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The Communication in Science Inquiry Project (CISIP): A Project to Enhance Scientific Literacy through the Creation of Science Classroom Discourse Communities

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This study reports on the context and impact of the Communication in Science Inquiry Project (CISIP) professional development to promote teachers' and students' scientific literacy through the creation of science classroom discourse communities. The theoretical underpinnings of the professional development model are presented and key professional development activities are described. Data are provided on teachers' fidelity of implementation of the CISIP instructional strategies, their understanding of the nature of science communication, and their ability to write scientific investigation reports. Student data includes an analysis of scientific arguments and the perception of their classroom as a science classroom discourse community. Two instruments to measure fidelity of implementation are introduced; the Discourse in Inquiry Science Classrooms for classroom observations of teachers and My Science Classroom Survey to measure students' perceptions of their teachers' use of the CISIP instructional strategies in their classroom.

Key Words: discourse community, nature of science communication, scientific argument

Study Context

This study presents preliminary data on the impact of the Communication in Inquiry Science Project (CISIP) professional development (PD) to promote scientific literacy among teachers

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and students. It focuses on teachers' understanding of the nature of science communication (NOSC) and their ability to create science classroom discourse communities (SCDCs), and students' ability to write scientific arguments.

The Communication in Science Inquiry Project (CISIP)

The Communication in Science Inquiry Project (CISIP) is a funded project that promotes scientific literacy by helping teachers create SCDCs in their classrooms. The CISIP definition of scientific discourse encompasses knowing, doing, talking, reading, and writing about science; and using appropriate forms of evidence (Lemke, 1990; Moje, Collazo, Carillo & Marx, 2001).

A Science Classroom Discourse Community (SCDC)

A SCDC is a community of learners who create a culture that reflects literacy practices in science. The culture promotes norms of interaction that foster scientific discourse, use of notebooks, scientific habits of mind, and scientific language acquisition through inquiry. Central to a SCDC are experiences for students to communicate, create, interpret, and critique scientific arguments using scientific principles and data from inquiry activities.

Our model uses situated learning where learning is a social activity (Lave & Wegner, 1992; Wegner, 1998), and learning to talk and write in the genres of science contributes to the development of structured and coherent ideas (Kelly, 2007). A SCDC supports achievement in science by promoting peer to peer interactions and discourse experiences.

Scientific Literacy

The definition of scientific literacy we use encompasses writing, speaking, and inquiry skills found in reform documents and standards (American Association for the Advancement of Science, 1989, National Research Council, 1996, 2000). In addition, we include academic language development. This is an important aspect of literacy in our context because of the number of English language Learners (ELLs) in our schools. Furthermore, the language of science presents challenges even for native speakers of English. Academic language development is a way to bridge everyday language to the vocabulary, structure, and genres of science.

Academic Language Development

SCDCs address the science language acquisition of all students including ELLs. Consequently, we help teachers use the language principles and theories of Carrasquillo and Rodriquez (1996) and the Cognitive Academic Language Approach (Chamot & O'Malley, 1987). We also emphasize strategies adapted from Herrell and Jorden (2007) and the research in science education about linguistically diverse students (Fradd & Lee, 1999; Lee & Fradd, 1996).

Writing

Traditionally, writing has been used for evaluation but is receiving more attention in science education with writing-to-learn strategies (Keys, 1999). Researchers assert that writing is not only a reflection of conceptual understanding but also a tool for understanding (Halliday & Martin, 1993; Lemke, 1990). The CISIP model relies on the research in writing-to-learn in science (Klein, 1999; Yore, Hand & Prain, 1999), with an emphasis on knowledge transformation (Bereiter & Scardamalia, 1987). Rivard (1994) summarized the research stating 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 …" (p. 975). Furthermore, explicit teaching of scientific writing helps students organize relationships among elements of text and knowledge (Callaghan, Knapp & Noble, 1999; Keys, 1999). We emphasize writing because the skills to understand scientific writing and the ability to write scientifically are important aspects of scientific literacy.

Oral Discourse

Although science is defined as making sense of the natural world, investigating nature is only part of knowledge generation (Kittleson & Southerland, 2004). Scientific knowledge is also socially and culturally constructed (Alexopoulou & Driver, 1996; Kelly & Crawford, 1997; Kelly & Green, 1998) through negotiation. A key element of this negotiation is oral discourse. Group processes therefore are central to understanding how knowledge is created in a science classroom (Kelly & Green, 1998). Newton, Driver, and Osborne (1999) argued that scientific discourse develops conceptual understanding, and builds a scientific community in the classroom. Since scientific discourse is socially mediated and constructed, students need to learn discourse norms through participation in discourse and explicit instruction (Kelly & Chen, 1999). As with writing, we emphasize oral discourse because the skills to engage in scientific discussions, understand scientific arguments, and understand the role of discourse in the creation of scientific knowledge are important aspects of scientific literacy.

Inquiry

Our PD is based in inquiry as a way to build scientific knowledge (National Research Council, 1996). Within inquiry, we focus on the nature of scientific communication emphasizing rhetorical stances, text structures, genres, and patterns of argumentation reflected by a modernist view (Halliday & Martin (1993).

Learning Principles

CISIP emphasizes teaching that promotes learning for understanding and lessons that promote scientific literacy through the implementation of learning principles (i.e., assessing prior understandings, linking fact to conceptual frameworks, metacognitive monitoring, setting performance expectations, providing feedback). These principles are derived from the research in the science of learning described in *How People Learn* and *How Students Learn* (Bransford, Brown & Cocking, 2000; National Research Council, 2005).

Scientific Literacy and Standards

The National Science Education Standards

CISIP addresses aspects of scientific literacy as defined by the national science education standards in the United States. These standards define scientific literacy as the ability to: a) ask and answer questions about the natural world, b) read, understand, and evaluate science articles in the popular press, c) identify scientific issues underlying political decisions, d) take positions on issues that are informed by science and technology, e) evaluate scientific arguments based on data, and f) develop scientific arguments using appropriate data and reasoning

(National Research Council, 1996). We place the greatest emphasis on asking and answering questions, and "thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments" (National Research Council, 1996, p. 105).

We follow recommendations that place less emphasis on "Science as exploration and experimentation", "Providing answers about science content", and "Concluding inquiries with the results of experimentation" (National Research Council, 2006, p. 113) and more emphasis on "Science as argument and explanation," Communicating science explanations," and "Applying the results of experiments to scientific arguments and explanations" (National Research Council, 2006, p. 113).

State Standards

Arizona's state science standards for students are generally modeled on the national standards. Students are expected to: a) engage in inquiry and develop questions that can lead to hypotheses, b) record their questions, ideas, and data using a variety of tools including science notebooks, c) choose appropriate ways to communicate results clearly and logically, d) support conclusions with logical scientific arguments, and e) understand the characteristics of a scientific argument with an emphasis on rules of evidence (Arizona Department of Education, 2007).

The state standards are less specific than the national standards for oral and written discourse. Although they address communication and scientific argumentation, they do not address developing a SCDC as a way to build a community of learners. School districts follow both state and national standards.

State Testing

Testing drives what is taught in schools. Consequently, although national and state standards emphasize communication in science, oral and written discourse, and crafting and evaluating scientific arguments, these standards are given little instructional time.

The state assessment (AIMS) in science is given at the fourth and eighth grade, and in high school. Items that assess scientific literacy fall under the categories of analysis and conclusions, and communication on the AIMS Inquiry scale. The fourth grade assessment has 54 items with six items addressing analysis and conclusions, and one addressing communication. Thus, only 11% of the fourth grade assessment measures scientific literacy. At eighth grade there are 58 items. Six items assess analysis and conclusions, and two assess communication. This is 13% of the questions. At high school there are 65 items. Of these, six assess analysis and conclusions, and four assess communication. These numbers send a clear message that instruction should emphasize content knowledge.

Pedagogies for Scientific Literacy

The CISIP PD provides teachers with experiences that models instructional strategies for scientific literacy that support the creation of SCDCs.

Academic Language

The academic language strategies used in our PD build upon students' language and promotes peer-to-peer interaction. Teachers support use of language and vocabulary by modeling and contextualizing academic language. Teachers use visuals aids, gestures, demonstrate procedures, and use supplemental materials (e.g., bilingual dictionaries). Teachers also adapt the linguistic complexity so that students can respond according to their stage of language ability. In addition, teachers provide direct instruction in learning strategies (e.g., underlining key vocabulary) and establish clear expectations for work.

Writing

The literacy strategies modeled in the PD begin with prewriting activities such as brainstorming. Rubrics used to evaluate writing are provided to facilitate revising. Writing is scaffolded with templates and examples to guide students in acquiring the language patterns to communicate scientific ideas. Using scientific vocabulary is facilitated by word walls (student generated displays of vocabulary and definitions), and student generated dictionaries housed in science notebooks. Science notebooks are used as a learning tool that contains multiple drafts of scientific arguments and metacognitive reflections that students can use to evaluate their own learning. The emphasis is on writing to learn content.

Oral Discourse

The PD presents literacy strategies designed to help teachers promote discourse. It models inquiry experiences and open ended questions about data that create a context for discussion. In classrooms, teachers emphasize the nature of scientific communication by modeling what scientific discourse sounds like with appropriate vocabulary. They also bridge everyday experiences to the language of science. For example, students will watch a movie about the discovery of the structure of DNA, identify instances of scientific talk, and contrast that talk with how they communicate with friends.

Inquiry

The PD models literacy strategies designed to help teachers engage students with scientific questions. Students are taught to give priority to evidence, which allows them to develop explanations. Once explanations have been formulated, teachers lead students through the process of evaluation of alternative explanations, particularly those reflecting scientific understanding. Finally, teachers provide students with opportunities to communicate and justify explanations by writing scientific arguments using claims, evidence, and reasoning.

Learning Principles

Scientific literacy is supported by teachers' use of learning principles. The CISIP PD helps teachers assess students' prior knowledge through questioning and consequently modify instruction based on students' prior knowledge. Lesson development emphasizes creating lessons that link facts to conceptual frameworks.

Metacognitive activities are also modeled. Teachers engage in reflective writing in notebooks or use a self-check form that identifies depth of understanding. Teachers are encouraged to modify and use these techniques to develop their students' ability to engage in metacognition. Teachers are also shown how to provide academic feedback to students using rubrics and examples of poor and quality work.

Research Design

Methods

The data were collected from middle and high school teachers and students in 2007-2008. The number of participants varied depending on when and what data was collected. Teacher data (*N*=46) were collected during a 2007 summer Institute and consisted of pre and post writing about the nature of science communication (NOSC), and a scientific investigation report written after science inquiry activities. A rubric was developed to score the NOSC writing (Appendix A). The scientific investigation report was scored qualitatively looking for provisional and tentative language.

During 2007-2008 the PD continued on Saturdays four times throughout the year. Additional teacher (*N*=43 CISIP, 20 control) data were collected during the fall and spring of 2007-2008 using the *Discourse in Inquiry Science Classrooms* (*DiISC*) protocol to make 160 classroom observations. The *DiISC* measures fidelity of classroom implementation of the CISIP model (Baker et al., 2008). Demographic teacher (e.g., highest degree, years teaching, years of PD) and, school and district data (e.g., number of students on free or reduced lunch, test scores) were also collected to construct an exploratory longitudinal model using hierarchical linear modeling (HLM) to identify factors that affected fidelity of implementation measured by the *DiISC*. The difference in the number of teachers who participated in the PD and number observed was due to fewer consenting to be observed.

Student data were also collected during fall and spring of 2007-2008. A random selection of science notebooks was collected from assenting students in the classrooms of CISIP teachers. The scientific arguments (*N*=77) in the notebooks were rated using a rubric.

Students (*N*=1,103) in CISP classrooms and control classrooms were given the *My Science Classroom Survey (MSCS)* in spring 2008. This instrument uses a Likert scale to measure student perceptions of the teacher's use of CISIP instructional strategies. It has four dimensions: Scientific Inquiry (e.g.,We design our own scientific investigations), Learning Expectations (e.g., We know what the teacher expects of us,) Writing (e.g., We revise when we write), and Use of Science Notebooks (e.g. We use science notebooks to records our data). The correlation between *MSCS* scores and *DiISC* scores was calculated to determine whether students in CISP and control classrooms perceived their classrooms differently.

Intervention: Summer Institute

The CISIP Summer Institute was held Monday through Thursday from 8:00 until 1:30 with a half hour lunch break. There were 60 contact hours that provided integrated pedagogy and content. Forty-six middle and high school teachers attended. The PD was delivered by current classroom teachers who were part of the PD design team.

During the Institute, we assessed the impact of the PD on teachers' scientific literacy in terms of their understanding of the nature of science communication (NOSC). Teachers attending the Institute had many opportunities to learn about NOSC and how to implement strategies in their classrooms to create a SCDC.

At the beginning of the Institute, teachers were asked to define NOSC and how scientists do science. Next, teachers engaged in a nature of science card exchange activity. During this activity, teachers worked in teams of 4 or 5 and discussed statements on cards reflecting various views of science including scientific communication. Some of the statements did not reflect normative views of NOSC. The teams were asked to agree or disagree with statements and to support their position with arguments. Statements most relevant to scientific communication described, among others, the social aspects of constructing knowledge, the centrality of language and communication to science, and the importance of writing for the development of scientific ideas. Statements also described aspects of what is more commonly thought of as the nature of science (NOS) such as tentativeness and skepticism. Non normative, positivist statements describing science as always a systematic process, totally objective, and without biased were included. Teams were built from pairs of teachers after they came to consensus so that the teachers had multiple opportunities to discuss their positions and hear the positions of others. Afterwards, teachers were asked to explain, in writing, if their view of the NOS and scientific communication (NOSC) had changed.

In addition, teachers participated in hands-on inquiry activities including biology investigations. One example was DNA extraction. Teachers were to determine factors affecting the amount of DNA extracted from a wheat germ solution. Groups were given different brands of wheat germ, detergents, and meat tenderizers; ethanol; and water of different temperatures. After following a set of directions, teachers designed a second experiment of their own. Teachers were asked to write a claim, provide evidence, and reasoning to support their claims in their notebooks. All data were collated and a discussion of the factors that affected the amount of DNA extracted concluded the activity.

Educational Outcomes

Teachers

We used the meta-analysis of NOSC research developed by Yore, Hand, and Florence (2004) to develop a Nature of Science Communication (NOSC) rubric to analyze teacher writing (Appendix A). The rubric coded scientific processes, subjectivity, knowledge development, verification, and discourse from a traditional, modernist, and postmodernist view (Yasar-Purzer, Uysal, Baker, Lewis & Lang, 2008). Yore et al. (2004) described these categories although they did not explicitly specify four. We added discourse because our goal was to develop a rubric for NOSC. We included ‘discourse for clarification’ under the modernist view because scientists hold a modernist view and define scientific writing and peer-reviewing as knowledge clarification. While the traditionalist view is based on how novice writers use writing, the postmodernist or constructivist perspective was based on experts’ view of writing (Bereiter & Scardamalia, 1987). Inter-rater reliability was established by two researchers scoring separately, discussing coding, and making a final decision together.

This pre-writing text by Teacher #5 is an example of writing that does not include the role of communication.

> The nature of science is to question, investigate, and draw conclusions about everything in our environments. It is the search for understanding and compression. Scientific communication is the discussion of the understandings and comprehensions learned through scientific inquiry. Scientists ask questions, investigate, and draw conclusions based on their investigations.

After the nature of science cards activity many teachers expanded their definitions. The post-writing of Teacher #5 addresses explicitly the various ways communication takes place in science.

> The nature of science is a multi-step process. First, scientists inquire about observations or further investigate theories. They develop conclusions and communicate

> their ideas to other scientists through several mediums [SIC]. Scientists recreate or develop new investigations to refute or agree with prior findings. Arguments or collaboration occur and information is disseminated [SIC] to the public. To inform other scientists or the public of intentions to investigate, conclusions/ assumptions, or agreement/ argument of prior studies/ theories. Communication is done via, oral communication, written communication, or visual communication. There is no one way to communicate. They formulate an idea, test it out, and then communicate their findings.

Seventy-eight percent of teachers added the role of discourse to their definitions after discussing the statements on the cards and 69% of the teachers developed a modernist view of verification in science. Teachers also discussed the role of evidence in refuting or supporting a hypothesis (Table 1). Three items (subjectivity, verification, and discourse) were the weakest components as revealed in initial definitions of NOS.

Table 1. Changes in teachers' views of the nature of science and scientific communication

	Before Activity	After Activity
Subjectivity (Human Error or Bias)	0%	17%
Verification (Tentativeness)	17%	35%
Discourse and Collaboration	24%	78%

After all NOSC activities were completed, teachers wrote a scientific investigation report about their final biology experiment (extraction of wheat DNA). In their reports, teachers generally used a modernist approach. When evaluating their hypothesis against their data, all but two teachers used provisional terms (e.g., the data supported our hypothesis) rather than absolute terms (e.g., our hypothesis was correct). Teachers were consistent in using the vocabulary that reflected the tentative nature of science. Only two teachers discussed human error in their reports. The majority of the teachers questioned research methodology or tools as limitations of the study. The excerpts which follow are from scientific investigation reports with provisional and tentative language that reflects NOS highlighted by italics.

> Although our hypothesis was not supported, our investigation brought up new questions. There were differences between the control sample and the second sample indicating that the temperature of the ethanol can affect the accuracy of DNA extractions. Additional investigations should test at what ethanol temperature the DNA begins to be less cohesive. There were limitations to this investigation. We did not have thermometers available to us in order to accurately monitor the temperatures of both the wheat germ mixture and the ethanol. Future investigations should accurately monitor the temperature of each.

Our explanation for our results is that *the data supported* our hypothesis.

> The cold water mixture didn't have near the amount of extractable DNA as the hot water and the tap water mixtures. We believe that temperature affects the amount of extractable DNA by causing the wheat germ to break down faster…This type of experiment has limitations and inherent errors in it. We felt that tap water had a greater amount of extractable DNA due to a possible error in the preparation of the wheat germ solutions. Three different members of a group were assigned to a specific beaker. The members of the group who prepared the tap water beaker may have stirred the solution more vigorously then the other two.

In addition to understanding NOS and NOSC, we have evidence that teachers are using the CISIP strategies to create SCDCs in classrooms. This is provided by the student survey (*MSCS*) and classroom observations (*DiISC).*

We used the total (*MSCS*) score per student (*N*=1,103) as the unit of analysis to determine if there were differences between control and CISP classrooms and between high school and middle school CISIP classrooms. We found that students in classrooms taught by teachers in the CISIP PD perceived their classroom environment as significantly different from students in control classrooms. Middle school (t(521) =2.89, p < .01), students of CISIP teachers had a mean of 50.7 and standard deviation of 8.7. The control group had a mean of 47.9 and standard deviation of 11.2. These results were mirrored at the high school (t(599) = 11.42, p < .001), where CISIP students had a mean of 57.2 and standard deviation of 8.1. The control mean was 47.6 with a standard deviation of 11.2. These differences indicated that students in the classrooms of CISIP teachers were aware that their teachers were using more CISIP literacy strategies than students being taught by control teachers. Though the differences are statistically significant they are not as large as we would have liked. However, the ability of students to perceive differences in instruction is educationally very significant.

Correlation coefficients were computed between *MSCS* and *DiISC* scores using the classroom as the unit of analysis. The results indicated that, for students whose teachers participated in the CISIP PD (*DiISC* M = 25.7, SD = 6.2), there was a statistically significant positive correlation between perceptions of the classroom environment and what observers saw taking place (*N*=29, R=.549, p=.002). The correlation between the *MSCS* and *DiISC* scores were not significant for the control group (*N*=43, R=-.291, p=.059). The data indicated that students in classroom of CISIP teachers, as well as observers of CISIP teachers perceived a difference in instruction, more aligned with CISIP principles, than students and observers in the control group classrooms. The data supports our assertion that teachers who are participating in PD are implementing changes in the classroom as verified by both outside observers and students.

Longitudinal modeling using HLM was also conducted using observation data from the *DiISC*. The data indicated that classroom implementation of CISIP strategies to create a SCDC is an incremental process. The only statistical predictive variable for fidelity to the CISIP model was the length of time spent in PD. The best HLM model for the data suggested that as teachers receive more PD, they demonstrated higher rates of implementation in classrooms within the second academic year of PD than they did in the first cycle of PD. The variables of grade level, number of students attending each teachers' school, state testing scores for schools, number of students in districts, classroom and total per pupil spending costs, percentage of students eligible for free or reduced lunch, average teacher pay, and number of years teaching were not predictors of the degree of implementation.

Students

A random selection of student notebooks (*N*=21) in classes of teachers participating in the CISIP PD was used for analysis of scientific arguments. Each notebook was examined in its entirety and all arguments or attempts were identified. A simple rubric for analysis of the arguments was developed that identified: a) number of arguments using a template and the degree of scaffolding, b) number of student generated arguments and the degree of teacher provided scaffolding, c) presence/absence of a research question, d) whether the research question was answered in the argument, e) use of diagrams, data tables, or graphs to support the argument, f) whether the data was referred to implicitly and/or explicitly. Raters achieved 100% inter-rater reliability.

One hundred and forty-five arguments or attempted arguments were identified. Seventy-seven were written using a template (53%) with 44 using a very structured template and 33 a less structured template. Sixty-eight student generated arguments (47%) were identified. Twenty-eight of which reflected more teacher scaffolding and 40 less teacher scaffolding. Sixty-three arguments had a clearly identifiable research question (44%) but 39 arguments had no research question. It was unclear whether the remaining 43 arguments had a research question due to the quality of writing. Fifty-nine of the 63 arguments (93%) answered the research question posed. Fifty-six of the arguments (39%) used graphs, diagrams, or tables to support claims. Ninety-five of the arguments (66%) referred to data implicitly or explicitly with explicit references (34) occurring almost twice as often as implicit references (16). The following is an example of a good student argument.

In the conclusions the student writes: “My unknown has baking soda, sugar, and flour.” She then realizes that she has overlooked a few things in her observations. “But I soon found out that cocaine was wrong. So I re-read my observations and know what is in it-baking soda, salt, and flour.” She then provides reasoning to link claims and evidence. “I think this because-baking soda. It bubbled in vinegar test. Salt. In iodine test, it turned green, and dissolved back.” Her reasoning for not eliminating flour stemmed from the heat test. She wrote, “clumped together.” The crystal shape was “fluffy like clouds, no crystal shape.”

Based on this argument, we concluded that the student went back to her observations to develop a reason for eliminating salt and confirming the presence of baking soda, salt, and flour. Though some of her sentences are incomplete, the student repeatedly reviewed her observations to link claims and evidence. This student is in the second developmental phase of crafting explanations because she can describe the relationship among variables (Woodruff & Meyer, 1997).

This next student did not have a research question but was skilled at recording observations when she mixed the mystery powder with water, vinegar and iodine. In the conclusions the student wrote: “When it was mixed with the three liquids, it did exactly what it said in the data on the board. The student reasoned that “So since it matches, it has to be baking powder.” The student later added incorrectly to her reasons that “A chemical property of reactivity is baking powder”. We concluded that this student is focusing on the functions of the variables and as such in the first developmental phase of crafting explanations (Woodruff & Meyer, 1997).

The data indicated that over a semester teachers were successful in helping students become more scientifically literate through the writing of scientific arguments. The majority of students were addressing their research questions in their arguments and among those using a research question, almost all answered it. Data was used implicitly and explicitly as were graphics to support arguments. However, it was not always easy to identify and code arguments. Nevertheless, the data suggests that students can be helped to become more scientifically literate (understanding some of the structure of a written scientific argument) through the application of the CISIP strategies.

A global analysis indicated that at the beginning of the year teachers were using the writing templates to scaffold student writing of scientific arguments. Forty-four highly scaffolded arguments were found. As the year progressed, teachers were able to withdraw some scaffolding and there were more student generated arguments. Although, teachers still provided some of scaffolding. By the end of the academic year, the number of highly scaffolded arguments fell to 33.

Conclusion

The CISIP project situates itself in the National Science Education standards definition of scientific literacy with an emphasis on "…the capacity to pose and evaluate arguments based on evidence and to apply conclusions from arguments appropriately (National Research Council, 1996, p. 22) as well as that of the PISA Governing Board (Roberts, 2007). It attempts to broaden teachers' understanding of the nature of science, beyond the need for evidence to support claims, to include how arguments using evidence and claims are constructed. It focuses on understanding the role of communication in science and providing teachers with the skills to help students craft scientific arguments. Understanding the nature of science and scientific communication and using that understanding to help students craft scientific arguments is an essential component of scientific literacy because "….explanations and the understanding of how and why something happens are major aims of science as a whole (Chinn & Brown, 2000, p.111).

The CISIP project has been successful in providing PD that had a positive impact on teachers': a) understanding of critical aspects of scientific literacy, b) ability to use CISIP literacy strategies as part of regular instruction to create a SCDC, and c) ability to help students craft scientific arguments. Students have also become more scientifically literate as a consequence of being in CISIP teachers' classrooms. They could, with varying degrees of support, craft scientific arguments, address research questions, and use data to support their arguments. We attribute this success to three factors identified in the research literature. We first focused on teachers understanding of the nature of science and scientific communication because it is well documented that teachers have many misconceptions about the nature of science which in turn makes it difficult for them to teach the appropriate view to their students (Abd-El-khalick & Lederman, 2000). We provided sustained PD by those who designed it and focused on the development of teacher knowledge (Wayne, Yoon, Zhu, Cronen & Garet, 2008). The PD was delivered by classroom teachers who were trusted by the participants and who could provide relevant examples for improving teaching (Lieberman & McLaughlin, 1992).

Despite the limited attention given to oral and written forms of discourse, and the crafting and evaluation of scientific arguments in the AIMS assessment, CISIP teachers have seen the value of these skills and have incorporated them into their classroom instruction. Future research will address whether an emphasis on scientific literacy through the creation of a SCDC has a more general impact on student achievement in science by examining both teacher made and state assessments of science knowledge.

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Appendix A: Rubric for the Nature of Science Communication (NOSC)

	(1) TRADITIONALIST	(2) MODERNIST	(3) POSTMODERNIST
Scientific Process	SP1: Scientific method is a linear, step-by-step process. Rigid adherence to the method provides validation to the generalizations.	SP2: Scientific method is cyclic and recursive and is not bound by a single universal set of steps but the method employed by a scientist depends on the circumstance.	SP3: People use multiple ways to construct descriptions.
Subjectivity	SUB1: Scientist is objective. Experiments should be repeatable. Knowledge is validated through predictions and observations. Sufficient proof may be impossible to establish because the generalizations must hold true for all situations, past, present, and future.	SUB2: Since scientists have preconceptions about the outcome of an investigation, most evidence the scientists would likely collect would support the existing hypothesis rather than refute it. Ontologically, descriptions and explanations are influenced by people's sensory, intellectual abilities, and diverse perspectives.	SUB3: There are a variety of sociopolitical factors about equity, power, and politics within the scientific enterprise. Ontologically, different explanations of the natural world are considered of equal validity.
Knowledge Development	KD1: Knowledge is epistemologically developed through investigations (observations, measurements) and plausible reasoning. Observations and measurements are interpreted and generalized to form a big idea (science claim) or intellect is used to produce rational speculation (science claim) about reality.	KD2: Knowledge epistemologically develops with a hypothesis (tentative causal speculation) and collected data that support or refute the hypothesis. Patterns of data that would either confirm or refute the hypothesis that is predicted prior to data collection and these predictions are then compared with the collected data to support or reject original hypothesis.	KD3: Epistemologically, explanations are developed in the context of their own personal experiences, beliefs, cultural values, and situations (times/places).
Verification & Reasoning	VER1: The truth about nature (theory, law, principle, concept, fact) is proven by the evidence gained through a series of generalizations using inductive reasoning. The validity of a generalization is tested through deduction when a general rule is used to explain other events and to predict future occurrences. Scientific knowledge is a collection of absolute truths that is unchanging	VER2: Hypotheticodeductive reasoning relies on the absence of refuting evidence and the presence of confirming evidence as support for hypothesis. Knowledge claims are not absolute, only supported or falsified. Science knowledge is a set of contemporary descriptions and explanations that best fits the existing evidence and can change over time. Well-established ideas are unlikely to change.	VER3: The verification processes cannot be conducted without the risk of introducing power conflicts that disempowering some members of the science community. Science knowledge consists of multiple descriptions and explanations of the world and it is impossible to know which of the interpretations. Things can only be true or false for a particular group at a certain time and place.
Discourse and Collaboration	DIS1: Purpose of discourse is knowledge telling. Peer Re-	DIS2: Purpose of discourse is knowledge clarification. Discourse, com-	DIS3: The goal of discourse is to reflect,

	view involves challenging or affirming accuracy or validity of findings.	munication, peer-review, and revising improve clarity and understanding of the problem investigated.	construct, and transform one's knowledge of science concepts. It involves subjective human dimension and metacognitive awareness.