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Measuring Short-Term Teacher Learning of Scientific Classroom Discourse Communities

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MEASURING SHORT-TERM TEACHER LEARNING OF SCIENTIFIC CLASSROOM DISCOURSE COMMUNITIES

ABSTRACT: The Communication in Science Inquiry Project (CISIP) provides school-based teams of secondary science and English and/or ELL teachers with year-round professional development with the goal of establishing scientific classroom discourse communities (SCDC). Teams participated in one of two three-week CISIP summer institutes. Four CISIP model elements of a SCDC can be framed within a pedagogical content knowledge (PCK) taxonomy at two levels: domain-specific PCK, including academic language development, written discourse, and oral discourse; and general pedagogy, specifically scientific inquiry. The fifth professional development element focuses on overarching learning principles that are applicable to any discipline. By situating the CISIP professional development model within teacher knowledge this clarifies the purpose of the institutes and the PCK taxonomy can be employed as a research lens. With the exception of scientific inquiry, both science and English/ELL teachers broadened their pedagogical awareness, but need more time to refine their conceptual framework of the five SCDC pedagogies. Both science and English/ELL teachers would benefit from more explicit distinctions between domain-specific and general pedagogical strategies. Not surprisingly participants exhibited a greater awareness of the ALD and discourse pedagogical strategies than on the scientific inquiry PCK, which was addressed less explicitly in the professional development activities.

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Introduction

Since the publication of the *National Science Education Standards* (National Research Council (NRC), 1996) and the *Benchmarks for Scientific Literacy* (American Association for the Advancement of Science (AAAS), 1993), science educators have grappled with how to address science instruction reform toward more inquiry-based practices. Yerrick and Roth (2005) note key differences between present and past reform recommendations in that teachers' content knowledge and pedagogy were often the main concern with little attention to student diversity or learning needs. Educational researchers have established that there is a persistent achievement gap in national and international test scores (Berliner & Biddle, 1995) due to racial isolation and concentrated poverty of public school children, especially in urban inner city schools (Kozol, 2005; Berliner, 2006). Additionally, schools are under pressure from state and federal high-stakes testing (Nichols & Berliner, 2007), which often results in top-down implementation of test prep curriculum and does not reflect the nature of science. Consequently, the science education community is witness to K-12 instruction that has not significantly improved learning for all students.

In her contribution to *The Changing Contexts of Teaching (91st Yearbook of the National Society for the Study of Education)*, Lieberman (1992) comments that it is a “little known fact that [professional development] is a young idea…not until the 1970s that staff development and the ways in which teachers actually transform new ideas into usable practices became an area of study” (p.7). Historically, two approaches to updating teachers’ knowledge base were common: a) lectures to large groups of teachers on new methods or curricula, and b) action research in teachers’ own classrooms done collaboratively by teachers and academics; despite these on-going efforts, “teachers’ learning of new methods for working with students has been problematic” (Lieberman, 1992, p.7).

The science teacher professional development research literature indicates that the community of teacher educators and in-service professional development providers understand very little about how teachers apply what they learn from professional development to their classrooms. This lack of understanding stems from the complexity of studying the phenomenon of teacher learning. Because of its complex nature, only a few studies have considered the interaction between teachers’ professional development, their classroom practice, and student performance (Hewson, 2007). Indeed, historically the effects of systemic reform itself have been difficult to measure due to a similar preponderance of interacting variables (Kahle, 2007).

The Communication in Science Inquiry Project (CISIP) endeavors to provide school-based teams of science and English and/or English Language Learner (ELL) teachers with year-round professional development to enact pedagogical strategies that create scientific classroom discourse communities (SCDC) in their classrooms. Two summer institutes were held for four days a week for three weeks in both June and July 2007 and used biology as the science vehicle in which to practice elements of a SCDC. This study investigates participant teachers’ pedagogical knowledge of the CISIP scientific classroom discourse community model categories at the beginning and the end of the summer institute. This first phase of teacher learning preceded the implementation of the strategies in the teachers’ classrooms at the beginning of the school year. Consequently, it was used to construct a conceptual understanding of the SCDC strategies using modeling and discourse embedded in professional development activities insulated from the social context of building a discourse community with teachers’ own students.

What is a CISIP Scientific Classroom Discourse Community?

Lemke’s (1990) identification of triadic dialogue (initiate-respond-evaluate, otherwise known as “IRE”) as a means for knowledge transmission from teacher to student in science education is the antithesis of science education reform. However, it is a favored staple of whole group discussion pedagogy in science classes. How can teachers improve student learning in science using more cognitively appropriate theories of language acquisition in their science classes and move beyond traditional discourse strategies? Numerous authors have written about the sociocultural, sociolinguistic, and philosophical elements of SCDCs that highlight the importance of language in learning science (Yerrick & Roth, 2005). Their and Daviss’ (2002) book *The New Science Literacy* and *Crossing Borders in Literacy and Science Instruction* (2004), edited by Saul, point toward a productive marriage of science, language, and learning that are on the cusp of science education reform.

Gee (2005) states that students need to experience science in order to be able to create meaningful discourse and develop conceptual understandings. This follows in the Vygotskian tradition of social learning and language (1986) and the educational theories of Dewey (1938). The CISIP model focuses on: a) academic language development (ALD); b) written discourse (WD); c) oral discourse (OD); d) scientific inquiry (SI); and e) learning principles (LP) (e.g., accessing prior knowledge, the use of conceptual frameworks and embedded metacognition (NRC, 2000, 2005). The professional development provided during the three-week teacher summer institutes focused on these model elements to varying degrees, largely within the context of middle and high school level life science activities. The life science activities were presented within an inquiry-based framework alongside the other CISIP model pedagogical strategies.

CISIP Model of a SCDC Framed Within a Pedagogical Knowledge Taxonomy

Pedagogical content knowledge (PCK) is a popular framework for understanding teacher knowledge (Shulman, 1986). Shulman defined PCK as the knowledge produced from the synthesis of knowledge of subject matter, pedagogy, and context. Teacher's knowledge is a complex network of interacting beliefs, subject knowledge, and knowledge of students. Magnusson, Karajick, and Borko (1999) defined PCK as consisting of five components: (a) orientations toward science teaching (teacher goals and general approaches to science teaching); (b) knowledge of science curriculum; (c) knowledge of assessment for science; (d) knowledge of science instructional strategies; (e) knowledge of student science understanding (Abell, 2007). The CISIP professional development goals crosscut all of these areas of teacher knowledge in an effort to reform science instruction.

Veal and MaKinster (1999) outlined a conceptual taxonomy of PCK that nests topic-specific PCK within domain-specific PCK, and domain-specific PCK within general PCK. They define general PCK as understanding general pedagogical concepts within a larger discipline (e.g., science), domain-specific PCK as specific to the subject matter within a discipline (e.g., biology), and topic-specific PCK as a topic or unit of study (e.g., genetics). The CISIP model of a SCDC can be framed within two PCK levels, domain-specific PCK (ALD, WD, and OD) and general pedagogy (SI). The model also includes overarching learning principles (LP) which can be employed in many disciplines, not just science. Scientific inquiry is considered to be at the general level as it cross-cuts all scientific endeavors and disciplines. Inquiry itself can be employed in all academic disciplines, but scientific inquiry relies on the investigation and exploration of the natural world. We situate the CISIP professional development within the framework of teacher knowledge and use PCK as a lens to examine the effect of those professional development activities.

Research Questions

The two 3-week summer institutes, high school and middle school levels, were intended to expand teachers' awareness of domain-specific PCK needed to construct a SCDC. To investigate the effect of the professional development we administered a pre- and post-test to address the following research questions:

> 1) How many different domain-specific pedagogies (ALD, WD, and OD), general pedagogies (scientific inquiry), and learning principles do teachers mention before and

after the CISIP summer institute? Is there a change, and if so, is it statistically significant?
2) Is there a significant difference between teacher subgroups based on content specialty, science or English/ELL, and/or grade level, middle school (8^{th} grade) or high school (10^{th} grade)?
3) What are the most frequently mentioned CISIP scientific classroom discourse community strategies before and after the professional development?

Methodology

Program & Participants

School-based teams of science and English and/or ELL teachers participated in the two 3-week summer institutes supported by the National Science Foundation and a state-funded Improving Teacher Quality (ITQ) grant. From these teams, teachers were recruited to participate in a study about constructing SCDCs in their classrooms. Eleven of the teachers in the study were previous participants in the CISIP development phase and had participated in at least one full year of professional development before attending these summer institutes. These teachers acted as mentors for colleagues who were new to the CISIP professional development.

Data Collection

Forty-four paired pre- and post-tests from 25 science (14 high school, 11 middle school) and 19 English/ELL (10 high school, 9 middle school) teachers were collected at the beginning and end of the summer institutes. The pre/post-test was composed of the same five open-ended questions on the core elements of the CISIP model of a SCDC. The first question asked, “What should the teacher do to support the development of academic language for all learners, but especially for second language learners?” The other questions replaced “academic language” with “written discourse,” “oral discourse,” “scientific inquiry,” and “learning principles.”

Analysis

The teachers’ written responses were tabulated in a spreadsheet for the purpose of performing frequency counts of the mentioned pedagogical strategies in each of the five areas of the CISIP SCDC model. Each question was analyzed separately and the responses were split into two categories of pedagogical strategies that were either domain-specific to the questions or belonged to another domain-specific category. Similar responses were grouped during data entry. The pre-test responses were reviewed by content experts who had acted as the CISIP professional development facilitators for triangulation purposes. Some new responses occurred on the post-tests and they were added to the subgroups according to the established sorting criteria. Collectively, the institute participants listed between 32 and 44 different types of pedagogical strategies for each question on the pre- and post-tests.

After splitting the responses by pedagogy, the participants were grouped by experience with the CISIP model (previous or new), grade level (high school (HS) or middle school (MS)), and content area (science or English/ELL). This resulted in 8 subgroups with very low sample sizes (N= 1 to 4) for previous participants and higher, but still low, sample sizes (N= 6 to 11) for new participants. Descriptive statistics were generated for 6 measures (2 sets of pre- and post-test measures: a) the number of total pedagogical strategies listed; b) the number of domain-specific pedagogies listed; and c) the number of other domain-specific pedagogies) on each question. Two approaches were applied to the data. The first was to aggregate the previous participant data with the new participant responses so that there were only 4 subgroups with a larger sample size; the second was to remove the previous participants' data. An independent-samples *t* test was conducted to evaluate if the difference between a) HS and MS science teachers and b) HS and MS English and/or ELL teachers was significantly different for each question. Additionally, independent-sample *t* tests were conducted on the same pairing listed above with the previous participants removed to re-evaluate these samples. If there was no significant difference between the grade and content groups, then the subgroups were combined into larger samples based on content (science and English and/or ELL). If there was a significant difference on the independent-samples *t* test, it was inferred that there was a high likelihood that the underlying distributions was not normal, or that there are so few samples that the *t* tests may not be robust. Therefore, a non-parametric test (Mann-Whitney U) was used to determine the significance, if any, of the differences between group medians at the 95% confidence level.

To complement the quantitative frequency counts of domain-specific pedagogical strategies, and to address the third research question, the analysis also investigated what were the most frequently mentioned teaching strategies before and after the summer professional development institutes. The strategies that the teachers mentioned were individually ranked by ordering their means, so as to be able to compare between sub-groups of teachers to see if there were any differences between groups of teachers' learning. The mean theoretically represents the average number of teachers who mentioned a related group of strategies on the pre- or post-test. However, occasionally teachers mentioned the same type of strategy more than once, therefore inflating the average for some questions. Consequently, an increase from the pre- to the post-test for a particular strategy category may mean that more teachers became aware of this type of strategy and/or an individual teacher became aware of more variants of this type of domain-specific strategy. Both quantitative and qualitative results are organized and reported according to the five aspects of the CISIP model.

Data & Interpretation

Academic Language Development

Employing independent-sample *t* tests on this data was challenging. The small sample for the subgroups was problematic and there appeared to be a significant difference between the HS (N=10) and MS (N=9) English/ELL teachers on two measures from the post-test, the total number of pedagogies listed and total number of ALD pedagogies. When the previous English/ELL participants were removed there was no significant difference, but then one pre-test measure, total non-ALD pedagogies, became significant. The lower sample sizes violate the assumptions of the independent-samples *t* test in this case. The HS (N=14) and MS (N=11) science teacher samples are closer to the recommended minimum sample size of 15 for this test and, upon comparison, all measures on the pre- and post-tests were not significant. However, the previous issue with the English/ELL teachers makes combining the four grade-level and content groups into only two content areas less valid. When the independent-sample *t* test was conducted with the previous CISIP participants removed, there was no significant difference between science (N=19) and English/ELL (N =14) teachers on all of the measures on the pre- and post-tests. But this still may not be a valid result as the four subgroup sample sizes (before combining groups) are not sufficiently large. The non-parametric Mann-Whitney test on only the new CISIP science and English/ELL teachers' responses also indicates that none of the six measures on the pre- and post-tests were significantly different. However, it would appear that both science and English/ELL teachers benefited in learning about ALD strategies from the professional development activities. This is supported by an inspection of the means showing that both content groups increased from pre- to post-test in both the total number of pedagogical strategies and the number of ALD pedagogical strategies they listed. The combined middle and high school science teachers (*N*=25) increased from a mean of 3.88 (SD=2.06) to 6.04 (SD=2.84) while the combined English/ELL teachers started at a higher mean of 4.05 (SD=1.87) and ended at a mean of 5.05 (SD=1.43). From these calculations the science teachers show more growth from pre- to post-test and listed more ALD strategies on average than the English/ELL teachers. However, the means of both groups did not decrease from pre- to post-test on the number of non-ALD pedagogical strategies in response to this question, with the science teachers listing slightly more strategies that they thought were domain-specific ALD strategies (pre-test: M=1.08, SD=1.73; post-test: M=1.08, SD=1.32) than the English/ELL teachers (pre-test: M= .63, SD= .68; post-test: M= .68, SD=1.00). This level of misidentification may mean that further clarification of what are and are not specific ALD pedagogies is necessary for all CISIP participants and somewhat more important for the science teachers.

The academic language strategies were organized in ranked order of most mentioned (highest mean scores) by teachers in the pre- and post-tests. ALD strategies that had a mean score above 0.50 are listed in order of most frequently mentioned from highest to lowest in Table 1. Different individual teachers and subgroups of teachers mentioned different strategies, however all four subgroups listed using visual clues and aids (word walls, pictures, realia, graphic organizers, gestures) as their top ALD strategy in both their pre-test and their post-test responses.

Written Discourse

There was no significant difference between HS and MS science teachers or HS and MS English/ELL teachers (with and without the inclusion of the previous CISIP teachers) as measured by independent-samples *t* tests from pre- to post-test for all six measures. A second set of independent-sample *t* tests between all science (*N*=25) and all English/ELL (*N*=19) teachers was then conducted on the same six measures. The three pre-test measures (total pedagogies, written discourse (WD) pedagogies, and non-WD pedagogies) were all significantly different between content groups. The science teachers started with a pre-test WD strategies mean of 2.64 (SD=1.60) and the English/ELL teachers a mean of 1.42 (SD=1.50). Both groups showed an improvement in this category of the CISIP model of a scientific classroom discourse community. The means for the science teachers (post-test WD strategies: M=5.12, SD=2.74) were significantly higher than the English/ELL teachers'(post-test WD strategies: M=4.74, SD=2.92) responses, but there was no significant difference between these groups on both the post-test mean total number of pedagogical strategies and mean number of written discourse strategies. This suggests that both science and English/ELL teachers are now equally aware of written discourse pedagogies that will support students' learning in science. However, there was a significant difference on both the pre- and post-test non-WD pedagogies listed, indicating that science teachers mentioned more pedagogical strategies that were outside of written discourse PCK both before and after the institute than English/ELL teachers. This suggests that these science teachers need more modeling during professional development to distinguish between written discourse and other pedagogical strategies to improve their PCK conceptual framework of written discourse.

Table 1. Academic language development (ALD) strategies mentioned by teacher subgroups on their CISIP awareness pre- and post-tests. The strategies are ranked by their means as shown in parentheses.

Pre-Test	Post-Test
High School Science *(N=14)*	
1) Visual clues/aids (word walls, pictures, realia, graphic organizers, gestures) (0.93)	1) Visual clues/aids (word walls, pictures, realia, graphic organizers, gestures) (1.79) 2) Vocabulary builders (0.64) Vocabulary strategies (0.64) 3) Modeling or cueing students (0.50)
Middle School Science *(N=11)*	
1) Visual clues/aids (word walls, pictures, realia, graphic organizers, gestures) (1.36) 2) Active Learning / Hands-on labs / Exercises / Manipulatives /Realia (0.55)	1) Visual clues/aids (word walls, pictures, realia, graphic organizers, gestures) (1.64) 2) Reveal or link to prior knowledge (0.64) 3) Modeling or cueing students (0.55)
High School English *(N=10)*	
1) Visual clues/aids (word walls, pictures, realia, graphic organizers, gestures) (0.80)	1) Visual clues/aids (word walls, pictures, realia, graphic organizers, gestures) (1.70) 2) Vocabulary strategies (1.0) 3) Reveal or link to prior knowledge (0.9) 4) Repetition (0.6)
Middle School English *(N=9)*	
1) Visual clues/aids (word walls, pictures, realia, graphic organizers, gestures) (1.00)	1) Visual clues/aids (word walls, pictures, realia, graphic organizers, gestures) (1.11) 2) Reveal or link to prior knowledge (0.67) 3) Vocabulary strategies (0.56) Vocabulary builders (0.56)

On the pre-test the high school science teachers were the only ones to mention notebooks / journal writing as a written discourse strategy above the cut-off (M > 0.50) level (Table 2). Interestingly, on the post-test no group of teachers mentioned the notebooks / journal writing strategy, even though the teachers themselves were actively using their own science notebooks as a means of modeling the strategy during the entire summer institute. The middle school English/ELL teachers mentioned so few strategies in this domain that they didn't break through the cut-off score on either the pre- or post-test. On the post-test the other three groups all mentioned the writing-to-learn strategies as an important way to help students learn science better. During the professional development workshop the middle school English/ELL teachers may not have responded to the questionnaire with the same level of engagement and as purposefully as the other groups because the focus was on science and not language arts. That the professional development was focused mainly on science content and was unfamiliar territory to the English/ELL teachers was feedback heard throughout the professional development. Their frustration and confusion as to their role in CISIP was also reported by the grant's external evaluator. Thus, these data may not be an accurate measure of these teachers' overall level of awareness of written discourse pedagogical strategies and should be treated with less confidence.

Table 2. Written discourse strategies mentioned by teacher subgroups on their CISIP awareness pre- and post-tests. The strategies are ranked by their means as shown in parentheses.

Pre-Test	Post-Test
High School Science *(N=14)*	
1) Notebooks / Journal writing (0.57)	1) Assessment / rubrics (0.93) 2) Group writing / peer review / cooperative learning (0.50) Writing to learn strategies (access prior knowledge) (0.50)
Middle School Science *(N=11)*	
• *No strategies above a mean of 0.50*	1) Lab reports, science investigation report (0.82) Writing to learn strategies (0.82) 2) Assessment / rubrics (0.64) 3) Clear instruction (0.55)
High School English *(N=10)*	
• *No strategies above a mean of 0.50*	1) Provide time (0.80) Writing to learn strategies (0.80) 2) Graphic organizers (0.70) Assessment / rubrics (0.70) 3) Clear instructions (0.60) 4) Brainstorming / Pre-writing (0.50)
Middle School English *(N=9)*	
• *No strategies above a mean of 0.50*	• *No strategies above a mean of 0.50*

Oral Discourse

There was no significant difference between pre- and post-tests on all six measures for HS and MS science teachers or HS and MS English/ELL teachers (with and without the inclusion of the previous CISIP teachers) as measured by an independent-samples *t* test. However, there was a significant difference between all science (*N*=25) and all English/ELL (*N*=19) teachers on the pre- and post-test total number of pedagogical strategies and oral discourse (OD) pre- and post-test pedagogical strategies mentioned. On all four measures, the science teachers listed significantly more strategies than the English/ELL teachers. For oral discourse strategies science teachers increased from a mean of 3.20 (SD=1.84) to a mean of 5.00 (SD=1.65) and the English/ELL teachers increased from a mean of 1.84 (SD=1.53) to a mean of 3.79 (SD=2.04). This suggests that these science teachers are more aware of oral discourse PCK, in the context of science activities, than the English/ELL teachers. There was no significant difference between content area teachers on the number of the non-OD pedagogies listed on the pre- and post-test. This suggests that both science and English/ELL teachers are equally as likely to mention non-OD pedagogical strategies when asked about oral discourse. Professional development providers may need to give more attention to this SCDC aspect of the CISIP model during the workshops to be held during the school year.

The middle school English teachers mentioned the least mean number of strategies on the oral discourse item on both the pre- and post-tests, and like the written discourse item did not break through the cut-off score (M > 0.50) even after the professional development (Table 3). The three other subgroups all mentioned that it was important to have established classroom norms and a safe environment to support students' oral discourse in the classroom; they also all mentioned that small groups / peer groupings / heterogeneous groupings support oral discourse.

Table 3. Oral discourse strategies mentioned by teacher subgroups on their CISIP awareness pre- and post-tests. The strategies are ranked by their means as shown in parentheses.

Pre-Test	Post-Test
High School Science *(N=14)*	
• *No strategies above a mean of 0.50*	1) Small group / peer grouping / heterogeneous grouping (0.79) 2) Whole group discussions (0.71) 3) Classroom norms / safe environment (0.64) 4) Promote questioning (0.57)
Middle School Science *(N=11)*	
• *No strategies above a mean of 0.50*	1) Classroom norms / safe environment (0.91) 2) Small group / peer group / heterogeneous grouping (0.55)
High School English *(N=10)*	
1) Whole group discussions (0.50)	1) Classroom norms / safe environment (0.80) 2) Small group / peer group / heterogeneous grouping (0.60) 3) Think. pair, share (0.50) Whole group discussions (0.50)
Middle School English *(N=9)*	
• *No strategies above a mean of 0.50*	• *No strategies above a mean of 0.50*

Scientific inquiry

The small subgroup sample sizes again violate the assumptions of the independent-samples *t* test. In this case it is the HS and MS science teachers, rather than the English/ELL teachers, who appear to be significantly different on two measures of the post-test (total number of pedagogies and total number of non-inquiry pedagogical strategies mentioned) even after removing the previous CISIP participants from the sample. However, the HS and MS science teachers did not differ significantly on the pre- and post-test inquiry strategies. When the MS and HS science teachers responses are combined (*N*=25) as one content group, the pre-test mean is 2.44 (SD=1.44) and post-test mean is 2.96 (SD=1.24). This is the least gain for all five categories of the CISIP professional development model. The combined pre-test mean of the English/ELL teachers' responses was 1.63 (SD=1.74) and post-test mean was 2.26 (SD=1.28). In this case the English/ELL teachers showed the greater gain of the two content area groups, although only a modest one and the least overall out of the five pedagogical categories as scored by English/ELL teachers, in learning about scientific inquiry-based strategies. This suggests that: a) HS and MS English/ELL teachers are equally less aware of scientific inquiry-based pedagogies; and b) that prior to the professional development there was no significant difference between HS and MS science teachers on the number of scientific inquiry-based strategies that they mentioned, but that after the high school institute, the HS science teachers listed a higher mean number of scientific inquiry-based pedagogical strategies than the MS science teachers. It appears that professional development should explicitly model scientific inquiry pedagogies as the activities in the summer institute apparently did not greatly improve awareness of scientific inquiry of a SCDC.

From the ranking of the inquiry strategies on the pre- and post-tests it is clear that there was little gained from the CISIP professional development summer workshop (Table 4). All groups, except for the middle school science group, mentioned that students shouldn't be given answers and that teachers should promote thinking and questioning. However, the middle school group demonstrated their awareness of this strategy on their pre-test, but the mean for this strategy decreased below the cut-off score of .50.

Table 4. Scientific inquiry strategies mentioned by teacher subgroups on their CISIP awareness pre- and post-tests. The strategies are ranked by their means as shown in parentheses.

Pre-Test	Post-Test
High School Science *(N=14)*	
• *No strategies above a mean of 0.50*	1) Don't give answers to students / promote thinking and questioning (model, wait-time) (0.64)
Middle School Science *(N=11)*	
1) Don't give answers to students / promote thinking and questioning (model, wait-time) (0.64)	• *No strategies above a mean of 0.50*
High School English *(N=10)*	
• *No strategies above a mean of 0.50*	1) Don't give answers to students / promote thinking and questioning (model, wait-time) (0.60)
Middle School English *(N=9)*	
• *No strategies above a mean of 0.50*	1) Don't give answers to students / promote thinking and questioning (model, wait-time) (0.89)

Learning principles

Again, the small subgroup sample sizes violate the assumptions of the independent-samples *t* test. However, the HS and MS science teachers appear to be significantly different on one pre-test (total number of LP pedagogies) and post-test measure (total number of pedagogies) even when removing the previous participants from the sample. There was no significant difference between the HS and MS English/ELL teachers on all pre- and post-test measures, with or without previous participants. The same concerns hold in this situation as outlined previously, but the analysis was tentatively conducted using the independent-samples *t* test as a preliminary evaluation of the data and found no significant difference on all pre- and post-test measures between science and English/ELL teachers, with or without previous participants included in the sample. This suggests that both groups benefited equally from the professional development on learning principles. A comparison of the means reveals that both science (pre-test LP strategies: M=1.16, SD=1.46; post-test: LP strategies M=2.8, SD=1.47) and English/ELL (pre-test LP strategies: M=0.74, SD=1.52; post-test LP strategies: M= 2.79, SD=1.87) teachers increased in the total number of pedagogies and learning principle pedagogical strategies, but both continued to mention general pedagogies at the same level on both the pre- and post-test.

All groups mentioned the importance of accessing students' prior knowledge and engaging students in their science lessons (Table 5). The middle school science group was aware of this learning principle before the professional development to the greatest extent of all four groups. The emphasis on student metacognition of their learning in science was another gain from the professional development for all teacher groups.

Table 5. Learning principles mentioned by teacher subgroups in their CISIP awareness pre- and post-tests. The strategies are ranked by their means as shown in parentheses.

Pre-test	Post-Test
High School Science *(N=14)*	
• *No strategies above a mean of 0.50*	1) Student background / prior knowledge / engagement (1.0) 2) Metacognition (0.71)
Middle School Science *(N=11)*	
1) Student background / prior knowledge / engagement (0.55)	1) Metacognition (0.64) 2) Student background / prior knowledge / engagement (0.55)
High School English *(N=10)*	
• *No strategies above a mean of 0.50*	1) Metacognition (0.80) 2) Student background / prior knowledge / engagement (0.70) 3) Performance expectations (0.60) 4) Conceptual framework (0.50)
Middle School English *(N=9)*	
• *No strategies above a mean of 0.50*	1) Metacognition (0.67) 2) Student background / prior knowledge / engagement (0.56)

Conclusions & Recommendations

While these results should be viewed with some caution, due to their small sample sizes, they do clearly point to raising teacher awareness of pedagogical strategies over the course of the 3-week CISIP professional development institute. The professional development focused on learning new strategies in preparation for implementation in the classroom as measured by an open-response questionnaire. Different results may have been found by using a different written instrument or research methodology.

However, it appears that both science and English/ELL teachers need further clarification of which pedagogies are and aren't within the academic language development suite, and science teachers need more examples of what constitutes written discourse pedagogy. English/ELL teachers would benefit from more professional development activities on oral discourse pedagogies situated within science, but science teachers' understanding of what isn't oral discourse pedagogy would also benefit from additional exploration. The participants appear to have put a higher priority on the academic language development and the oral and written discourse pedagogies than on how to teach using scientific inquiry methods, which was less explicitly modeled than the oral and written discourse pedagogical strategies related to the activities. Both science and English teachers appeared to benefit from the CISIP professional development focus on learning principles, but there needs to be further refinement of all teachers' conceptual framework of those pedagogies that are and aren't subsumed under the learning principles umbrella. In essence, all teachers broadened their pedagogical tool boxes, but need more time to construct their PCK conceptual framework of a SCDC. It will be interesting to observe what teachers choose to enact in their classrooms during the course of the year and to measure their written knowledge again at the end of an entire school year, using the same instrument, after applying their conceptual knowledge of CISIP to a socially interactive one involving students.

The need for professional development to emphasize the strategies for learning science using inquiry-based instructional practices cannot be underestimated. In this case the CISIP professional development was successful in improving teachers' knowledge of many aspects of the scientific classroom discourse community, but minimally affected teachers' knowledge of inquiry strategies. This may have been due to an assumption that science teachers were already familiar with inquiry-based teaching practices and an over-emphasis on other, perhaps perceived as more needed aspects of the CISIP model of constructing a scientific classroom discourse community.

General Interest to NARST Membership

The effectiveness of in-service science teacher professional development is critical for promoting science education reform for all students. Measurable and significant changes in teachers' understanding of domain-specific pedagogical knowledge and learning principles may lead to improvements in student learning and scientific literacy. Professional development providers can benefit from: a) broader conceptions of teaching and learning in science, e.g., constructing scientific classroom discourse communities; and b) a better understanding how teachers may develop the necessary pedagogical content knowledge.

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APPENDIX A

Table A-1. Question 1 (ALD) descriptive statistics and independent *t* test means for all science and all English/ELL teacher comparisons.

Group Statistics

	CONGROUP	N	Mean	Std. Deviation	Std. Error Mean
Q1PRETOT	science	25	4.9600	2.89367	.57873
	English	19	4.6842	2.08307	.47789
Q1POSTOT	science	25	7.1200	3.32064	.66413
	English	19	5.7368	1.79016	.41069
Q1PREALD	science	25	3.8800	2.06801	.41360
	English	19	4.0526	1.87005	.42902
Q1POSALD	science	25	6.0400	2.83549	.56710
	English	19	5.0526	1.43270	.32868
Q1PREGEN	science	25	1.0800	1.73013	.34603
	English	19	.6316	.68399	.15692
Q1POSGEN	science	25	1.0800	1.32035	.26407
	English	19	.6842	1.00292	.23009

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Q1PRETOT	Equal variances assumed	.153	.697	.352	42	.727	.2758	.78453	-1.30745	1.85903
	Equal variances not assumed			.367	41.908	.715	.2758	.75054	-1.23896	1.79054
Q1POSTOT	Equal variances assumed	4.131	.048	1.640	42	.108	1.3832	.84314	-.31837	3.08469
	Equal variances not assumed			1.771	38.382	.084	1.3832	.78085	-.19708	2.96340
Q1PREALD	Equal variances assumed	.117	.733	-.286	42	.777	-.1726	.60432	-1.39220	1.04694
	Equal variances not assumed			-.290	40.663	.774	-.1726	.59592	-1.37642	1.03116
Q1POSALD	Equal variances assumed	7.324	.010	1.387	42	.173	.9874	.71208	-.44968	2.42441
	Equal variances not assumed			1.506	37.231	.140	.9874	.65546	-.34045	2.31519
Q1PREGEN	Equal variances assumed	5.373	.025	1.066	42	.293	.4484	.42073	-.40065	1.29750
	Equal variances not assumed			1.180	33.024	.246	.4484	.37994	-.32456	1.22140
Q1POSGEN	Equal variances assumed	.206	.652	1.089	42	.283	.3958	.36361	-.33800	1.12958
	Equal variances not assumed			1.130	41.998	.265	.3958	.35025	-.31104	1.10262

Table A-2. Question 2 (WD) descriptive statistics and independent *t* test means for all science and all English/ELL teacher comparisons.

Group Statistics

	SUBGROUP	N	Mean	Std. Deviation	Std. Error Mean
Q2PRETOT	HS Sci	14	4.6429	2.37316	.63425
	HS Eng	10	2.3000	1.63639	.51747
Q2POSTOT	HS Sci	14	6.6429	3.07864	.82280
	HS Eng	10	6.3000	3.80205	1.20231
Q2PREWRD	HS Sci	14	3.0714	1.89997	.50779
	HS Eng	10	1.6000	1.34990	.42687
Q2POSWRD	HS Sci	14	4.7857	2.51698	.67269
	HS Eng	10	5.7000	3.52924	1.11604
Q2PREGEN	HS Sci	14	1.5714	1.34246	.35879
	HS Eng	10	.7000	.82327	.26034
Q2POSGEN	HS Sci	14	1.8571	1.70326	.45522
	HS Eng	10	.6000	.84327	.26667

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Q2PRETOT	Equal variances assumed	2.492	.129	2.690	22	.013	2.3429	.87080	.53693	4.14879
	Equal variances not assumed			2.862	21.992	.009	2.3429	.81857	.64521	4.04050
Q2POSTOT	Equal variances assumed	.511	.482	.244	22	.809	.3429	1.40495	-2.57083	3.25654
	Equal variances not assumed			.235	16.846	.817	.3429	1.45690	-2.73307	3.41879
Q2PREWRD	Equal variances assumed	1.290	.268	2.095	22	.048	1.4714	.70247	.01459	2.92827
	Equal variances not assumed			2.218	21.998	.037	1.4714	.66338	.09566	2.84720
Q2POSWRD	Equal variances assumed	.951	.340	-.743	22	.465	-.9143	1.23096	-3.46713	1.63856
	Equal variances not assumed			-.702	15.327	.493	-.9143	1.30310	-3.68663	1.85806
Q2PREGEN	Equal variances assumed	2.266	.146	1.817	22	.083	.8714	.47968	-.12337	1.86622
	Equal variances not assumed			1.966	21.631	.062	.8714	.44329	-.04881	1.79167
Q2POSGEN	Equal variances assumed	2.930	.101	2.144	22	.043	1.2571	.58630	.04123	2.47305
	Equal variances not assumed			2.383	20.044	.027	1.2571	.52757	.15680	2.35749

Table A-3. Question 3 (OD) descriptive statistics and independent *t* test means for all science and all English/ELL teacher comparisons.

Group Statistics

	CONGROUP	N	Mean	Std. Deviation	Std. Error Mean
Q3PRETOT	science	25	3.6800	1.88680	.37736
	English	19	2.2105	1.68585	.38676
Q3POSTOT	science	25	5.6800	2.07605	.41521
	English	19	4.3684	2.03335	.46648
Q3PREORD	science	25	3.2000	1.84842	.36968
	English	19	1.8421	1.53707	.35263
Q3POSORD	science	25	5.0000	1.65831	.33166
	English	19	3.7895	2.04339	.46879
Q3PREGEN	science	25	.4800	.77028	.15406
	English	19	.3684	.83070	.19058
Q3POSGEN	science	25	.6800	.94516	.18903
	English	19	.5789	.76853	.17631

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Q3PRETOT	Equal variances assumed	.590	.447	2.677	42	.011	1.4695	.54888	.36179	2.57716
	Equal variances not assumed			2.719	40.831	.010	1.4695	.54036	.37807	2.56088
Q3POSTOT	Equal variances assumed	.144	.706	2.094	42	.042	1.3116	.62632	.04762	2.57554
	Equal variances not assumed			2.100	39.313	.042	1.3116	.62450	.04872	2.57444
Q3PREORD	Equal variances assumed	.839	.365	2.591	42	.013	1.3579	.52407	.30029	2.41550
	Equal variances not assumed			2.658	41.611	.011	1.3579	.51089	.32658	2.38921
Q3POSORD	Equal variances assumed	.326	.571	2.170	42	.036	1.2105	.55797	.08451	2.33655
	Equal variances not assumed			2.108	34.118	.042	1.2105	.57425	.04366	2.37739
Q3PREGEN	Equal variances assumed	.239	.627	.460	42	.648	.1116	.24249	-.37779	.60094
	Equal variances not assumed			.455	37.274	.652	.1116	.24506	-.38483	.60799
Q3POSGEN	Equal variances assumed	.418	.522	.380	42	.706	.1011	.26596	-.43567	.63778
	Equal variances not assumed			.391	41.771	.698	.1011	.25850	-.42070	.62280

Table A-4. Question 4 (Inquiry) descriptive statistics and independent *t* test means for all science and all English/ELL teacher comparisons.

Group Statistics

	CONGROUP	N	Mean	Std. Deviation	Std. Error Mean
Q4PRETOT	science	25	3.1200	1.39403	.27881
	English	19	2.4737	2.36569	.54273
Q4POSTOT	science	25	4.5600	1.63503	.32701
	English	19	4.2632	1.36797	.31383
Q4PREINQ	science	25	2.4400	1.44568	.28914
	English	19	1.6316	1.73879	.39891
Q4POSINQ	science	25	2.9600	1.24097	.24819
	English	19	2.2632	1.28418	.29461
Q4PREGEN	science	25	.6800	1.24900	.24980
	English	19	.8421	1.01451	.23275
Q4POSGEN	science	25	1.6000	1.44338	.28868
	English	19	2.0000	1.20185	.27572

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Q4PRETOT	Equal variances assumed	5.094	.029	1.134	42	.263	.6463	.57012	-.50424	1.79687
	Equal variances not assumed			1.059	27.327	.299	.6463	.61015	-.60491	1.89754
Q4POSTOT	Equal variances assumed	1.276	.265	.639	42	.526	.2968	.46454	-.64064	1.23432
	Equal variances not assumed			.655	41.561	.516	.2968	.45324	-.61812	1.21180
Q4PREINQ	Equal variances assumed	1.084	.304	1.683	42	.100	.8084	.48027	-.16079	1.77764
	Equal variances not assumed			1.641	34.699	.110	.8084	.49267	-.19207	1.80891
Q4POSINQ	Equal variances assumed	.215	.645	1.818	42	.076	.6968	.38339	-.07686	1.47055
	Equal variances not assumed			1.809	38.189	.078	.6968	.38522	-.08287	1.47656
Q4PREGEN	Equal variances assumed	.034	.855	-.461	42	.647	-.1621	.35133	-.87112	.54691
	Equal variances not assumed			-.475	41.777	.637	-.1621	.34142	-.85124	.52703
Q4POSGEN	Equal variances assumed	.970	.330	-.977	42	.334	-.4000	.40941	-1.22623	.42623
	Equal variances not assumed			-1.002	41.601	.322	-.4000	.39920	-1.20584	.40584

Table A-5. Question 5 (Learning Principles) descriptive statistics and independent *t* test means for all science and all English/ELL teacher comparisons.

Group Statistics

	CONGROUP	N	Mean	Std. Deviation	Std. Error Mean
Q5PRETOT	science	25	4.1200	3.21870	.64374
	English	19	2.6316	3.60879	.82791
Q5POSTOT	science	25	5.3600	2.61215	.52243
	English	19	4.5263	2.41220	.55340
Q5PRELP	science	25	1.1600	1.46287	.29257
	English	19	.7368	1.52177	.34912
Q5POSLP	science	25	2.8000	1.47196	.29439
	English	19	2.7895	1.87317	.42974
Q5PREGEN	science	25	2.9600	2.57358	.51472
	English	19	1.8947	2.80663	.64389
Q5POSGEN	science	25	2.5600	2.45085	.49017
	English	19	1.7368	1.82093	.41775

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Q5PRETOT	Equal variances assumed	.799	.376	1.442	42	.157	1.4884	1.03218	-.59460	3.57145
	Equal variances not assumed			1.419	36.373	.164	1.4884	1.04873	-.63775	3.61459
Q5POSTOT	Equal variances assumed	.031	.861	1.083	42	.285	.8337	.76953	-.71929	2.38665
	Equal variances not assumed			1.095	40.346	.280	.8337	.76104	-.70402	2.37139
Q5PRELP	Equal variances assumed	.053	.819	.934	42	.356	.4232	.45300	-.49104	1.33735
	Equal variances not assumed			.929	38.076	.359	.4232	.45550	-.49890	1.34522
Q5POSLP	Equal variances assumed	3.192	.081	.021	42	.983	.0105	.50397	-1.00652	1.02757
	Equal variances not assumed			.020	33.350	.984	.0105	.52090	-1.04883	1.06989
Q5PREGEN	Equal variances assumed	.185	.670	1.308	42	.198	1.0653	.81444	-.57834	2.70886
	Equal variances not assumed			1.292	37.018	.204	1.0653	.82433	-.60496	2.73549
Q5POSGEN	Equal variances assumed	.703	.406	1.228	42	.226	.8232	.67051	-.52998	2.17630
	Equal variances not assumed			1.278	41.989	.208	.8232	.64404	-.47657	2.12288