale included additional items that operationalized the learning principles for assessing prior knowledge, setting performance expectations, connecting factual knowledge within conceptual frameworks and providing academic feedback. Second, we limited the components that described each item to three examples in order to increase agreement between raters. Each item on the scale now included three possible observable teacher behaviors. This draft of the DiISC observation instrument was shared and feedback was used for additional revisions.

The fourth draft was based on telephone interviews with experts in academic language development and teachers resulting in modifications of the *Academic Language Development* scale. The fifth and final draft included a rubric to aid observers in making decisions about the ratings of the items and to further improve rater agreement. We have included the inquiry scale as an example of one scale and its items (Appendix A).

**Table 2. Examples and Non-Examples of Inquiry Instructional Strategies
(from Baker, et al., 2008)**

Items	Examples	Non-Examples
1. Creating an environment that supports inquiry	• There is hands-on exploration and data analysis • Activities support conceptual understanding	• Hands-on activities do not support inquiry (e.g., cutting shapes)
2. Asking questions	• The teacher engages students in formulate questions about the natural world • The focus is on explanations for questions • Activities distinguish between scientific and non-scientific questions	• Fact recall questions • Non-scientific questions (e.g., is the Jerome Hotel haunted?) • Answers do not require explanations
3. Designing and planning exploration of the natural world	• Scientific investigations planned and conducted by individuals or in groups • Opportunities to justify procedures before investigations	• Teacher provides the procedures • Students follow procedures without any questioning or discussion
4. Using data to explain the results of scientific exploration (I)	• Activities include making observations and recording data • Teacher requires data to be presented in logical forms that show patterns and/or connections	• No data collection • No requirements for graphical displays of data
5. Using data to explain the results of scientific exploration (II)	• Teacher asks students to make claims, provide evidence, and develop explanations • Teacher asks students to revise explanations and models using data and logic • Teacher provide opportunities for making predictions and building models	• Teacher tells students what they are to conclude • No predictions before activities • No model building using data after activities
6. Generating scientific arguments	• Discussions encourage thinking of other ways to interpret data using scientific knowledge and logic to generate scientific arguments • Discussions identify limits and exceptions of interpretations • Discussions explore the effects of error on results and suggest ways to reduce error	• Discussions are focused on a single explanation or claim • Discussions emphasize certitude

Using the DiISC Instrument

Before using the DiISC teacher observation instrument observers were calibrated through an iterative process consisting of a series of steps to insure consistency across observers. The first step was an in-depth conversation about the meaning of each item and the overall meaning of the scales to avoid divergent interpretations that can affect rater agreement. To help observers understand the items examples and non-examples can be found in the DiISC manual, but due to space limitations in this chapter we only include the examples that accompany the inquiry scale (Table 2).

The second step was to practice scoring videotapes of science lessons using the DiISC. First, each individual researcher scored the videos, then ratings were discussed as a whole group to further clarify the meanings of the items. Researchers then made classroom observations in pairs. Ideally these teams were composed of one experienced and one novice observer. After observations had been completed, the ratings were discussed and reconciled. All observers also met regularly as a group to discuss the experience of making observations and the degree to which observations were in agreement. Paired observations with all possible combinations of observers continued until differences in scores were minimal and observations could be treated interchangeably.

No single lesson can capture all of the strategies that the DiISC measures. Nor, can a single observation be a full measure of a teacher's use of strategies. For long-term studies using this instrument, observations should be made on a regular basis (e.g., six to eight times) over the course of at least one school year with approximately the same number of observations at the beginning, middle and end of the year to accommodate natural fluctuations that may be influenced by district- and state-level testing schedules, curricular demands, and other school-level policies. Further work to produce a modern validity argument for the DiISC is currently being undertaken; until this work is completed the instrument should not be used to generalize research findings from other studies.

Focus on Argumentation

To ensure a scientifically literate population, high school graduates need to be able to read, understand, and evaluate science articles and develop written scientific explanations using appropriate data and reasoning (NRC, 1996). We endeavored to help teachers help their students to become more scientifically literate through the CISIP PD. Central to the CISIP PD was how to create SCDCs as vehicles for promoting scientific literacy. When done well, a SCDC engages students in talking and writing about science, especially writing scientific explanations.

In order for teachers to provide effective instruction that creates a SCDC and supports students' writing of scientific explanations, they must acquire the skills of talking and writing about science, especially writing scientific explanations, themselves. Thus, to determine whether CISIP PD had an impact on students' ability to write scientific explanations using claims, evidence, and reasoning in answering scientific questions we worked to develop teachers' understanding of making an appropriate claim, supporting it with appropriate evidence, and supplying correct reasoning linking the two when writing a scientific explanation. In addition we explored the effect of context on students' scientific explanation writing abilities.

Literature Review

Communication skills in science, especially the capability to share scientific information with rational arguments and distinguish sound from unsound arguments are critical scientific habits of mind (AAAS, 1993). Within scientific practice the results of inquiry are presented in peer-reviewed publications in the form of arguments or explanations that attempt to make clear connections between claims, evidence, and reasoning among them (Haack, 2003). An integral part of writing scientific explanations is the ability to recognize and reproduce the correct patterns of written language in the form of an argument; yet cognitive psychologists have shown that students: (a) have a limited capacity in relating data to explanatory theories (Halliday and Martin, 1993; Yore et al., 2004), (b) struggle to construct claims (Berland and Reiser, 2011, and (c) have difficulty distinguishing between claims and evidence (Berland and Reiser, 2009) even when argumentation is specifically taught teachers these effort are sometimes only partially successful (Berland and Reiser, 2011).

Despite the pervasiveness of references to communication skills in reform documents (AAAS, 1993; National Research Council, 1996; NGSS Lead States, 2013) there is little in the PD research that examines teachers' communication skills or their ability to teach communication skills to students. Additionally, some researchers have found that we do know that some teachers do not identify explanations as an essential feature of inquiry (Kang, Orgill, Crippen, 2008). When preservice teachers' explanations are examined, it appears that they are better at linking evidence to support claims than they are at the reasoning that links claims to evidence (Robertson 2004; Sadler, 2006). Preservice elementary teachers also find writing in science to be more difficult than other types of writing (Robertson, 2004). However, when teachers are asked to reflect and describe how they are reasoning their explanations are better and there is a larger impact on their learning of content (Monet and Etkina, 2008).

Teachers' understanding of scientific explanations also has an effect on the quality of student written scientific explanations. Whether teachers have sufficient understanding to scaffold the writing of explanations by modeling scientific explanations, defining scientific explanations, or making the rationale of a scientific explanation explicit influences students' ability to construct explanations (McNeill and Krajcik, 2008). In a follow-up study to teacher PD using the argument-driven inquiry instructional model, Sampson, Enderle, Grooms, and Witte's (2013) study of middle and high school students showed that persistent integration of writing arguments in conjunction with eight laboratory activities resulted in an improvement in students' science-specific argumentative writing skills and their understanding of core scientific ideas.

Effective Communication of Research and Evaluation Findings in Support of Professional Development

The CISIP PD model had both a research and an evaluation component. Each served different purposes and had different goals. The research component began with the writing of the grant proposal. The design of the research was such that it met the data needs of the school districts and the university faculty member's (Dale Baker) interest in determining the effects of the PD design on teachers' knowledge, skills, and classroom implementation. This

research had a developmental arc due to the exploratory nature of a PD program under development; we describe our research approach with more detail in the next section.

As required for grants funded by the NSF, there was an external evaluator who was concerned with whether we carried out the PD as described in the funded proposal. She was also concerned with whether the teachers involved were satisfied with the PD in terms of pacing of activities, structure of the PD, and whether we were meeting their needs. The external evaluator collected information after many PD sessions so that the CISIP development and PD provider team could make mid-course adjustments for the next PD session. This formative evaluation allowed us to use a "just-in-time" model to make the necessary changes in the PD and activities and model of delivery. The primary PD provider, Michael Lang, also used a "plus delta" technique with the participants at the end of each PD session to determine what activities and approaches were received positively (i.e., the plus) by the teachers and what should change (i.e., the delta). This information, along with that of the external evaluator, was discussed daily during the implementation of the PD program with the leadership and research teams and provided the research team with additional guidance for the kinds of questions we should be asking and the kinds of data necessary to answer them.

The university researcher and her team were also involved in evaluating the PD materials before they were used with teachers. These materials were created by faculty at the Maricopa Community College who were part of the PD delivery team. Most, but not all, of the materials they created needed just a few modifications. As mentioned earlier in the chapter, however, asking teachers to use scripted science content lessons was a failure. In addition, an evaluation of the scripted lessons against the components of the PD revealed additional problems. Although the lessons were excellent examples of standard inquiry activities, they did not reflect the other components of the PD such as oral discourse, academic language development, and written discourse. This told us that the kinds of discourse-rich instruction we wanted our teachers to implement was even difficult for community college instructors to deliver. This insight, as well as the feedback to the lesson creators, resulted in both receptive reconsideration by some of the initial group of PD providers and others deciding to leave the project. We describe how the CISIP program shifted its philosophical underpinning and how serious rethinking was necessary to produce the kinds of lessons and activities we wanted to model and how much change in practice we could reasonably expect over a year's time. The teachers in the PD program also reacted similarly, those who were willing to be self-critical of their own teaching practices stayed in CISIP, while others who were unwilling to try new approaches to teaching tended to leave the PD. We discuss this further in the concluding sections of this chapter.

Table 3. Main Foci and Key Findings from Published CISIP Research Studies

Publication	Context	Science Content Focus	Elem/Middle Teachers	Secondary Teachers	Key Research Findings
Lewis, Baker and Helding (2015)	Inservice teachers in PD learning how to use scientific classroom discourse community instructional strategies	Not one in particular		X	Teachers who engaged in long-term PD implemented more of the CISIP model with a higher frequency of use of the strategies in their classrooms.
Lewis, Dema, and Harshbarger (2014)	Preservice teachers in a university science teaching methods course that used a model of a scientific classroom discourse community	Not one in particular	X		Elementary preservice teachers gained confidence in how to teach inquiry-based elementary science and recognized inquiry-based science as an effective means for engaging student learning.
Bueno Watts, Baker, and Semken (2013)	Inservice high school teachers in PD that used both the CISIP model and a strong emphasis on science content	Energy in geology and biology		X	PD activities concerning energy in systems. Pre-post tests indicated that teachers developed a good understanding of concepts, but an analysis of their scientific explanations indicated problems with connecting claims, evidence, and reasoning.
Baker, Lewis, Uysal, Purzer, Lang, and Baker (2011)	Inservice middle school teachers in PD that used both the CISIP model and a strong emphasis on science content	Biology:genetics	X		Teachers developed understanding of genetics concepts of heritability and human characteristics, but found probability difficult. Science teachers gained more knowledge than language arts teachers.
Lewis, van der Hoeven Kraft, Bueno Watts, Baker, Wilson, and Lang (2011)	Inservice 5th and 6th grade teachers in PD program that used both the CISIP model and a strong emphasis on science content.	Geology: flooding	X		Teachers demonstrated growth in some flooding concepts through scaffolded inquiry lessons modeled in the PD. Teachers who had greater prior knowledge and demonstrated more use of self-regulated learning showed the most change toward a normative view.

PROJECT RESEARCH SYNTHESIS

Through an iterative, multi-year involvement with the PD the research team paralleled the development of CISIP itself. At every stage of PD design reports from the research and external evaluation efforts were used to modify the project. As described above, a PD-aligned classroom observation instrument (Baker et al., 2008) was also developed that has been downloaded over 800 times in over 40 countries as of this writing (March 2016). The research questions we asked and the data generated changed over time as we analyzed data and used our findings to decide the next steps of our investigation. Additionally, as new doctoral students joined the research team, their research interests became part of the questions we asked and data we collected. This resulted in a large set of data, examined from a variety of perspectives, which yielded rich insights. Research assistants, doctoral students in science education, also gained experience and were mentored in educational research; one conducted her doctoral dissertation (Lewis, 2009) using CISIP as the context for teacher learning and change. We generated over 25 conference paper presentations, and seven publications with multiple authors, many of which we discuss in this chapter and are summarized in Table 3. We have not included the conceptual PD program pieces since they were not explicitly research.

Concurrent with the NSF funding there were two state-funded grants that also provided teacher PD (Lewis, et al., 2011; Bueno Watts, et al., 2013), and later an additional effort to use the model of a SCDC with preservice elementary teachers as a framework for their science teaching methods course (Lewis, Dema, and Harshbarger, 2014). Short summaries of our findings from the project are presented here organized by: (a) science content-focused teacher PD; (b) learning that occurred when the PD focused on scientific argumentation; (c) different grade level applications; and (d) further use and application of the CISIP model with preservice and in-service teachers after the grant was completed.

Teachers' Use of CISIP in their Classrooms and Instructional Changes over Time

A major focus of our research was to not only develop a PD-aligned research instrument to observe teachers using what they learned from CISIP in their classroom, but also to determine what, if any, change in teachers' instructional practices over time. Some teachers participated in the CISIP program for more than one year and we also observed a comparison group of teachers. Thus, we were able to build a structural equation model, a hierarchical linear model, using two years' worth of classroom observations. We also analyzed which CISIP instructional strategies were observed to occur most often and which ones appeared to be most challenging for teachers to adopt. The model building and research findings are described in detail in Lewis, Baker, and Helding, 2015, but we provide some of the highlights here.

Research Question #1: Teachers' Adoption of SCDC Instructional Strategies

During the first year of PD we found that teachers' use of the CISIP scientific classroom discourse community model varied in implementation. On each scale the science teachers, based upon a comparison of their z-scaled means, scored from highest to lowest in their use

of groups of strategies: (a) oral discourse, (b) academic language development, (c) written discourse, (d) learning principles, and (e) scientific inquiry. The means were used to rank order all teachers' ($n = 16$) use of the CISIP instructional strategies to see which elements of CISIP were used most and least. Generally, the teachers' frequency of use of these strategies within lessons fit into three categories: (a) *Most-observed* (*often-* and *sometimes-used*) strategies that required teachers to change their own communication, classroom management, and direct instructional behaviors; (b) *Occasionally-observed* strategies that provided opportunities for greater oral and written discourse to facilitate students' meaning-making of science; and (c) *Least-observed* strategies that encouraged students' executive control of their own learning and teachers' use of formative assessment to be more responsive to students' diverse learning needs (Table 4).

Research Question #2: Predictors of Teachers' PD Implementation

Specifically, we designed two two-level HLMs. Both models were compared against a null model, i.e., a model with no predictors at either level of the analysis. This was to ensure there was variance to model at each level by the predictors we would ultimately include. It would also provide a baseline fit statistic with which to compare more complicated models. We used the total raw DiISC measures to describe teacher characteristics that might predict teachers' level of implementation of a scientific classroom discourse community in their own classrooms. Of note is that while no individual student-level information was available, we used the percentage of each teacher's school's students who qualified for a free and reduced lunch program as a proxy for socioeconomic status (SES). Also, we used the significant variables to describe potential factors that account for teachers' change over time in the amount of PD strategies they used.

We claim an effect on teachers' instructional practices, presumably due to the PD, as this was supported by both models' results, and corresponding interpretations. This can be seen in a simplified model (Figure 1) where the intercepts, the teachers' starting points, were constrained in order to demonstrate how the slopes varied across levels of treatment. The model shown in Figure 2 allows both SES and total amount of PD to vary simultaneously in the more complex representation that includes the two factors (time spent in PD and SES) that were statistically significant. In the graphs, the effect of SES is uniformly related to the amount of initial, CISIP-related instructional practices that teachers used, and the amount of PD (or whether they received it at all or not) determined use of PD-related strategies over time.

Findings Regarding Teacher Change over Time

The length of time that the teachers received PD, or their experimental group membership, was chosen as the predictor of teacher change while a schools' percentage of students who qualified for free and reduced lunch was chosen as the exclusive predictor of the intercept or starting point. Over two years, the teachers who had participated for longer periods of time used more of the CISIP model strategies and had higher rates of change than newly participating teachers. The model indicated, with statistical significance, that SES predicted teachers' initial levels of PD-associated behavior. While the overall SES of the school's students was important in determining where teachers began, the amount of PD accounted for how teachers changed over time.

Table 4. Frequency of Use of Instructional Strategies through First Year of PD
(From Lewis, Baker, and Helding, 2015)

Scale	Often used (M = 1.51 +)	Sometimes (M = 1.01 – 1.50)	Occasionally (M = 0.51 – 1.00)	Rarely used (< M= 0.50)
Scientific Inquiry (SI)		SI 1 inquiry environment	SI 4 observe/data collection SI 5 claims-evidence	SI 2 students ask questions for investigation SI 3 design exploration SI 6 data interpretation/sources of error
Oral discourse (OD)		OD 8 whole group divergent questions OD 9 small group discussion OD 10 bridge everyday with academic OD 11 model science discourse vocabulary	OD 12 Nature of science discussions	
Written discourse (WD)		WD 14 prewriting WD 16 practice scientific writing WD 18 use of notebooks		WD 13 formal scientific writing WD 15 rubrics for revision of writing
Academic language development (ALD)	ALD 20 clear instruction	ALD 19 vocabulary acquisition ALD 21 visual aids gestures	ALD 22 bridge language and culture with science ALD 24 direct instruction learning strategies ALD 25 organize groups' structure roles	ALD 23 differential instruction language ALD 26 available supplementary resources
Learning principles (LP)		LP 42 feedback LP 38 community norms LP 39 teacher expectations LP 32 review concepts LP 31 facts and conceptual framework	LP 34 metacognition	LP 28 assessing prior knowledge LP 35 self-monitoring LP 37 executive control LP 36 self-awareness LP 29 modifies instruction

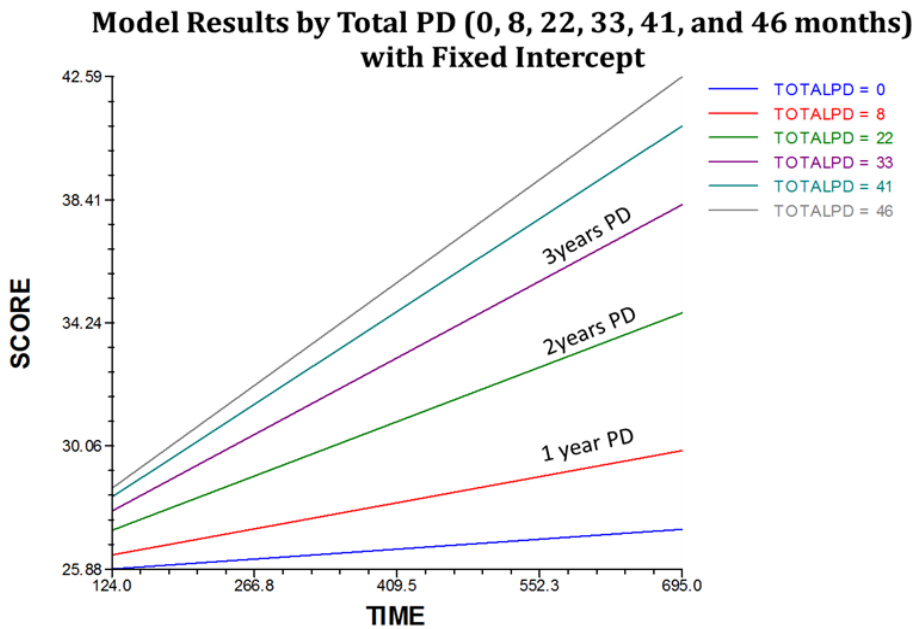Figure 1. Slopes of teacher change due to amount of PD, holding intercept constant at zero. The lowest regression line represents the comparison group with no PD with an additional year of professional development for each higher line. (From Lewis, Baker, and Helding, 2015).
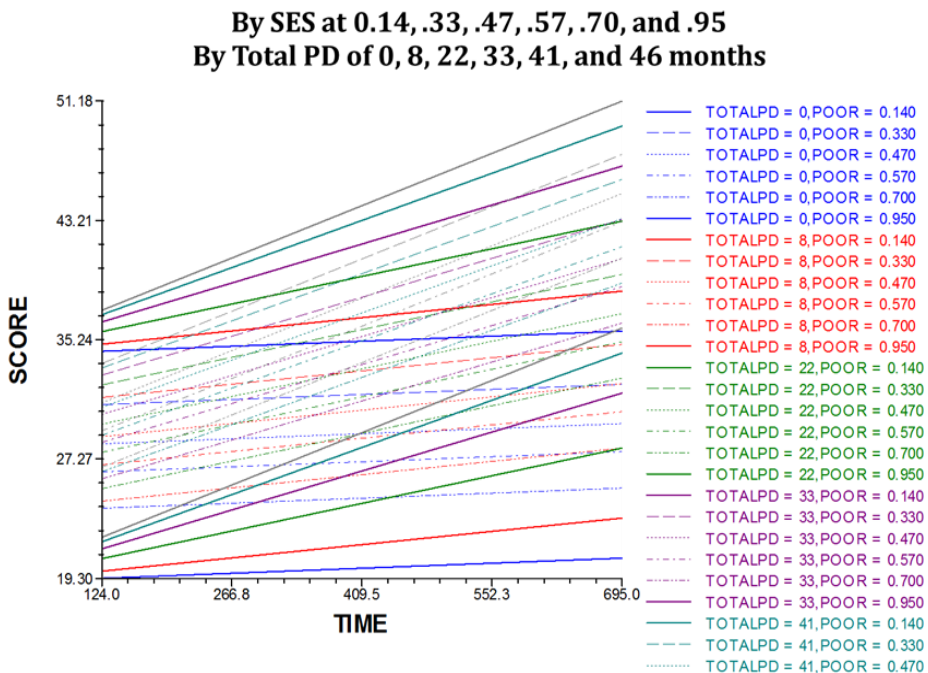

Figure 2. Complex full model that allows both slope and initial intercept (SES) to vary within subgroups. (From Lewis, Baker, and Helding, 2015).

Science Content-Focused Teacher Professional Development

While the original CISIP grant used a variety of science disciplinary content to meet the objectives of the PD program, there were several instances of PD that were delivered using a domain of science as a way to also improve teachers' science content knowledge. The focus audience for these PD workshops were either middle school or high school teachers and the PIs of the original NSF grant received two state-funded Improving Teacher Quality (ITQ) grants to conduct these PD programs. The areas of science that were chosen were genetics, hydrogeology, and energy.

Genetics

Genetics content was embedded in the CISIP professional development model to answer whether using inquiry activities with learning principles, academic language development, and oral and written discourse increased teachers understanding of genetics concepts. Furthermore, we wanted to know if middle school science and language arts teachers benefited equally from the intervention and which genetics concepts were resistant to instruction (Baker et al., 2011). Twenty-three teachers worked in school-based teams on inquiry activities to explore human characteristics and inheritance, e.g., a DNA extraction from wheat experiment, and an internet exploration of controversial topics related to genetics over a period of nine days. Activities were supported by activating teachers' prior knowledge, using vocabulary building strategies, encouraging symbol comprehension (e.g., the chemical symbol Si for silicon), structuring discussions, and use of transfer questions. Learning was reinforced by writing in science notebooks, and public presentations of inquiry activity findings during the PD. Before and after the inquiry activities, teachers were given a pre-post genetics science knowledge test.

There was a statistically significant improvement for the entire sample ($t=5.88$, $p<.000$) and between the scores of the science and language arts teachers for both the pre-assessment ($t=F=36.63$, $p<.00$) and post-assessment ($F=16.91$, $p<.001$) with science teachers scoring higher. However, the increase from pre to post for both science and language arts teachers indicated that both groups of teachers benefited equally. Science teachers increased by 4.9 points from pre to post and language art teachers increased by 5.2 points. The gains were not statistically significantly different for science and language arts teachers. Overall, teachers developed an understanding of the concepts of genotype and phenotype, dominant and recessive genes, alleles, and genetic material. An analysis of the items that did not change from pre- to post-PD activities indicated that some concepts were difficult for the teachers to understand even after the PD. Concepts that were the most difficult dealt with were autosomal dominant traits and probability, and most difficult of all was the application of genetics concepts to a real world problem.

Even though not all of the concepts presented were mastered (e.g., autosomal dominant traits, probability) in part, we think, due to inadequate time exploring these concepts, we are satisfied with the results. The use of the CISP model enabled teachers, even middle school language arts teachers with hardly any formal background in science, to develop a better understanding of complex genetic concepts in a short period of time. Active learning and a

strong content focus along with working in school-based teams accelerated the acquisition of teachers' knowledge.

Flooding Concepts

In CISIP, we were concerned with enhancing elementary teachers' scientific literacy, specifically to better understand Earth systems science, within a framework of instructional strategies that support the development of a scientific classroom discourse community. To be effective in these efforts as teacher professional development providers and educational researchers, it is critical that we understand how teachers,' and consequently their students,' ideas affect their learning about, and perceptions of, their environment as part of their global literacy (Mayer, 2002). The CISIP provided fifth and sixth grade teachers with PD through a state ITQ grant with the dual goal of learning how to establish scientific classroom discourse communities and learning more science content. This section summarizes key findings from Lewis, van der Hoeven Kraft, Bueno Watts, Baker, Wilson and Lang, 2011 and more details of the conceptual framework and investigation can be found therein.

This study focused on elementary teachers' comprehension of flooding before and after an inquiry-based PD program. While teachers learned about flooding over a few weeks within a summer PD context, the ultimate PD goal was that they would use the inquiry-based and metacognitive instructional strategies modeled for them to reform their own science instruction with their elementary students. We chose to examine the role of metacognition in teachers' learning because it is one of the three key learning principles identified by the National Research Council (NRC, 2000; NRC, 2005) that was part of the PD model and employed regularly within the PD flooding activities. This PD program was designed with the NRC standards in mind, and as such was designed with a metacognitive lens. However, in our research, we chose to take a broader perspective of self-regulated learning (SRL), of which metacognition is a component (Zimmerman, 1995; Zimmerman, 2001). We interpreted the two-tier pre-post test data on teachers' learning of flooding to reveal degrees of normative scientific understanding. Two-tier tests use an extended multiple choice format in which the respondents select an answer to the item prompt and then provide an explanation for why they chose that answer from the possible multiple choice answers. Key flooding concepts on our test included: reading topographic maps, periodicity of flooding events, effects of runoff, properties of flood types, map and graph reading comprehension, and flooding term recall. The pre-post assessment included eleven two-tier multiple choice questions and two constructed response questions. All of the test questions concerned various types and causes of flooding except for the final question, which concerned identifying the difference between hands-on and inquiry-based instruction and was not used in our analysis of teachers' learning gains on flooding concepts. We then compared teachers' degree of SRL reflection on embedded writing prompts with their demonstrated learning gains.

Our analysis indicated that there was an improvement in teachers' understanding toward a normative view from pre- to post-PD ($n = 17$, mean gain = 4.3, SD = 3.27). Several misunderstandings and a general lack of knowledge about flooding emerged from the pre-test, some of which persisted throughout the PD seminar while other responses provided evidence of teachers' improved understanding. The concepts that teachers struggled with were also apparent upon examining teachers' reflections upon their learning and teaching practices

throughout the seminar. Teachers were challenged as they attempted to add new academic language, such as storm surge and discharge, to their prior understandings.

Teachers' greatest areas of improvement occurred in understanding probability and the role of ground conditions in flooding events. Flooding concepts that teachers showed the least improvement on included analyzing a topographic region, reading a map image, and hydrograph interpretation. Teachers demonstrated considerable growth in their understanding of some flooding concepts through scaffolded inquiry lessons modeled throughout the PD. Those teachers who had greater prior knowledge and demonstrated more use of self-regulated learning showed the most change toward a normative view of flooding. We found that nine of eleven (82%) teachers who achieved a normative view of flooding demonstrated a higher degree of self-regulated learning, underscoring the importance of employing self-regulatory learning strategies in PD activities to help participants learn content. We purport that the explicit modeling and participation in inquiry-based science activities and written responses to self-regulatory learning prompts throughout the CISIP seminar supported teachers' learning.

Energy

We investigated the effect of writing intensive, inquiry-based PD on high school teachers' science content knowledge of *Energy in Systems*. We developed a two-tier energy test, linked to both national and state science standards, which was administered both before and after 11 high school science teachers participated in 35 hours of PD. Teachers had been teaching from one to 30 years, and all were certified to teach in their content areas. We analyzed the pre- post- test for changes in content knowledge in both the multiple choice and written explanation tiers of the test. This section summarizes findings from Bueno Watts, Baker, and Semken (2013).

The energy test used for pre- and post-assessment in the study was a 30-item, two-tier multiple-choice test with four choices. The three distracters were common misconceptions as documented in the research literature. The development of the energy test was a recursive process in which items were designed, evaluated, and modified several times to determine whether they were appropriate, meaningful, and useful. This process contributed to the content and face validity. The content validity of the instrument was established using two methods. First, the items were written by a university faculty with extensive experience in research on and teaching about energy in Earth systems, and then the items were reviewed by the research team to insure that they reflected the PD activities and the research literature on misconceptions about energy. Topics assessed by the energy test included energy transformation, potential, kinetic, mechanical, electrical, and chemical forms of energy; energy sources most commonly used in electrical generation, transportation, and heating; energy efficiency; energy degradation; energy storage; energy transport; and energy density.

Energy in systems is a complex topic which both crosses disciplinary boundaries and conceptual boundaries. It has been heavily studied, and many misconceptions have been documented. During the PD, teachers tracked energy fluxes in the Earth system and learned about radioactivity, photosynthesis, fossil fuels, and combustion. They created and solved quantitative problems in energy transfer and density, explored case studies of environmental, economic, and energy issues (e.g., wind energy vs. nuclear), conducted photosynthesis

experiments, analyzed fossil fuel samples, and constructed solar powered systems. We found evidence of seven energy misconceptions in either the teachers' test or written responses. Unfortunately, despite our best efforts to provide a PD program that was heavily grounded in research, our evidence suggests we did little to rectify misconceptions in these adult learners.

The least persistent misconceptions seemed to be that energy is associated only with living things, energy is associated only with movement, and energy change occurs only when the effects are perceivable. Teachers who expressed these ideas on the pre-test corrected their answers on the post-test. The idea that energy is a substance that is used up appeared in the written responses of four teachers to a single question about non-renewable resources on both the pre- and post- test. Two other misconceptions, however, stood out as being strongly resistant to change. The first, which states that energy can be created, destroyed, expended, or used up, was intentionally embedded in the distracters of two test questions. Six out of eleven (55%) teachers chose the distracter that claimed 'one form of energy is destroyed and another form is created at the same time.' In addition to selecting this response, teachers' written explanations reinforced their assertion of this misconception. At the end of the PD this misconception had surfaced in eight out of the eleven (73%) teacher's energy tests despite that this concept was discussed at length during the PD sessions. Another strongly persistent misconception was that energy cannot be quantified or measured. This misconception was written into several energy test distracters. Six of the eleven (55%) teachers incorrectly chose the distracter that stated 'not all energy in the process can be accounted for.' Unfortunately this also increased to 73% on the post-PD energy test. In addition, many of the teachers' written responses echoed this misconception and also included a reference to energy being lost. We concluded that, even though the teachers knew, on a rote memorization level, that energy cannot be created, destroyed, or used up; they had a problem understanding on a deep level that energy can be accounted for or measured.

In the end, the CISIP PD did increase teachers' content knowledge of energy in systems, as indicated by the pre-post test results, but when we thoroughly analyzed the data we found that simply looking at pre-post test results was inadequate to get a clear picture of teacher understanding. Our study showed decreasing evidence for teacher understanding as we asked them to move from the rote memorization stage to the experimental application stage of scientific learning. It would have been helpful to have conducted cognitive interviews with a sample of teachers to help us better understand how teachers' thinking went astray. We encourage other PD evaluators and researchers to further investigate these persistent misconceptions about energy.

Focusing on Aspects of Scientific Argumentation

A strong focus of the CISIP program was on the nature of science and use of oral and written discourse in the genre of scientific writing, in particular how to write an argument. A general formula was adopted by the program whereby a claim was constructed and was supported by evidence and reasoning. This was typified by the "Mystery Box" activity that was used during the teacher PD (see the vignette in Box A). A rubric was also developed for teachers and researchers on the project to evaluate written argumentation. A focus of our investigations was how scientific explanations were integrated into teachers' science lessons after the PD.

Box A. A Professional Development Provider's Perspective

As a two-year college geology faculty member of more than 15 years, I find one of the greatest challenges in helping students understand how Earth science gains new knowledge is the unobservable. Many geologic processes are not directly observable (e.g., plate tectonic motion, rock-forming processes, and geologic time), but are based on observations of indirect consequences of these larger processes. In an effort to support student (and teachers in professional development) understanding of what claims and evidence can be reasoned through indirect observation, my colleagues and I modified a common nature of science activity called "Mystery Boxes" during the CISIP development process. The purpose of this activity was to help teachers experience the process of discovery so they could support their students' development of making a claim, using evidence and provide reasoning about something they could not see or touch. This classic activity mirrors the process of doing science in which scientists are engaged in discovery and use observations to collect data in order to develop and support a claim.

During CISIP, teachers would break into groups and were provided with different mystery boxes and attempt to answer the research question, "What is in the box?" The teachers would develop models (empty boxes) to test their claims and ultimately write out a full scientific explanation of what their final claim was in the mystery box and share their findings with other PD participants through a poster session. Reflective of the real process of doing science, they do not ever actually open the box, just as we cannot open the earth or travel back in time. As a collaborative team of science, English and English language learners faculty members, we developed the activity to support teachers' development of the understanding of the nature of science with scaffolded supports for non-English speakers and with explicit instructions on how to write the scientific argument for the poster session debrief at the workshop.

After teachers experienced their own curiosity and frustrations similar to those of their students, we then asked them to reflect on their experiences both as the participant and what the implications were for teaching a similar topic to their students. After experiencing the activity from the participant side, teachers were then able to process the experience from the teacher side. It was through this kind of experience that teachers would engage in the content in an authentic way, but still be able to reflect on their own teaching practices in order to determine how they could implement something similar for their own classrooms. It was through this iterative process of teacher-participant and teacher-reflector that they were able to develop curriculum that would work for their own students and their own school culture.

When I first started working on CISIP, I was already teaching at the community college and had engaged in some self-study of my own teaching practices and student learning, but had a limited understanding of formal education research methods and current findings. Participation in CISIP helped me to craft a framework around which something like "Mystery Boxes" could be developed. In addition, I started to re-frame most of what I was teaching in my own class. Developing the mystery boxes activity started from something I already used in my classroom, but through collaborating with other educators, we were able to create a project that worked for middle school to higher education students, but still had the fundamental aspects of effective instruction. I learned that effective instruction included the use of metacognitive prompts, group collaboration, distinct definitions of claim, evidence and reasoning (CER) and asking students to develop their own CERs, with opportunities to revise their work.

Working so closely with other PD providers, the PIs of the grant and research team, allowed me to better understand how education research was actually done and ultimately led to me earning a Ph.D. in Curriculum and Instruction. I continue to teach geology at a two-year college and integrate the fundamental concepts of effective science instruction and scientific communication into all of my lesson plans.

Two groups of teachers engaged in PD where they wrote scientific explanations. The first group consisted of 50 middle school teachers who choose to participate in either a life science (n=28) or Earth science (n=22) strand. The second group consisted of 35 high school teachers who attended in school-based teams of science (n=22) and English (n=12) teachers. One social studies teacher also participated because he taught bioethics. High school teachers were not separated into content strands.

CISIP Professional Development in Scientific Explanations

Teachers engaged in hands-on inquiry activities to generate data under a variety of conditions to support the writing of explanations using claims, evidence and reasoning. Some of the inquiry activities were highly structured with a template (e.g., prediction, variables, controls, procedure) and one required the teachers to design their own investigation. For some of the activities we provided background information and for others we did not. Some of the writing was scaffolded and some did not have scaffolding. The following is an example of the scaffolding prompts that were used:

List the data you gathered during your investigation.
Your conclusion: "We think____. (Claim)
We think so because_____. (Evidence)
These data support the claim because___. (Reasoning)

Some of the explanations were written by individuals and others collaboratively by a group. In some cases, the teachers received feedback on the quality of their explanations and then rewrote their statements. In other cases, rewriting took place without feedback.

Professional Development Activities

The middle school teachers in the life science strand explored mystery boxes, cell structure and plants. The middle school teachers in the Earth science strand explored mystery boxes and river flooding. The high school teachers explored mystery boxes, and a physics activity to determine the effects of variables on the height a rubber disk would bounce (poppers). Table 5 lists PD activities and their contexts.

Table 5. Activities and Contexts

Activity	Inquiry Structured	Explanation scaffolded	Individual or Group Writing or Rewriting	Feedback	Background Information
Mystery Box A	Yes	Yes	Individual Writing	No	Yes
Mystery Box B		Yes	Group Rewriting	Yes	
Mystery Box C		Yes	Individual Rewriting	Yes	
Cells Poster A	Yes	No	Individual Writing	No	No
Cells Report B		No	Individual Rewriting	Yes	
Plants Poster	Yes	Yes	Group Writing	No	No
Plants Report		No	Individual Rewriting	Yes	

Table 5. (Continued)

Activity	Inquiry Structured	Explanation scaffolded	Individual or Group Writing or Rewriting	Feedback	Background Information
Rivers Poster	None	Yes	Group Writing	No	Yes
Rivers Report		Yes	Individual Rewriting	Yes	Yes
Poppers A	Yes	Yes	Group Writing	No	No
Poppers B		Yes	Individual Writing	Yes	
Poetry A	Yes	Yes	Individual Writing	No	Yes
Poetry B		Yes	Individual Rewriting	Yes	
Poetry C		Yes	Individual Rewriting	Yes	
Hero A	Yes	Yes	Individual Writing	No	Yes
Hero B		Yes	Individual Rewriting	Yes	

A= original explanation, B= rewriting, C= second rewriting

Activity Contexts

Teachers were exposed to writing scientific explanations in a variety of contexts. Three different types of scientific explanations were explored: (a) a mystery box activity, (b) science articles; and (c) inquiry investigations. The "Mystery Box" activity consisted of teachers being given an enclosed box with an unknown object inside of it. The teachers were asked to determine what was inside the box and provide an explanation. They did this by writing a claim, providing appropriate supporting evidence, and stating their reasoning. Logical reasoning should correctly link evidence to the claim and its supporting conceptual framework. In the case of the "Mystery Box" activity the conceptual framework is the nature of science and purpose of investigating a phenomenon.

Teachers were also given science articles and then asked to identify the claim, evidence and reasoning from the results sections. Initial examples were one paragraph with one claim, then actual science magazine articles with several claims backed by evidence were used. Articles were specifically chosen for the purpose of sparking discourse between CISIP community members.

Teachers were provided with materials for inquiry activities and asked to develop their own question for investigation. One example of this type of activity is an investigation of photosynthesis using spinach leaves. After performing their experiments, teachers were asked to write results in the form of a scientific explanation. As a result of these activities, a total of 473 scientific explanations were written; 143 written by high school science teachers, 80 by high school English teachers, 166 by middle school teachers in the life science strand and 84 by middle school teachers in the earth science strand. The scientific explanations written by teachers were assessed qualitatively and a rubric was created to assign a numerical level score to the explanations that reflected the qualitative assessment. Explanations were scored by raters separately who then met in pairs and reconciled differences to obtain a consensus score for all of the explanations. Each of the three components of the explanation was scored separately. For analysis purposes we considered scores in the 0-2 range to be poor explanations, a 3 was considered good, and a 4 was an excellent explanation. We then looked for patterns in the data and conducted statistical analyses. The rubric in Table 6 was used to score the explanations.

Table 6. Scientific Explanation Rubric

	Level 0	Level 1	Level 2	Level 3	Level 4
Claims	Does not make a claim.	Makes an inaccurate or incomplete claim.	Makes an accurate and complete claim, but it does not address the research question.	Makes an accurate but incomplete claim that answers the original question.	Makes an accurate and complete claim that answers the original question.
Evidence	Does not provide evidence.	Provides inappropriate evidence (evidence that does not support the claim).	Provides appropriate and sufficient evidence to support the claim, but it does not includes specific data from the activity.	Provides appropriate evidence to partially support the claim, which includes specific data from the activity.	Provides appropriate and sufficient evidence to support the claim, which includes specific data from the activity.
Reasoning	Does not provide reasoning.	Reasoning does not link the evidence to the claim. Reasoning, claim and evidence do not link the Theory/NOS/ Standards.	Provides reasoning that explains how the evidence supports the claim, but reasoning may not be entirely clear. Reasoning not clearly linked with Theory /NOS/ Standards	Provides appropriate reasoning that clearly explains how the data counts as evidence to link with and supports some of the claim, but does not explain all the claims. Reasoning based on Theory/NOS/ Standards.	Provides reasoning that clearly explains how the data counts as evidence to link with and support the claim. Reasoning based on Theory/NOS/ Standards.

Overall, teachers' claim writing scored higher than their use of evidence and reasoning, and teachers' use of clear and correct evidence scored higher than their reasoning. See Figure 3. Total scores for scientific explanations increased when teachers' received feedback on the quality of their explanations and the explanations were rewritten. How inquiry activities are structured seemed to have an effect on scores. When teachers were asked to generate their own question and design their own inquiry-based experiment, scores were much lower in all three categories.
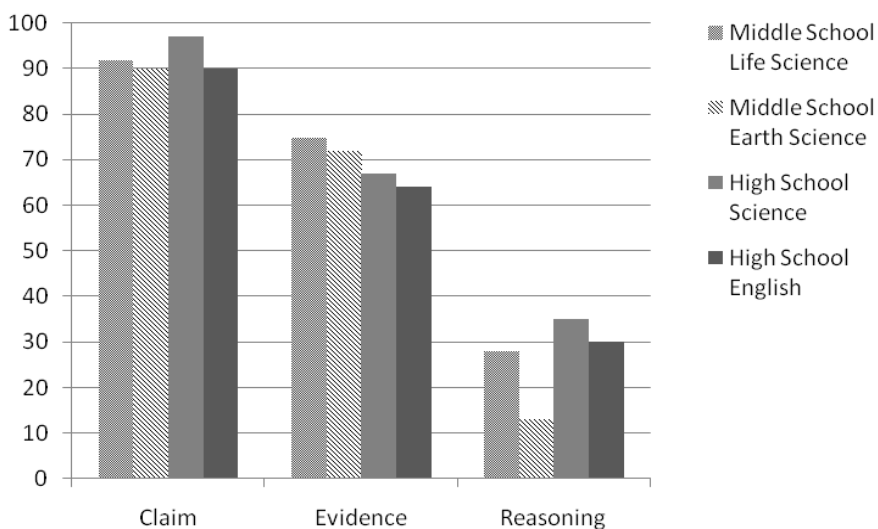
Figure 3. Percent of each teacher group scoring "excellent" (4) or "good" (3) on each part of their scientific explanation using the scientific explanation rubric (see Table 6).

Student Explanation Data

Samples of student explanations were collected from students of the high school science teachers at two time points during the year, the first in the fall semester, and the second at the end of the spring semester. Each piece of data was assigned a student ID code and had all identifying information removed before distribution for scoring with the explanation rubric. In the end we collected pairs of explanations from196 students taught by six CISIP science teachers. Results in this section are based on the analysis of these pre-post academic year written explanations by students. We found that overall student scientific explanation scores (out of a maximum of 12 points) did improve from a mean of 6.14 in the fall to 9.07 in the spring.

Teachers had autonomy in the type of science explanation students were assigned. For the fall data collection, two teachers assigned "Mystery Boxes," one a science article, and four inquiry-based activities (one teacher assigned one group of students to do an inquiry investigation, while his other classes did "Mystery Boxes"). When data was collected in the spring, five teachers had assigned a science article, while one assigned an inquiry-based lab. When the results were disaggregated by explanation type, students did better when finding claims, evidence, and reasoning in a science article at the end of the school year regardless of the activity they engaged in at the beginning of the year. When "Mystery Boxes" was followed by an inquiry lab, however, student scores were lower for the inquiry lab.

It is important to note that each of these types of activities have a different cognitive demand. In any science article the study's claims are already written, students need only to correctly identify the components of the claim. The "Mystery Box" activity is a scaffolded investigation that is content free, having more to do with the nature of science rather than a particular science concept, but students do have to write their own explanations. Finally, the inquiry labs focus on specific science concepts that require students to not only understand

how to write a claim with evidence and reasoning, but to also understand the science as well. Students' success in writing a claim correctly for inquiry-based activities may hinge more upon such factors as the opportunity to revise a claim with specific feedback and having regular practice throughout the school year in writing claims independently as found by Sampson, Enderle, Grooms, and Witte (2013). Additionally, reasoning links the claims and evidence to larger conceptual frameworks, which can be the cause of difficulties with reasoning. Many students have a poor understanding of "big picture" conceptual frameworks, such as energy in a system, and consequently do less well at writing their reasoning. Our study showed that a PD program that focuses on providing teachers opportunities to construct scientific explanations through the use of appropriate claims, evidence, and reasoning can have a positive effect on their students' abilities to develop stronger argumentation skills.

Applications of the CISIP Model to Teacher Preparation and other PD Settings

We have made other efforts to disseminate the CISIP learning model to other groups of teachers. The majority of the work of CISIP was done with in-service science teachers in the Southwest U.S., but on occasion we have had the opportunity to work with science teachers in short workshop sessions at the National Science Teacher Association and NSF Noyce Regional Science conferences (Lewis et al., 2010; Lewis, 2015). We then took this workshop session and wrote an article for use with professional learning communities by lead science teachers and/or district-level curriculum coordinators (Lewis, Baker, Bueno Watts, and Lang, 2014).

Furthermore, the lead author of this chapter has used the CISIP learning model to frame preservice science teaching methods courses at the elementary and secondary levels. Initially this effort was taken with preservice elementary teachers and led to further investigation (Lewis, Dema, and Harshbarger, 2014) as to the effectiveness of organizing such courses around the CISIP model using the core cognitive learning principles, inquiry-based teaching strategies, and rich discourse and academic language development approaches to teaching science. Elizabeth Lewis has also used it to frame science teaching methods courses for secondary preservice teachers in the master's level science teacher preparation program she currently coordinates (Lewis, Musson, Lu, 2014).

Michael Lang has continued to use the CISP model of professional development with teachers and school districts throughout Arizona through collaboration with the Arizona State Department of Education. This collaboration has led to the strategies being used in urban and rural districts, in rich and poor districts, in districts with large minority student populations, and in districts with high- and low-achieving students as measured by state tests.

IMPLICATIONS: PROFESSIONAL DEVELOPMENT CHALLENGES AND LESSONS LEARNED

In this section we discuss three categories of challenges, by no means an exclusive list of possible issues that can arise, that we faced during the CISIP PD program and our investigation into its effects on teaching and learning.

Challenges of Enacting and Studying the Effects of the Professional Development

Every PD project faces challenges that require revising and rethinking the original plan of delivery and research. For us there were two major challenges. The first had to do with the extent to which stipends obligated teachers to participate in the PD but not the research. Initially, teachers received stipends for attending the PD even though most refused to participate in the research or allow us access to classrooms for observations. This left us with no way to determine the impact of the PD. Discussions with the Institutional Review Board allowed us to revise our procedures so that teachers could participate in the PD even if they did not participate in the research component, but only those teachers who participated in the research component would receive a stipend. This was not ideal since some districts did not allow us to make classroom observations even though we could still collect data during the PD sessions.

The second major challenge was attrition. Attrition made the school-based team model difficult to implement. A single teacher from a school did not have a same-school colleague to work with in the PD or at school and thus sometimes experienced and expressed some feelings of isolation. These teachers lost the benefits of peer support when implementing new instructional strategies, a sympathetic ear when faced with difficulties, and colleagues with whom to work together during the PD on activities and to develop lessons for the coming year. Some teachers understandably dropped out of the PD because they were transferring to non-participating districts or schools, but others left the program because they felt a stronger affinity with a culture of learning that did not align with the CISIP learning model.

Teachers who remained in the PD also faced challenges. These included: (a) science teachers' struggles to enact inquiry-based lessons; (b) science teachers' perceptions of teaching language arts skills as part of their responsibility to teach science; and (c) the English/ELA teachers were less comfortable with expository/non-fiction texts than fictional reading and writing. We discuss each of these briefly.

Science Teachers' Struggles with Time to Do Inquiry

Over time teachers were able to plan and write high-quality, inquiry-based science lessons that included oral and written discourse, academic language development, and learning principles. On the other hand, they struggled to find time to deliver the CISIP model-informed lessons. Specifically, teachers often reported that they had too much content to cover, had to move through the required material to completion by a certain date, and needed to make time to prepare students for state-wide testing with review sessions. They continued to believe that inquiry-based lessons took too much time to implement, thus making it

impossible to cover all required topics, complete topics on time and provide review sessions for testing. Despite the PD, they believed that it was faster and more efficient to tell students what they needed to know. However, despite telling us that they were pressed for time, teachers also reported that they were implementing inquiry lessons, perhaps out of fear of being judged negatively. This is a common finding in PD evaluation and research when relying solely upon teacher self-reports, which is why progressive research in science teacher PD necessitates making classroom observations (van Driel et al., 2012) to determine the extent to which time and other factors may be a barrier to implementation and the degree to which teachers actually use what they learn in PD.

Science teachers also struggled with a reconceptualization of their role as a teacher. Most rejected the notion that it was their responsibility to teach reading, writing and speaking in a science classroom. They believed those tasks to be the responsibility of the English/language arts teacher; a science teacher's responsibility was to teach science. However, there was one instructional technique that did resonant with science teachers, which was the science notebook. It looked like what scientists did (i.e., keeping a logbook or field book of observations and ideas, like Leonardo Da Vinci, whose work was held up as a classic example of scientists' use of a journal). Most teachers adopted the use of science notebooks in their classrooms because it was a requirement of the PD and it was easy to set up with their students. CISIP incorporated extensive training on using notebooks during the PD and all teachers were required to keep one themselves during the workshops. But rather than have students use notebooks for their intended purpose as a learning tool to plan inquiry activities, record data, write scientific arguments, reflect on their own thinking, and learning and revise writing it was mostly used for organizing student work (e.g., worksheets were pasted in to the notebook). Science teachers found it difficult to find class time for students to write and revise their writing and additional out-of-classroom time for grading their students' notebook entries.

In contrast to the science teachers, the English/language art teachers were more receptive to the idea of reading, writing and speaking as their responsibility. However, despite seeing reading, writing, and speaking as part of their instructional role, they were less comfortable with expository and non-fiction content texts and writing than they were with fiction and creative writing (Perkins et al., 2010). Thus, they sometimes questioned the purpose of their participation in the CISIP program and felt somewhat peripheral when the PD activities modeled laboratory-oriented lessons.

Research Challenges

No research is without challenges. In addition to the aforementioned problem of recruiting participants for the research and attrition of PD participants there were the challenges of determining fidelity of implementation through instrument development that accurately aligned with the PD, making sufficient classroom observations, training observers, and increasing inter- observer reliability across multiple observers. Once we had developed the DiISC instrument for classroom observations and trained our observers, we were faced with reducing teacher anxiety. To reduce teacher anxiety, we reassured teachers that we were interested in making observations and describing what was happening in classrooms rather than evaluating them. In as much as possible we also assigned the same researcher to the

same school so that trust could be built over time. Making the classroom observations sometimes required multiple scheduling calls with teachers who often had to cancel due to unforeseen circumstances such as illness or a school-wide assembly. Driving to and from schools, making the observations and scoring the observation instrument also took an enormous amount of time on the part of the researchers who also had other responsibilities. Yet, despite the large number of observations that we were able to make, we were also limited by the funding to support this time-intensive work.

Even more so we were also challenged by the difficulty of getting student-level data for making comparisons with teachers in the PD. Many schools refused to be in a comparison group to see if there were differences between students who had teachers who had participated in CISIP and students who did not have CISIP teachers for fear of looking less competent. In the end, only one district agreed to participate with comparison teachers. Unfortunately, this was a high-SES district and the comparison of students of CISIP teachers who came from high-needs school districts with large number of poor and ELL students was both unfair and a poor research design.

Creating rubrics for assessing scientific arguments, scoring the arguments, and establishing interrater reliability was another time-consuming, but necessary task that required many hours and discussion among the research team. Reading through student notebooks was also time-consuming. Finally, creating aligned content knowledge assessments with the content of the PD that measured accurately what teachers learned was one more research challenge.

Despite the many challenges to measure the impact of the PD, the CISIP program helped everyone involved to become better PD providers and it was an intellectual challenge that helped graduate students become scholars. In closing this chapter we address some larger issues and recommendations for science teacher professional development.

CONCLUSION AND RECOMMENDATIONS

CISIP was productive, providing sustained, long-term PD for school-based teams of STEM and English teachers. Teachers who participated for greater than one year showed the most change in their teaching practices, becoming more standards-aligned. Current and future directions in science teacher PD include: (a) designing flexible teacher PD models that build on the research base in science education; (b) studying how teacher PD affects student learning; (c) building modern validity arguments for research instruments to be used for generalizing findings from multiple PD contexts, and (d) the need for improving PD providers' understanding of how to conduct effective PD and engage in research that contributes to our understanding of 21st century science education reform as reflected in policy. We discuss each of these directions briefly here and hope that other PD providers and educational researchers seek collaboration with those individuals whose expertise and experience can assist with the development of both PD design and productive research designs; we know increasingly more about both domains and only through employing current methods and approaches can we further the field.

Flexible Designs

In our example of CISIP as an effective science teacher PD program we acknowledged the critical shift from science lessons written by content experts to developing a PD program that taught teachers a set of tools through which they themselves could revise and develop engaging, discourse-rich science lessons. PD providers may be disappointed to learn that while teachers appreciate the utility of example lessons and activities that they can use directly with their students, teachers are unlikely to unquestioningly adopt a different approach (e.g., using inquiry-based instruction) to teaching those lessons unless they are dissatisfied with how they are currently teaching. Dissatisfaction may occur when teachers engage in formative assessment (Black and Wiliam, 1998) that reveals students' persistent misconceptions in science. Even when teachers desire to change their teaching practice, they may be discouraged to do so if they feel pressure from their schools and districts to raise test scores of struggling students (Nichols and Berliner, 2007; Lewis, 2011).

Studying of Effects of Teacher Professional Development

Investigating the effects of teacher PD should be a top priority for PD providers. The best time to consider how one will investigate any potential effects is long before implementing the PD program. Planning ahead and engaging in proactive steps can alleviate some potential challenges, not limited to the ones we mention here, such as: (a) documenting teachers' initial knowledge prior to beginning a PD program; (b) acknowledging that there will likely be participant attrition from one's PD program over time and over-recruiting participants; and (c) negotiating researchers' access to classroom context to observe how teachers use what they learned with their own students. We discuss each briefly.

First, the initial knowledge, beliefs, and self-efficacy that teachers bring to a PD program can vary greatly due to what they learned from their teacher preparation program, experiences with other PD programs and initiatives, and their disposition toward learning new approaches to teaching and change. Without some method of documenting and measuring teachers' initial knowledge and attitudes toward change prior to starting a PD program, it is impossible to know what teachers learned from their experience in that program, and thus how effective the program was overall.

Second, not all teachers will complete the PD program that they start. This is especially true for sustained PD in which absences on particular days will occur, but is unfortunate as it is only through long-term, sustained teacher PD that change is likely to occur (Banilower, Heck, and Weiss, 2007). Teachers stop attending PD for many reasons, e.g., they are busy with multiple demands on their time and are forced to choose among such competing demands, waning interest in what is being offered, discomfort with expectations that they may need to change their approach to teaching science, and of course any personal issues that sometimes arise. Regardless of why they stop attending, any attrition from a PD program makes studying the effects of teacher learning more difficult, (e.g., pre-post testing of content knowledge with 20% fewer participants at the end than started).

We recommend, when conducting research in teacher PD, to carefully think through the process of gaining access to schools and teachers' classrooms before designing the PD. It is crucial to work with administrators, teachers, and schools and their institutional review boards

in advance to gain entry and support for collecting evidence of teacher learning that may affect student learning. It can be possible to develop positive partnerships through proactive communication with district-level science curriculum coordinators and building principals with the purpose of better understanding the professional learning goals that are already in place in those individual contexts, such that one's teacher PD program may be able to synergistically meet such goals, as well as testing the effectiveness of the PD program itself. Without laying such groundwork conducting longitudinal studies can potentially miss critical data that prevents meaningful interpretations, or reliable and/or credible findings.

Developing Valid and Reliable Instruments to Study PD

A critical need to productively studying teacher PD is building modern validity arguments for research instruments so that they can be used with proper methodologies and analytics when making generalizations (e.g., PD that works in school A also works in school B). This has classically been difficult because whenever PD has been enacted it constitutes a unique context. Thus, researchers are seldom able to compare findings from one design and context to another using traditional experimental designs (e.g., ANOVA, ANCOVA, MANCOVA) due to measurement issues. Many survey and observation instruments have undergone initial development, but stall when developers fail to build complete validity arguments that are necessary such that those instruments can produce consistent results (Messick, 1989; Shadish, Cook, and Campbell, 2002). Perspectives on modern validity involve multiple phases of development that are important to and should be clearly communicated in the user manuals, associated publications, and other supporting documents that describe how the instrument was produced and how it should be used, with whom, and when.

Professional Development for PD Providers

There is a need for improving PD providers' understanding of how to conduct effective PD and engage in research that contributes to our understanding of 21st century science education reform. Just as there are standards for teacher preparation, teacher PD providers should also be attentive to vital aspects of PD designs and implementation. While content experts may be able to offer teachers access to their body of knowledge and research foci, it is rare that scientists and university science faculty understand how to teach and/or how to conduct educational research. For example, many National Science Foundation grant proposals require an educational component to be included, but most STEM faculty have not been trained in educational theory, teacher professional development standards, student learning, or educational research methods. Thus, partnerships with faculty in education, particularly science education, are critical to be able to design programs and conduct studies of science teacher professional development.

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APPENDIX A

Full List of CISIP Professional Development Reference List

Peer-Reviewed Journal Articles

Lewis, E.B., Baker, D.R. and Helding, B.A. (2015). Science teaching reform through professional development: Teachers' use of a scientific classroom discourse community model. *Science Education, 99(5),* 896-931.

Lewis, E.B., Dema, O. and Harshbarger, D. (2014). Preparation for practice: Elementary preservice teachers learning and using scientific classroom discourse community instructional strategies. *School Science and Mathematics, 114(4),* 154-165.

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Lewis, E.B., van der Hoeven Kraft, K.J., Bueno Watts, N., Baker, D.R., Wilson, M.J. and Lang, M.G. (2011). Elementary teachers' comprehension of flooding through professional development and use of self-regulation strategies. *International Journal of Science Education, 33 (11),* 1473-1512.

Baker, D.R., Lewis, E.B., Purzer, S., Bueno Watts, N., Uysal, S., Wong, S., Beard, R. and Lang, M. (2009). The *Communication in Science Inquiry Project* (CISIP): A project to enhance scientific literacy through the creation of science classroom discourse communities. *International Journal of Environmental and Science Education, 4(3),* 259-274.

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Lewis, E.B. (2009). Secondary Science Teachers' Views Toward and Classroom Translation of Sustained Professional Development. Unpublished Dissertation, Arizona State University, Tempe, AZ.

Technical Reports

Baker, D., Beard, R., BuenoWatts, N., Lewis, E., Özdemir, G., Perkins, G., Uysal, S., Wong-Kavas, S. and Yaşar-Purzer, S.* (2008). *Discourse in Inquiry Science Classrooms* (DiISC): Reference Manual, Technical Report No. 001. The Communication in Science Inquiry Project (CISIP): Arizona State University. *(* Authors listed in alphabetical order)*

Conference Presentations

Baker, D., Bueno Watts, N., Sen, T., Perkins, G. and Chaudhuri, D. (2011). The relationship of teacher implementation of professional development to student scientific explanations and grades. *Proceedings of the National Association of Research in Science Teaching,* Orlando, FL.

Bueno Watts, N., Baker, D., Perkins, G., Sen, T., Chaudhuri, D. (2011). Improving Student Scientific Explanation Skills. *Proceedings of the National Association for Research in Science Teaching,* Orlando, Florida.

Lewis, E.B. (2011). Secondary Science Teachers' Translation of Professional Development through Affinity- and Institution-identity. Paper presented at the 2011 annual meeting of the National Association for Research in Science Teaching: Orlando, FL.

Perkins, G., Baker, D., Bueno Watts, N., Sen, T., Chaudhuri, D. and Lang, M. (2011). Arguments of * CESIP students: Science versus English comparisons *Proceedings of the National Association of Research in Science Teaching,* Orlando, FL.

Sen, T., Baker, D., Bueno Watts, N., Perkins, G. and Lang, M. (2011). Changes in inquiry practices of English and science teachers over time. *Proceedings of the National Association of Research in Science Teaching,* Orlando, FL.

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Lewis, E.B., Uysal, S., Yasar-Puzer, S., Baker, D. (2008). The Communication in Science Inquiry Project: Teacher Learning of Scientific Classroom Discourse Communities.

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Lewis, E.B., Baker, D.R., Yasar, S., Lang, M. (2008). Measuring Short-Term Teacher Learning of Scientific Classroom Discourse Communities. Paper presented at the annual meeting of the National Association for Research in Science Teaching: Baltimore, MD.

Baker, D.R., Lewis, E.B., Uysal, S., Yasar, S., Lang, M., Baker, P. (2008). Using the Communication in Science Inquiry Model to Facilitate Learning Biology. Paper presented at the annual meeting of the National Association for Research in Science Teaching: Baltimore, MD.

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Lewis, E.B., Baker, D.R., Yasar, S., Uysal, S. (2007). Perceptions of Secondary and Post-Secondary Interdisciplinary Faculty on CISIP Professional Development: A Teacher Learning Community Designing Scientific Classroom Discourse Communities. Paper presented at annual meeting of the National Association for Research in Science Teaching: New Orleans, LA.

Ozdemir, G., Lewis, E.B., Baker, D.R. (2007). Development and Validity of the CISIP Classroom Observation Instrument (COI). Paper presented at the annual meeting of the National Association for Research in Science Teaching: New Orleans, LA.

Uysal, S., Perkins, G., Lewis, E.B. (2007). The Dynamics of Different Group Composition on Interdisciplinary Lesson Development during a Summer Workshop. Paper presented at annual meeting of the National Association for Research in Science Teaching: New Orleans, LA.

* = CESIP is used here as the focus was on the English teachers, not a typo in the title.

Associated Grants

1) Improving Teacher Quality (ITQ) State Grant ESEA Title II, Part A, Arizona Board of Regents, Middle School Teacher Cohort (2007-2008).
2) Improving Teacher Quality (ITQ) State Grant ESEA Title II, Part A, Arizona Board of Regents, Communication in English and Science Inquiry Project (CESIP), High School Teacher Cohort (2008-2010).

APPENDIX B

(I) Inquiry Scale

This scale measures the degree to which teaching takes place in a student-centered classroom where students are engaged in hands-on activities to explore the natural world with varying degrees of investigative independence.

1. Teacher creates an environment that supports inquiry	**Observed:** 0 1 2 3
Teacher provides students with: a) guidelines and time for (hands-on) exploration b) tools and techniques for analysis of data c) opportunities to elaborate on conceptual understanding	Rubric: *0= teacher lecture, vocabulary worksheet; 1= low level inquiry, directed, convergent activity; 2= medium, somewhat divergent; 3= high, open-ended exploration*
2. Teacher engages students in asking scientific questions for the purpose of investigation (hands-on or other means)	**Observed:** 0 1 2 3
Teacher provides students opportunities to: a) formulate questions about the natural world b) present explanations for questions c) distinguish between scientific and non-scientific questions	Rubric: *0= teacher generates question or no investigation; 1= limited opportunity, rote, cookbook activity; 2= students directed to form scientific questions to be investigated; 3= students form and explain reasoning behind the scientific questions for their investigation*
3. Opportunities for students to design and plan exploration of the natural world individually or in groups	**Observed:** 0 1 2 3
Teacher provides opportunities and guidance to: a) plan and conduct scientific investigations individually b) plan and conduct scientific investigations in groups c) justify procedures before carrying out investigations	Rubric: *0= no activity or activity has a set procedure; 1= students are all expected to design the same procedure; 2= students design a procedure but are not required to justify; 3= students design, plan, and justify their approach to exploration of a topic*
4. Opportunities for early stages of scientific exploration: making observations, recording data, and constructing logical representations (e.g., graphs)	**Observed:** 0 1 2 3
Teacher provides opportunities to: a) make observations through doing the activity b) record and use data c) record and represent data in logical forms that show patterns and/or connections	Rubric: *0= no exploration; 1= limited opportunity to engage in exploration; 2= students collect and/or manipulate data; 3= extensive exploration*

5. Opportunities for later stages of scientific exploration: explaining phenomena via claims and evidence, making predictions, and/or building models	Observed: 0 1 2 3
Teacher provides students opportunities to: a) make claims, provide evidence, and develop explanations b) revise explanations and models using data and logic c) make predictions and build models	Rubric: *0= no use of data for scientific explanation; 1= teacher-led, incidental use of claims and evidence; 2= students generate scientific explanation and/or models; 3= includes all of 2 and teacher directs students to evaluate their scientific explanations and revise*
6. Generating scientific arguments and constructing critical discourse about limits and sources of error	Observed: 0 1 2 3
Teacher provides students opportunities to: a) think of other ways to interpret data using scientific knowledge and logic to generate scientific arguments b) identify limits and exceptions of interpretations of data c) discuss the effects of error on results and suggest ways to reduce error in collecting data	Rubric: *0= no evaluation of scientific arguments or conclusions; 1= teacher provides possible sources of error in their investigations; 2= students generate sources of error and alternative explanations are generated; 3= students are directed to revise and evaluate their scientific explanations, consider alternative explanations, and sources of error*

APPENDIX C

Table C-1. Description of the Energy in Systems Science Content Professional Development Activities

Activity	Description	Objective	Teacher Outcomes
1.01 Day 1 Activity 1: Water Analogy	Teachers, split into two teams, go outside and try to fill a bucket of water from a flowing source, incorporating a minimum of four transfers, using their bare hands. Writing and Discussion Teachers write about activity in notebooks. Teachers discuss energy flow within an ecosystem Vocabulary	Use water as an analogy for energy flow through system. Introduce concepts of energy, system, source, sink, storage, transfer, and efficiency. Use water analogy to build conceptual framework of energy in systems; relate to energy flow within an ecosystem (trophic levels, producers, consumers) as an example of energy flow through a system.	• Participate in a hands-on inquiry activity which may be used in the classroom to Engage students in energy flow through system. • Promote team-work among PD participants • Begin to think about energy as being the *ability to cause change.* • Introduce energy vocabulary: energy, system, source, transfer, storage, sink • Relate energy flow in a system to energy flow within an ecosystem.

Table C-1. (Continued)

| 1.02
Day 1
Activity 2: Spinach Leaf Disk Mystery | Given a choice of materials (light sources, baking soda, water, leaves, colored cellophane, thermometers, etc.), teachers explore the concept of transfer of energy in systems via photosynthesis. | Explore photosynthesis by formulating a question, planning and conducting a scientific investigation.
Make observations, record and use data.
Explain results using claims, evidence and reasoning.
Demonstrate how photosynthesis can be used as an example of transfer of energy from light to leaf systems. | • Participate in a hands-on inquiry activity which may be used in the classroom to allow students in Explore energy flow through system.
• Formulate scientific question
• Plan and conduct scientific investigation
• Write scientific explanation using claims, evidence, and reasoning to answer a scientific question. |

Table C-2. Description of the Energy in Systems Science Content Professional Development Activities

2.03 Day 2 Activity 3: Bank Account Analogy	Money is like energy. It can be: stored, transferred and transformed into goods and services. When it is transferred out of your system (account), it still exists, but is unusable to your system.	Elaborate on the concepts of energy storage, transference, and transformation.	• Participate in discussion which may be used in the classroom to allow students to Elaborate on their understanding of energy storage, transference, and transformation.
2.04 Day 2 Activity 4: Interactive Lecture – Society's Energy Systems	Interactive lecture on the comparative nature, advantages, and disadvantages of the different energy resources and conversion systems currently used to power human society. Vocabulary	Engage in thinking about electrical energy sources and distribution by drawing a *concept sketch* which traces electrical energy from the electrical outlet on the wall back to its original energy source. Learn about electrical power generation, fossil fuels, energy conversion and efficiency, energy sources and energy density through interactive lecture.	• Participate in an activity which may be used in the classroom to Engage students in thinking about the *sources* of electrical energy. • Overview of U.S. energy sources, conversion, and distribution systems through direct instruction. • Differentiate between potential and kinetic energy; and among chemical, mechanical and thermal energy.
2.05 Day 2 Activity 5: Inquiry into Energy Density	Teachers explore the concept of *energy density* as a measure of the energy stored in a system through whole group discussion using energy density data tables, and then they write quantitative problems using the concept for use in their classroom.	Explore *energy density* as a means of comparing different energy sources. Explain the importance of energy density to decisions about energy resource usage. Elaborate on understanding of the concept of energy density by writing quantitative problems for use in the classroom.	• Participate in an activity which allows students to Explore the concept of *energy density* and its importance to the energy resource debate. • Write quantitative problems about energy density which can be solved in the science classroom.

Table C-3. Description of the Energy in Systems Science Content Professional Development Activities

3.06 Day 3 Lesson 6: Science Curriculum Topic Study *Jigsaw*	Teachers are assigned a topic for study (*Science for All Americans*): A. Energy transformations B. Flow of Matter and Energy C. Energy Sources D. Energy Use Teachers compare big ideas, major concepts, and insights with a partner. In groups of four, look for interconnections. *Repeat*, looking for misconceptions and alternative ideas from these readings: *Benchmarks for Scientific Literacy* A. Energy Transformations B. Flow of Matter and Energy *Making Sense of Secondary Science: Research into Children's Ideas* C. Energy Transfer Processes D. Photosynthesis	Increase science content knowledge about energy and photosynthesis and related student misconceptions.	• Participate in an activity which allows teachers to deepen scientific content knowledge about energy in systems. • Participate in peer discourse about big ideas and major concepts of *energy in systems*, as well as student misconceptions. • Discuss with peers how knowledge of student misconceptions can be used in the classroom to improve student understanding.
3.07 Day 3 Lesson 7: Contextual Rubrics	Teachers write a scientific explanation using a simple data table. Teachers then score their explanation using 1) an example rubric without specific exemplars, and then 2) an example rubric with specific exemplars of the scientific explanation they were asked to write	To understand the difference between using a generic rubric to score student arguments and using a rubric in which specific exemplars of each proficiency level have been described.	• Discover the difference between using generic rubrics and rubrics which provide specific exemplars of claims, evidence, and reasoning for each level of a scientific explanation. • Write a scaffolded rubric tailored to a specific investigation
3.08 Day 3 Lesson 8: Designing Explanation Scaffolds	Teachers learn the difference between continuously scaffolding student scientific explanations, and gradually removing parts of the scaffold.	Provide teachers with two alternative plans for scaffolding student scientific explanations. Discuss the pros and cons of each	• Teachers should be able to decide which scaffolding approach they plan to use with their students for the up-coming school year.

Table C-4. Description of the Energy in Systems Science Content Professional Development Activities

4.09 Day 4 Activity 9: Introduction to the Wedge game and strategies *Jigsaw*	Teachers read and discuss one of five different packets on carbon emission reduction. Jigsaw – reform groups and teach other group members about your method.	Provide teachers with deeper understanding of carbon emissions and their link to global climate change. Provide teachers with deeper understandings of the pros and cons of each option for reducing carbon emissions.	• Participate in an activity which allows teachers to deepen understanding about carbon emissions and their link to global climate change, proposed options of reducing carbon emissions, and their environmental, economic and social equity impacts.
4.10 Day 4 Activity 10	Teams of teachers create stabilization triangles. Teams complete sustainability rating graphs with respect to social equity, economics, and effect on the environment.	Provide teachers with deeper understanding of various methods of carbon reduction and their impact on the environment, economics, and social equity. Demonstrate a method of graphing three different values simultaneously.	• Participate in an activity which allows teachers to discuss the impacts of various methods of carbon reduction with regards to impact on the environment, economics, and social equity issues. • Acquire proficiency in graphing and evaluating three different data sets simultaneously.
4.11 Day 4 Activity 11	Participants individually write scientific explanations for mock Global Nations International Climate Summit	Provide teachers with practice writing scientific explanation using claims, evidence, and reasoning.	• Write scientific explanation using claims, evidence, and reasoning to answer a scientific question.
4.12 Day 4 Activity 12	Teams of three participants share individual scientific explanations with each other, then develop and record a 2 minute video of a persuasive argument which clearly state claim with evidence to support and reasoning linking claim and evidence.	Provide teachers with practice communicating a persuasive scientific argument using claims, evidence, and reasoning. Allow teachers to clearly see the link between scientific explanations (science) and persuasive arguments (language arts).	• Participate in an activity which will allow teachers to practice negotiation and collaboration skills • Share scientific explanation using claims, evidence, and reasoning in a succinct manner. • Collaborate with English teachers to produce a persuasive scientific argument.

BIOGRAPHICAL SKETCHES

Name: Elizabeth B. Lewis

Affiliation: University of Nebraska-Lincoln

Education:
Ph.D., Curriculum and Instruction, Arizona State University, 2009
M.S., Ed. Teaching and Learning, University of Southern Maine, 1999
M.S., Geological Sciences, University of Maine, 1997
B.S., Geology, The College of William and Mary, 1991

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Research and Professional Experience:
- 2015 - Present, Principal Investigator, National Science Foundation Robert Noyce Teacher Scholarship Program Grant (Track I, Phase II), University of Nebraska-Lincoln. Start date: 9/15/15; $799,890.
- 2014 - 2015, Co-PI, Nebraska Coordinating Commission for Postsecondary Education, Nebraska Department of Education, Improving Teacher Quality: Enhancing Nebraska 6-12 Science Teachers' Knowledge of Earth Science Content, Mindi Searls (PI), Leilani Arthurs (co-PI), and Elizabeth Lewis (co-PI). Start Date: 2/3/14; $82,042.
- 2013 - 2015, Co-PI, University of Nebraska-Lincoln, Kelly Fund, Development of Biochemistry Undergraduate Students' Writing and Graduate Students' Teaching Skills, Paul Black (PI), Sue Ellen DuChenne, and Elizabeth Lewis (co-PI). Start Date: 6/01/2013; $24,900.
- 2013 - 2015, Principal Investigator, University of Nebraska-Lincoln, Office of Research, Layman Seed Program Grant: Moving Beyond Marginalization: Investigating Earth and Space Science Education. Start Date: 6/01/2013; $9,970.
- 2012 – Present, Principal Investigator, National Science Foundation Robert Noyce Teacher Scholarship Program Grant (Track I, Phase I), University of Nebraska-Lincoln. Jon Pedersen (PI, 9/1/2010-8/31/2012, co-PI since 9/1/2012), Elizabeth Lewis (PI since 9/1/2012, co-PI from 9/1/10 to 8/31/2012), Dan Claes (co-PI), Tiffany Heng-Moss (co-PI). Start date: 9/1/2010; $1,194,387.
- 2005-2009, Graduate Research Associate, NSF-Funded Communication in Science Inquiry Project (CISIP), Arizona State University, Tempe, Arizona.
- 2006-2007, Graduate Research Assistant: NSF-Funded Science Teacher Induction Grant, Arizona State University, Tempe, Arizona.

Professional Appointments:
2015 - Present, Associate Professor, Department of Teaching, Learning and Teacher Education, College of Education and Human Sciences, University of Nebraska-Lincoln

2009 - 2015, Assistant Professor, Department of Teaching, Learning and Teacher Education, College of Education and Human Sciences, University of Nebraska-Lincoln

2005 - 2008, Instructor, Elementary Education Program, Arizona State University, Tempe, Arizona

2002 - 2005, Science Faculty, North Andover High School, North Andover, Massachusetts

1998 - 2002, Science Faculty, Cape Elizabeth High School, Cape Elizabeth, Maine

1995 - 1997, Teaching Assistant (Lab and Recitation Instructor), Department of Geological Sciences, University of Maine, Orono, Maine

1993 - 1995, Staff Geologist, Robert G. Gerber, Inc., Freeport, Maine

Honors:

- *2016 College of Education and Human Sciences Distinguished Teaching Award*, University of Nebraska-Lincoln
- *2008-2009 Dissertation Fellowship*, Arizona State University Alumni Faculty-Preparing Future Faculty
- *2007-2008 Dean's Excellence Award for Graduate Research*, Mary Lou Fulton College of Education, Arizona State University, Tempe, Arizona
- *2006-2007 Science Education Program, ASU Graduate School Award for Graduate Student Excellence*, Arizona State University, Tempe, Arizona
- *2003-2004 Distinguished Secondary Educator*, Massachusetts Department of Education

Publications Last 3 Years:

Journal articles:

Lewis, E.B., Baker, D.R. and Helding, B.A. (2015). Science teaching reform through professional development: Teachers' use of a scientific classroom discourse community model. *Science Education, 99, 5,* 896-931.

Lewis, E.B., Dema, O. and Harshbarger, D. (2014). Preparation for practice: Elementary preservice teachers learning and using scientific classroom discourse community instructional strategies. *School Science and Mathematics, 114, 4,* 154-165.

Lewis, E.B., Baker, D.R., Bueno Watts, N. and Lang, M. (2014). A professional learning community activity for science teachers: How to incorporate discourse-rich instructional strategies into science lessons. *Science Educator, 23, 1,* 1-9.

Book review:

Lewis, E.B. (2015). Seeking research-enhanced geoscience outreach that complements subject knowledge with pedagogical expertise. *Studies in Science Education, 51, 2,* 251-256.

Name: Dale Rose Baker

Affiliation: Arizona State University

Education:
    Ed.D, Science Education, Rutgers University, 1981
    M.A.T., Elementary/Early Childhood Education,
    Trenton State College, 1975
    B.A., Anthropology, University of Oklahoma, 1971

Address:
Division of Educational Leadership and Innovation, Mary Lou Fulton Teachers College, P.O. Box 871811, Arizona State University, Tempe, AZ, 85287-1811

Professional Appointments:
    2015 - Present, Research Professor, Arizona State University
    1998 - 2015, Professor, Arizona State University
    1989 - 1998, Associate Professor, Arizona State University
    1987 - 1989, Associate Professor, University of Utah
    1981 - 1986, Assistant Professor, University of Utah
    1980 - 1981, Instructor, University of Utah

Honors:
- NARST 2013 Distinguished Contributions to Science Education Through Research Award
- Mary Lou Fulton Teachers College award for Research with Sustained Impact, 2012 for research in assessment and equity issues in science
- Fellow, American Educational Research Association, 2009
- Fellow, American Association for the Advancement of Science for research and leadership in gender equity in science, 2004
- Most influential research in the past 40 years of the *Journal of Research in Science Teaching* for Baker, D. and Leary, R. (1995). Letting girls speak out about science. *Journal of Research in Science Teaching, 1*, 3-27. (One of 12 articles selected.)
- 1989 Outstanding Research Award in Classroom Applications for Baker, D. Piburn, M. and Niederhauser, D. If I were the teacher: Students attitudes towards the science curriculum. National Association of Research in Science Teaching, San Francisco, CA.
- Outstanding Paper of 1988 published in *Science Education*, Award of Merit for Piburn, M. and Baker, D. Sex Differences in Formal Reasoning Ability: Task and interviewer effects.

Publications Last 3 Years:
Baker, D. (2016). Understanding Girls: Quantitative and Qualitative Research. Sense Publishers.

Dori, J, Zemira, M. and Baker, D. (Eds.) (2016). Cognition, Metacognition and culture in STEM Education. Springer Publishers.

Lewis, E.B., Baker, D.R. and Helding, B.A. (2015). Science teaching reform through professional development: Teachers' use of a scientific classroom discourse community model. Science Education. Science Education, 99, 5, 896-931.

Baker, D., Wood, L., Corkins, J. and Krause, S. (2015). Tinkering and technical self-efficacy of engineering students at the community college. Community College Journal of Research and Practice, 39, 6, 555-567.

Lewis, E., Baker, D., Bueno Watts, N. and Lang, M. (2014). Professional learning community activity for science teachers: Building classroom discourse community. Science Educator, 23, 1, 1-9.

Purzer, Ş., Moore, T., Baker, D. and Berland, L. (2014). Engineering in the Next Generation Science Standards (NGSS): A Position Statement on the Implementation of Engineering as Covered in the NGSS. Position Paper invited by NARST, A Worldwide Organization for Improving Science Teaching and Learning through Research, https://www.narst.org/ngsspapers/index.cfm

Bang, E.J. and Baker, D. R. (2013). Gender differences in Korean high school students' achievements and attitudes toward science in three different school settings. Mevlana International Journal of Education, 3, 2, 27-42.

Bueno Watts, N. Baker, D. and Semken, S. (2013). The impact of writing intensive professional development on high school teachers' science content knowledge of energy in systems. Global Journal of Human Social Sciences, 13, 3, version1.0.

Baker, D. (2013). What Works: Using Curriculum and Pedagogy to Increase Girls Interest and Participation in Science and Engineering. Special Issue Theory into Practice, 52, 1, 14-20.

Name: Nievita Bueno Watts

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Institute of Environmental Health, Center for Coastal Margin Observation and Prediction, Oregon Health and Science University

Education:
Ph.D., Science Education, Arizona State University, 2011
M.S., Geoscience, Arizona State University, 2007
B.S., Geoscience, University of Arizona, 2004

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Research and Professional Experience:

- 2011 – 2012 Postdoctoral Research Associate, *Gold Mine Exhibit*, Purdue University, Department of Earth, Atmospheric and Planetary Sciences.

- 2008-2011 Graduate Research and Teaching Assistant, *Communication in Science Inquiry Project (CISIP),* Arizona State University, Mary Lou Fulton Teachers College
- 2006-2008 Graduate Research and Teaching Assistant, *Time Scale Cognition Experiments for the Trail of Time at Grand Canyon National Park*, Arizona State University, School of Earth and Space Exploration
- 2004-2006 Graduate Research and Teaching Assistant, *EarthScope,* Arizona State University, School of Earth and Space Exploration
- 2003-2004 Research Assistant, *Debris Aprons on Mars*, Planetary Science Institute, Tucson, AZ
- 2002-2003 Research Assistant, *Debris Aprons on Mars*, NASA Space Grant, University of Arizona, Lunar and Planetary Imaging lab
- 2001-2004 SAT Instructor, Office of Early Academic Outreach, University of Arizona
- 2001-2002 Research Assistant, *EarthScope,* University of Arizona, Department of Geosciences

Professional Appointments:

2012-Present, Academic Program Director, Environmental Systems and Human Health Master of Public Health, Joint School of Public Health, Oregon Health and Science University and Portland State University

2012-Present, Director of Academic Programs, Center for Coastal Margins Observation and Prediction and Senior Instructor, Institute of Environmental Health, Oregon Health and Sciences University

2015- Present, Affiliate faculty, Purdue University, West Lafayette, Indiana

1989-2001, Paraeducator, Special Education, Atascadero High School, Atascadero, California

Honors:

- Eagle Feather Leadership Award, Geoscience Alliance, March 2015
- SACNAS Leadership Institute, 2013
- Ronald E. McNair Scholar
- Phi Beta Kappa

Publications Last 3 Years:

Bueno Watts, N. and Dalbotten, D. (2015), Exploring the impact of a changing climate on tribal communities, *Eos, 96,* doi:10.1029/2015EO037309. Published on 20 October 2015.

Bueno Watts, N., Smythe, W.F., Geraghty Ward, E., Green, V., Tano, M., Berthelote, A. and Dalbotten, D. (2014) The Geoscience Alliance: Building Capacity to Use Science for Sovereignty in Native Communities. In *Future Earth: Advancing Civic Understanding of the Anthropocene*, American Geophysical Union.

Lewis, E.B., Baker, D., Bueno Watts, N. and Lang, M. (2014). A professional learning community activity for science teachers: How to incorporate discourse-rich instructional strategies into science lessons. *Science Educator, 23, 1,* 1-9.

Bueno Watts, N. and Smythe, W.F. (2013). It Takes a Community to Raise a Scientist: A Case for Community-Inspired Research and Science Education in an Alaska Native Community. *Current: The Journal of Marine Education* 28, 3.

Green, V., Bueno Watts, N., Wegner, K., Thompson, M., Johnson, A., Peterson, T. and Baptista, A. (2013). Coastal Margin Science and Education in the Era of Collaboratories. *Currents: the Journal of Marine Education. 28, 3.*

Bueno Watts, N., Baker, D., Semken, S. (2013). The Impact of Writing Intensive Professional Development on High School Teachers' Science Content Knowledge of Energy in Systems. *Global Journal of Human Social Science-G,* 13, 3, 45-57.

Name: Katrien J. van der Hoeven Kraft

Affiliation: Whatcom Community College

Education:

Ph.D., Curriculum and Instruction, Arizona State University, 2014
M.S., Geology, Arizona State University, 1999
B.A., Geology, Colby College, 1995

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Research and Professional Experience:

- 2015-2018, NSF GEO, Consultant for Fort Lewis College, Supporting the Academic and Social Integration of Incoming Transfer Students, Improving Undergraduate STEM Education (IUSE) Grant (Award #: 1540545)
- 2015-2016, NSF GEO, Consultant and Advisory Board member for Indiana University of Pennsylvania, Science, Technology, Engineering and Math Student Experiences Aboard Ships (Award #: #1540645)
- 2010-2014, National Science Foundation (NSF) Department of Undergraduate Education (DUE) CCLI Phase 2, Principal Investigator for Mesa Community College, Collaborative Research: GARNET II: Self-regulated learning and the affective domain in physical geology (Award #: 1022980, $88,358).
- 2009-2010, NSF, Geo Directorate Program, Co-Principal investigator for William and Mary, The Role of Two-year Colleges in Education and Broadening Participation in the Geosciences: A Planning Workshop (Award #: 939671, $47,290)

Professional Appointments:

2014-present, Assistant Professor, Whatcom Community College, Science Department, Geology.
1999-2014, Professor, Mesa Community College, Physical Science department, Geology.

Honors:

- 2015, National Association of Geoscience Teacher, Outstanding Reviewer
- 2011-2012, Arizona State University, Graduate Fellowship

- 2007-2008, Maricopa Community College District, Maricopa Institute for Learning Fellow

Publications Last 3 Years:

Kortz, K. and van der Hoeven Kraft, K. J. (2016). Geoscience Education Research Project: Student Benefits and Characteristics of Effective Design of Undergraduate Research Experiences, *Journal of Geoscience Education, 64*(1), 24-36.

Teasdale, R., van der Hoeven Kraft, K. J., Poland, M. P. (2015). Using near-real-time monitoring data from Pu'u'O'o vent at Kilauea Volcano for training and educational purposes: promoting authenticity in learning, *Journal of Applied Volcanology, 4*(11), 1-16.

Budd, D.A., van der Hoeven Kraft, K.J., McConnell, D.A., Vislova, T. (2013). Characterizing teaching in introductory geology courses: a direct measure of classroom practices. *Journal of Geoscience Education, 61*(4), 461-475.

Hilpert, J., Stempien, J., van der Hoeven Kraft, K. J. and Husman, J. (2013). Evidence for the latent factor structure of the MSLQ: A new conceptualization of an established questionnaire. *SAGE-Open, 3*, 1-10, doi: 10.1177/2158244013510305.