THE EFFECT OF PROFESSIONAL DEVELOPMENT IN

SCIENCE AND LITERACY

by

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STATEMENT OF PERMISSION TO USE

In presenting this professional paper in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the MSSE Program shall make it available to borrowers under rules of the program.

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TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

Elementary teachers in Barre, Vermont must help their students achieve Common Core State Standards for English Language Arts (CCSSELA) to bolster student performance on statewide assessments used to determine adequate yearly progress (AYP). AYP is a measure used to secure each school's federal and state assistance. Vermont adopted the Next Generation Science Standards (NGSS) in June of 2013 and Vermont teachers now must also direct their science instruction toward helping students achieve NGSS. To assist teachers with addressing both the CCSSELA and NGSS simultaneously, an 11-week *Science and Literacy: A Natural Fit* professional development (PD) course was conducted with 14 kindergarten through sixth-grade teachers of science in the Barre Supervisory Union. This PD course was designed to help teachers weave student talk and notebook writing strategies into science instruction to bolster students' conceptual reasoning about the natural phenomena they experience through science inquiry. This research study investigated whether or not this PD course led to changes in teachers' knowledge base and classroom implementation for teaching science using best practices that incorporate student dialogue and writing to bolster conceptual reasoning during science inquiry. Changes in teachers' self-efficacy for teaching science (sense of the effect their science teaching has on their students) were also measured at the start and finish of the course. Study participants completed a pre-course and post-course knowledge survey. Also, the Science Teaching Efficacy Belief Instrument (STEBI-B) was administered at the start and finish of the course to measure self-efficacy. Study participants were observed instructing science early and late in the course, and then the Reformed Teaching Observation Protocol was employed for analysis of the observation sessions. In addition, participant interviews and journals provided direct quotations about the changes that occurred for teachers throughout the course. The body of evidence gathered indicates that the *Science and Literacy: A Natural Fit* course taught in fall 2013 helped participating teachers increase significantly their knowledge and improve their classroom implementation for teaching science inquiry using student talk and notebook writing. Participants' self-efficacy for teaching science also improved through the course.

INTRODUCTION AND BACKGROUND

As a contracted science curriculum consultant, I currently provide science

professional development during nine full-day, 2013-2014 in-service meetings for the

Vermont school district where I served as the kindergarten through eighth-grade Science

Curriculum Specialist/Coordinator from 2005-2007. This 2013-2014 work is helping the

district's K-8 science teachers understand the Next Generation Science Standards

(NGSS) that Vermont's Board of Education adopted on June 25, 2013 as the state's

guiding document for K-12 science education. Each grade-level science team is working

with me to collaboratively plan for alignment of the district's science curriculum,

instruction and assessment with NGSS.

Due to pressure created by federal No Child Left Behind legislation (NCLB), this

district's two K-8 schools need to improve their students' performance on literacy and

math state-wide standardized testing to achieve the goals of NCLB or risk losing a

portion of their federal funds to operate. Both schools have failed to meet adequate yearly

progress for all populations and are in the school improvement process with the Vermont

Agency of Education (VT AOE). Both of the schools have a contracted school

improvement coach to assist with the school improvement process, as required by NCLB.

The contracted school improvement coach works to help schools with planning (Barre

Town School) and implementation (Barre City School) of their state approved school

improvement plans.

Because of NCLB, both schools are under pressure to help students achieve The

Common Core State Standards for English and Language Arts (CCSSELA).   As a result

of the drive to improve student literacy, district teachers increasingly address science

concepts through reading, writing, and speaking and less frequently through scientific inquiry. Now that NGSS has been adopted in Vermont, Vermont teachers need to integrate instruction of NGSS with instruction of CCSSELA to help students achieve state standards.

Speaking and writing are central to science inquiry. Good inquiry science instruction incorporates the use of literacy strategies to bolster students' reasoning and build understanding. An integrated approach wherein science and literacy are taught together to help students construct sound reasoning and conceptual understanding through science inquiry can address standards in both CCSSELA and NGSS. Teachers in this district need to understand ways to teach science through inquiry using pedagogy that incorporates literacy to bolster students' conceptual development. In this way, authentic inquiry provides the real context for the development of literacy skills.

With this goal in mind, during fall semester, 2013 the district's Literacy Coordinator, Karen Heath, and I co-instructed a professional development course designed to help K-8 teachers build pedagogical knowledge to integrate science and literacy during science inquiry. Based on *Science and Literacy: A Natural Fit: A Guide for Professional Development Leaders* (Worth, Winokur, and Crissman, 2009), the course strived to help teachers combine balanced literacy with inquiry science instruction to improve teachers' knowledge of and ability to use literacy strategies that support and enhance science inquiry instruction.

K-8 teachers in the district possess varied levels of understanding and facility with using science inquiry in the classroom. In general, middle-school (5-8) teachers are more practiced in teaching science through inquiry than their primary- and intermediate-school

(K-4) colleagues. The K-4 teachers, responsible for all subjects in self-contained classrooms, are more practiced with teaching literacy, but are less well versed in instructing science through inquiry.

This action research project investigated the effects of using the *Science and Literacy* professional development model to help participating K-8 teachers bolster student science reasoning and conceptual development through inquiry using literacy strategies. This research focuses on the following questions:

1. What effect does implementation of this PD program have on teachers' knowledge of best practices for science inquiry instruction that use dialogue and writing to foster conceptual understanding?

2. What effect does implementation of this PD program have on teachers' self-efficacy for teaching science through inquiry using dialogic strategies, discourse, and writing? (Self-efficacy means one's self-confidence in the effect of his/her teaching on the students he/she teaches.)

3. What effect does implementation of this PD program have on teachers' inquiry pedagogy, specifically on teachers' use of discourse and writing to help students develop evidence-based reasoning during inquiry?

CONCEPTUAL FRAMEWORK

A review of literature about professional development that supports the use of discourse and writing to enhance learning through inquiry science has three components. First, the need for and definitions of inquiry-focused instruction in the K-8 classroom are discussed. Next, the use of literacy strategies to help students build conceptual understanding during scientific inquiry is explored. Finally, studies of professional

development approaches meant to improve teachers' inquiry instruction using literacy strategies with an emphasis on questioning and dialogic practices are addressed.

<u>The Need for and Definition of Inquiry Instruction</u>

In *Taking Science to School: Learning and Teaching Science in Grades K-8,* the National Research Council (NRC) identifies four strands of scientific proficiency:

Students who are proficient in science:

1. know, use, and interpret scientific explanations of the natural world;

2. generate and evaluate scientific evidence and explanations;

3. understand the nature and development of scientific knowledge; and

4. participate productively in scientific practices and discourse.

(Duschl, Schweingruber, & Shouse, 2007, p. 36)

The NRC emphasizes the interrelated and inseparable nature of the strands and the compelling need for kindergarten through eighth-grade students to learn science as it is practiced in order to build conceptual understanding. "The science-as-practice perspective invokes the notion that learning science involves learning a system of interconnected ways of thinking in a social context to accomplish the goal of working with and understanding scientific ideas" (Duschl et al, 2007, p. 38).

Authors of the National Research Council's *A Framework for K-12 Science Education* outline three dimensions of science learning that need to be interwoven in all aspects of science instruction: scientific and engineering practices; crosscutting concepts; and disciplinary core ideas (NRC, 2012). A wide body of research suggests that combining all three components to engage students in scientific inquiry and engineering

design will help students construct scientific understanding (Bansford, Brown, and Cocking, 1999).

Scientific inquiry is the practice through which scientists construct knowledge about the natural laws that govern our universe.

Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. (NRC, 1996, p. 23)

Guiding students to use the scientific inquiry process to help them build conceptual understanding facilitates students' construction of scientific concepts (NRC, 2012) and helps them build core ideas and science practices outlined in the Next Generation Science Standards. NGSS will likely be adopted by a considerable majority of states and provide the underpinnings of curricula, instruction and assessment throughout the United States for the next 15-20 years (Michaels, 2013). June 25, 2013, Vermont adopted NGSS as the state's science standards.

Eight scientific and engineering practices are outlined in NGSS, including: defining problems; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematical and computational thinking; constructing explanations and designing solutions; engaging in argument from evidence; and obtaining, evaluating, and communicating information (Achieve, 2013). With the implementation of NGSS, K-8 teachers throughout the United States will need

to learn to instruct science by helping their students practice science as it is practiced in the world to build scientific understanding. Teaching science well will need to incorporate inquiry instruction to help students achieve the performance expectations outlined in NGSS.

During professional development using *Science and Literacy: A Natural Fit* teachers study how to help students use the Inquiry Learning Cycle as they engage in science practices through scientific inquiry (Appendix A). Using the cycle, teachers learn that students engage in the following practices to develop understanding:

Engage (explore, notice, wonder, speculate)

Design and conduct investigations (determine question, predict, plan

investigation; collect and record data; organize data, interpret data,

analyze and reflect on data; and raise new questions.)

Draw conclusions (analyze and synthesize data, make claims based on

evidence, explain); and

Communicate (write, present, defend, debate).

(Worth et al, 2009, p. 5)

These Inquiry Learning Cycle steps are not linear, but rather students cycle through the activities and return to earlier stages as needed in their investigation to build understanding. Students talk and write throughout the inquiry process to discuss, defend, elaborate and share their scientific conceptions, working together to adjust their conceptual frameworks as they learn. They learn to draw conclusions by making claims supported by evidence gathered, written about and discussed throughout their inquiry experience.

The Need To Use Literacy Strategies During Inquiry

Bansford et al (1999) emphasize that when students use and develop language in order to argue evidence and claims, they build deeper understanding of concepts. In addition, the authors emphasize the important role of dialogue for sharing information and learning from and arguing against others' conceptions and claims. Michaels, Shouse and Schweingruber (2008) explain that oral and written language is the primary tool for communication and for making thinking public in the science classroom. According to the wide body of research cited in both of these NRC publications, strategies that help students use oral and written language to build scientific understanding in a social context help to deepen student science learning.

Educational standards teachers are required to address provide compelling reasons to integrate science and literacy in the classroom through use of science inquiry. The CCSSELA and NGSS share three important emphases for instruction: helping students develop evidence-based reasoning practices; need for the use of discourse that is productive and intensive to build conceptual understanding; and a shift to helping students develop the ability to reason rather than recite facts (Michaels, 2013). Professional development that helps teachers build students' scientific literacy by building skills of speaking, listening, arguing with evidence and writing will help address CCSSELA while simultaneously helping teachers address NGSS.

However, many teachers rely on an initiation-response-evaluate dialogic model (I.R.E) when questioning students in science (Michaels, 2013). Mercer, Dawes, & Staarman (2009) showed that often teachers asked closed questions, questions with answers that are either right or wrong and fail to draw out further dialogue and deepen

thinking. The I.R.E questions were directed toward checking for student understanding rather than toward building student reasoning. Yet what is needed is a method of directing discourse that deepens students' thinking and reasoning about the phenomena they are exploring through inquiry.

The Science Writing Heuristic (SWH) is one example of a literacy-focused strategy used to improve reasoning and argumentation through science inquiry. The SWH engages students in oral and written language during scientific inquiry to help them learn science concepts by scaffolding their ability to discuss and argue claims with evidence they gather in their investigations (Nam, Choi, & Hand, 2011). Using this model, students learn content by practicing science in real contexts, determining their own questions, seeking answers, and discussing and arguing their findings, then continuing their inquiry with new questions. Nam et al studied the effect of training teachers to use the SWH approach, and witnessed that students in classrooms that used the SWH approach scored significantly better on the summary writing test than did their control group peers whose instruction did not use the SWH approach.

<u>Professional Development Research</u>

Professional development designed to help teachers learn to teach inquiry well is challenging given the large pedagogical shift required for any teacher more accustomed to using didactic, lecture-style instruction to convey science concepts. Therefore, this section of the literature review first will look broadly at literature that describes professional development designed to influence K-8 grade teachers' ability to teach science through inquiry.

Professional development can have a substantial impact on teachers' ability to use sound inquiry pedagogy. Buczynski and Hansen (2010) in a study of 118 grade 4-6 teachers reported improvement in the frequency with which teachers involved in an inquiry-focused professional development program said they used inquiry practices in the classroom after their PD. Brand and Moore (2011) have shown that, not only can teacher knowledge of inquiry practices be increased with PD, but also teacher self-confidence in implementing inquiry-based strategies can be improved after an inquiry-focused PD program. In addition, Lakshmanan, Heath, Perlmuter, & Elder (2011) demonstrated that when the inquiry science PD is imbedded into professional learning communities, teacher self-efficacy improved and teachers reformed their inquiry-focused teaching.

Professional development intended to help teachers understand and adopt literacy practices that help students construct meaning during inquiry have been shown to alter teacher's instruction. Nam et al (2011) found that 8th grade teachers use of the SWH techniques learned during their SWH professional development classes translated into significantly higher scores on the Reformed Teaching Observation Protocol as compared to scores for their control group classes that did not use the SWH approach. A longitudinal case study conducted by Martin & Hand (2009) demonstrates that a PD approach consistent with the Science Writing Heuristic Approach helped a veteran teacher shift instructional use of dialogue to assist students' reasoning. When this teacher encouraged students to determine their own questions for inquiry rather than focus on inquiry questions of the teacher's design, she also began to ask questions that focused their attention on claims and evidence. At this point, the teacher shifted from an I.R.E.

pattern of questioning to questioning that elicited stronger student voice and required higher order reasoning to construct meaning with classmates.

Professional development that focuses on enhancing teachers' ability to question students during inquiry activities can change the types of questions teachers ask their students. Oliveira (2010) showed through video analysis and observation that frequency of teachers' student-centered questions increased with PD that focused on using dialogue during inquiry. In addition, the types of questions teachers posed changed in many ways after PD: Referential (evidence-based) questions increased and comprehension-checking questions decreased drastically.

Worth et al's (2009) *Science and Literacy: A Natural Fit* uses as part of the professional development training a set of pre-existing videos of teachers involved in inquiry. Watching, analyzing and discussing these videos is intended to help participating teachers learn about discourse and the use of oral and written argument during inquiry and see it in action so that they better understand how to structure discussions around the concepts and the evidence generated during inquiry. This approach is not unique to this professional development program: Zembal-Sail (2009) explain that implementing a pre-service science teacher program that uses a framework focused on the use of discourse and argument can help encourage early emphasis on argument and reasoning. The Zembal-Sail pre-service program incorporated video analysis of veteran teachers' use of dialogic practices during inquiry and the author explains this approach helps increase pre-service teachers' ability to use questioning and argument with students.

In conclusion, a review of the literature demonstrates a pressing need for teachers to learn to use inquiry practices to help students construct conceptual understanding and build science practices. Professional development focused on using inquiry-teaching practices in the science classroom can positively impact teachers' self-efficacy, understanding of inquiry, and instructional reform efforts. More specifically, professional development intended to build teachers' use of literacy strategies that help students make sense of and argue evidence during inquiry has been shown to change teacher dialogue and argument practices as they guide student inquiry.   Teaching teachers to use literacy strategies to support inquiry instruction can have a significant impact on teacher pedagogy.

METHODOLOGY

This project studies the outcome of a once per-week fall professional development course taught to K-6 teachers of science in the Barre Supervisory Union in Barre, Vermont. More specifically, the research investigates the effect of training in *Science and Literacy: A Natural Fit* on teachers' understanding, self-efficacy and pedagogical use of dialogue, discourse and writing to help students construct meaning from evidence gathered during inquiry. The study focuses on three research questions:

1. What effect does implementation of this PD program have on teachers' knowledge of best practices for science inquiry instruction that use dialogue and writing to foster conceptual understanding?

2. What effect does implementation of this PD program have on teachers' self-efficacy for teaching science through inquiry using dialogic strategies, discourse, and writing?

3. What effect does implementation of this PD program have on teachers' inquiry pedagogy, specifically on teachers' use of discourse and writing to help students develop evidence-based reasoning during inquiry?

<u>Participants</u>

All K-8 teachers of science in the Barre Supervisory Union, including Barre Town Middle and Elementary School and Barre City Elementary and Middle School, were invited to enroll in this course. Although the course was not advertised outside the Barre school district, through word-of-mouth one K-8 elementary teacher from another central Vermont school also heard about and enrolled in the course. Nine Caucasian teachers participated in this research, including seven females and two males. Three study participants have taught for 24 to 30 years. Four participants have taught for 8 to 17 years, and two participants are in their second year of teaching. Table 1 outlines the grade levels taught by the course participants and by the nine study participants.

Table 1

Grade Levels Taught by Teachers in the Course and Teachers in the Study

Grade Level	# of teachers participating in the Science and Literacy course	# of teachers participating in this research study
Kindergarten	1	0
1st Grade	4	3
2nd Grade	2	0
3rd and 4th Grade (looping)	1	1
4th Grade	2	2
5th Grade	2	1
5th and 6th Grade (looping)	2	2
Total #	14	9

Participants possess varied levels of experience and expertise with use of science inquiry in their teaching. Prior to the course, most participating teachers were using inquiry instruction infrequently and in limited ways. All course participants have expressed that they do not have adequate time to teach science due to the pressing need to focus on math and language arts. During their previous professional development, none of the study participants had focused in depth on learning how to use a combination of talk and writing strategies to build reasoning during inquiry. For this reason, a 'comparison group' was not used to measure the effect of my intervention. Rather, I tracked changes that occurred across the duration of the intervention.

Intervention

Class activities were based on *Science and Literacy, A Natural Fit: A Guide for Professional Development Leaders* (Worth, Winokur & Crissman, 2009). The intervention course met on Wednesday afternoons from 3:45 to 6:45 p.m. from September 25 through December 11, 2013. Throughout the course, outside of class time,

participants conducted discussions with their classmates in an online forum and used the online site to post reflections on their course learning. After successful participation in the course, including online discussions, participants received three graduate credits through Union Institute and University.

Throughout the intervention, teachers participated in activities outlined in modules one through seven of *Science and Literacy, a Natural Fit* with some modification. First, our course used a greater number of teacher inquiry investigations in an effort to help participants better understand through direct experience how they can facilitate student inquiry and integrate discussions and writing to help students build conceptual understanding. Also, our course infused structured opportunities for teachers to practice facilitating discussion techniques outlined in *Science and Literacy* with their classmates using data collected during our class inquiry investigations. Table 2 summarizes the intervention activities.

Each module is designed to take 2-3 hours to facilitate/instruct, but my co-instructor and I used an average of 4 hours to address topics within each module because we incorporated additional resources that pertained to the topics addressed. For example, we used material from TERC's The Inquiry Project, including their online publication entitled *Talk Science Primer*. We also incorporated time to look at CCSSELA standards and NGSS standards addressed throughout the course. These additions increased the time required to adequately address each module's focus area and updated the content, given recent adoption of the new ELA and science standards.

Table 2
Description of Intervention Activities

Module Number	Title of Module	Summary
1	Science Inquiry	Teachers are introduced to the course and conduct scientific investigations to experience and learn more about the stages of the inquiry process while instructors model use of literacy strategies to bolster student reasoning.
2	Teacher Questions that Support Inquiry	Teachers learn how to construct productive questions for different stages of the inquiry process by analyzing and crafting productive questions and creating productive questions for their classroom curricula's inquiry.
3	A Culture of Talk	Teachers learn about setting classroom norms for productive whole group discussions, and instructional strategies that encourage productive talk.
4	Classroom Talk – Gathering Ideas Discussions	Teachers learn about the purposes and characteristics of Gathering Ideas discussions through viewing, analyzing and discussing videos and reading transcripts of classroom talk.
5	Classroom Talk – Making Meaning Discussions	Teachers conduct inquiry to gather data that can be used for a making meaning discussion, then they use a 'fishbowl' observation during the making-meaning discussion to learn first-hand how making meaning discussions work. They then focus on instructor behavior and student behavior analyzing a classroom video and transcript to look for teacher moves and student skills.
6	The Science Notebook – Structure and Characteristics	Teachers learn about and discuss the purposes and goals of science notebooks and analyze student work samples. They also watch a video to witness the use of notebooks in the classroom.
7	The Science Notebook – Implementation and Use	Teachers analyze student notebook examples and learn scaffolding strategies through guiding and supporting students' effective use of science notebooks.

To summarize the intervention: throughout this course, participating teachers analyzed

and practiced specific strategies for implementing whole group discussions to build

scientific reasoning. In particular, activities focused on intentionally using language in science to help students gather ideas, make meaning of their investigations, argue with evidence and draw conclusions. Participants learned and practiced using specific strategies for implementing student scientist notebooks to intentionally teach science concepts and build reasoning through writing during inquiry. They planned for, practiced and reflected on use of inquiry, discourse strategies and writing during science in their classrooms.

Data Collection

To measure teachers' self-efficacy, teachers completed the Science Teacher Efficacy Belief Instrument (STEBI-B) (Appendix B) within the first week of the course and began keeping online journals to reflect on their comfort with implementing strategies learned in the course. Online journal entries and discussions responded to prompts outlined in Appendix C. At the start of the course, I began keeping an instructor journal to reflect on teachers' comments and apparent confidence with the material covered throughout the course. Participants also completed a Knowledge Survey in Google Forms within the first week of the course as a pretest to check for pre-existing knowledge of inquiry and best practices in use of literacy strategies during inquiry (Appendix E). In addition, during week 2 of the course, I observed and audiotaped 7 of the study participants teaching science class and then analyzed my observations and audiotapes using the Reformed Teaching Observation Protocol (RTOP).

Throughout the intervention, participants continued to use their online journal and discussion area to reflect on their comfort level, knowledge and use of literacy strategies during inquiry. I also continued to record in my instructor journal my observations of

teacher learning and reflection on discourse and writing strategies for inquiry. My co-teacher and I observed teachers teaching in their classrooms again in the middle of the course to offer coaching and feedback.

At the end of the intervention, teachers repeated the STEBI-B and I conducted teacher interviews (Appendix D) to determine the effect of the course on teachers' self-efficacy and their view of their course learning. Teachers also completed a post-knowledge survey in Google Forms at the conclusion of the course and I conducted another round of classroom observations with audio recordings and used the RTOP to analyze these sessions. This observation data included evidence of teachers leading 'gathering ideas' and/or 'making meaning' discussions to determine the effect of the intervention on teachers' use of discourse strategies to bolster student thinking and reasoning. I also analyzed teacher online journal and discussion entries to gather qualitative data that suggested changes in participants' knowledge, self-efficacy and implementation.

In summary, data was collected from multiple sources and triangulated to answer the three focus questions, as outlined in Table 3.

Table 3
Triangulation Matrix

Focus Question	Data Source 1	Data Source 2	Data Source 3
What effect does implementation of this PD program have on teachers' knowledge of best practices for science inquiry instruction that use dialogue and writing to foster conceptual understanding?	Pre and post knowledge survey	Teacher interviews	Teacher journals
What effect does implementation of this PD program have on teachers' self-efficacy for teaching science through inquiry using dialogic strategies, discourse, and writing?	Pre and post STEBI-B	Teacher interviews	Teacher journals Instructor journal
What effect does implementation of this PD program have on teachers' inquiry pedagogy, specifically on teachers' use of discourse and writing to help students develop evidence-based reasoning during inquiry?	Pre and post audio taped classroom inquiry discussion with RTOP used for analysis.	Teacher interviews	Teacher journals Instructor journal

DATA AND ANALYSIS

The following sections describe the analysis of data for each of the research focus

questions. The first subsection describes my analysis of the data for the first research

question: What effect does implementation of this professional development (PD)

program have on teachers' knowledge of best practices for science inquiry instruction

that use dialogue and writing to foster conceptual understanding? This first subsection

begins with an overview of the themes that emerge in the pre-and post-course knowledge

survey data to provide a framework for viewing the data from teacher interviews and journal entries.

The second subsection addresses data to answer the second research question, "What effect does implementation of this PD program have on teachers' self efficacy for teaching science through inquiry using dialogic strategies, discourse and writing?" This section first offers an overview of the themes within the data, and then discusses the specific themes that emerge in teachers' interviews and journal entries. Finally, STEBI-B data are shown.

The final subsection analyses data concerning the final research question: What effect does implementation of this PD program have on teachers' inquiry pedagogy, specifically on teachers' use of discourse and writing to help students develop evidence-based reasoning during inquiry? This section begins with an overview of what was learned from the data then explores teacher interview and teacher journal data, before describing the results from the RTOP that support the analysis of themes in the interview and journal data.

Data gathered for all three focus questions suggest significant changes occurred for teachers as a result of the *Science and Literacy* course: every study participant developed new understandings of best practices for instructing science through inquiry using discussion and writing; nearly all participants' self-efficacy improved for teaching science through inquiry using discussion and writing; and every participant's implementation of using discussion and writing during inquiry appears to have changed significantly.

Data include several quantitative measures, including results of the STEBI-B and the RTOP. Because the participant sample size was small (nine), however, the quantitative results did not show statistically significant differences. The majority of data analyzed here is qualitative in nature, including teachers' descriptions of their learning on pre- and post-course knowledge surveys, in their teacher journals and during teacher interviews. In order to describe, make sense of and interpret the data present within teacher statements, I read and reread teacher statements from each qualitative instrument many times.

When I conduct professional development for school districts, I am often unable to directly witness in classrooms the change that I am trying to affect in teacher instruction through my PD instruction.   I chose to study these three research questions so that I could look closely at the teacher outcomes and compare them to my instructional goals. As researcher and co-instructor of the course under study, I cannot be considered unbiased in my evaluation of whether or not teachers learned what I intended for them to learn through this course.   I took two steps to decrease the likelihood that my biases would affect the research. First, the co-instructor of the intervention, my capstone advisor and 3 other educators who were not involved in this PD course reviewed and critiqued my data and analysis to ensure it accurately reflects the changes witnessed from the beginning to the end of the course. Second, to account for my bias toward witnessing significant change in teachers' learning and in order to provide descriptive validity to this research, I include many direct quotes from teacher interviews and teacher journals to demonstrate the themes in the data. With these controls in place, the qualitative data

themes that emerge, when combined with the suggestive quantitative results, paint a clear picture of participant learning from this PD course.

<u>Knowledge of Best Practices</u>

This section addresses the first research question: What effect did implementation of this professional development program have on teachers' knowledge of best practices for science inquiry instruction that use dialogue and writing to foster conceptual change? Qualitative data gathered throughout the course demonstrate significant changes in teachers' knowledge of best practices as a result of this course. Although the participant sample size was not large enough to generate statistically significant data, the pre- and post-knowledge surveys seem to confirm growth in teacher's knowledge of the stages of the inquiry cycle, knowledge of best practices for pre-inquiry discussions, knowledge of best practices for student discussions to analyze data, and increased understanding of the value of student talk to help build understanding. Teacher interview and journals provide additional insight into the ways that teachers' knowledge of best practices shifted throughout the course.

<u>Knowledge Survey</u>

Due to illness, only seven of the nine study participants completed both the pre- and post- knowledge survey. When the pre-course survey was administered, eight of the nine teachers took less than 25 minutes to complete it. Most of them also expressed nervousness about not knowing correct answers to many of the test questions. I encouraged them to simply say, "I do not know," and reminded them the survey would not impact their grade for the course. When the post-survey was administered, participants spent 50-60 minutes completing the survey.

The seven pre-course knowledge surveys show that before the course all participants understood the inquiry cycle as a process that involves students in questioning and exploring. Teachers of younger students listed only questions they thought students should think about during inquiry, for example, "I wonder… I notice…?" Teachers of older students diagrammed the inquiry cycle in a variety of ways, but all involving gathering data from experiments and returning with new questions to start the process over again.

After the course, every participant diagrammed or listed the following stages of the inquiry cycle: Engage, Design and Conduct Investigations, Draw Conclusions, Present Findings. These responses represent a significant change in thinking. Prior to the course, participants' responses all centered on the act of investigating (the design and conduct investigations phase) and teachers were unaware of the existence of an engage phase where students are drawn into the science inquiry through sharing their thinking and prior experiences about the specific content of the inquiry they are about to undertake. Pre-surveys show that participants were unaware before this course that drawing conclusions is a distinct and important phase of inquiry which requires discussion and writing about the concepts to develop deeper understanding of the content, relying on evidence to support thinking and reasoning about the results of their investigations. Lastly, pre-surveys show participants were not aware of the stage of inquiry that involves presenting not only one's findings, but also one's thinking and learning to peers and the wider community. To illustrate some of the types of changes that occurred between the pre- and post-knowledge survey inquiry cycle diagrams, Appendix F shows the pre-

knowledge survey inquiry diagram and the post-knowledge survey inquiry diagram for one of the study participants.

The knowledge survey data also suggest that participants' knowledge of whole- and small-group discussion strategies to be used throughout the inquiry cycle changed a great deal. Before the course, teachers did not know the meaning of the terms 'gathering ideas discussion' or a 'making meaning discussion' and said so. When asked to describe these types of discussions, teachers either did not know (for example, "Not sure. Students share their learning?" Participant number six) or the participants guessed (for example, "It sounds like this is before you actually work with any ideas and you are just helping students bring their thoughts out in the open." Participant number nine)

On the pre-knowledge survey, three teachers shared the KWL discussion strategy as a before-the-inquiry discussion strategy that would prepare students for science inquiry. The KWL strategy involves hosting a whole-class discussion before students undertake a new instructional unit. The discussion has students share ideas about the following questions, "What do you know (about the topic we are about to study)? What more do you want to know about that topic?" When the unit concludes, teachers using the KWL strategy then host another discussion by posing the question, "What did you learn about the topic?"

KWL is a popular strategy used in many classrooms, not just in science. One of the problems with KWL for science inquiry is that KWL discussions tend to focus on broad topics rather than focusing on helping students bring forward and consider their prior thoughts about the content and concepts of the specific inquiry investigation they are about to conduct. The question posed to initiate discussion during a KWL is often

very broad, (e.g. – What do you know about spiders?) And as a result, K and W often

initiate a wide variety of answers that stray widely from the specific content of the

inquiry investigation about to take place.

Three teachers in this research shared on the knowledge survey the KWL strategy

as a before-the-inquiry discussion strategy. For example, on participant wrote, "Use the

KW part of KWL. What do you know? What do you want to know? Make a list of prior

knowledge and questions either with the whole class or carousel style on different pieces

of paper around the room." (Participant number seven)

Of the seven teachers responding on both the pre- and post-knowledge survey, the

four teachers who did not mention using a KWL strategy said that as a pre-investigation

discussion strategy they would show and discuss a picture or give students materials and

ask them how they think they could use the materials. Neither of these strategies

connects students to thinking about the specific task at hand or about the concepts

students are about to address through inquiry.

Yet, when asked on the post-course knowledge survey to describe a discussion

strategy that could be used before beginning an inquiry investigation to help students

connect to a new science topic, five participants identified and proceeded to describe the

gathering ideas discussion strategy they learned about in the course. A sample teacher

response that demonstrates this theme follows:

Teachers can use the gathering ideas discussion strategy before beginning

inquiry exploration to help students connect with the new science topic.

Teachers should provide students with something they can connect to

start their thinking. Have them share their thinking with a partner to

> prepare them to talk in a circle to the larger group then do a circle
>
> discussion [whole class discussion]. (Participant number two)

The remaining two participants discussed the importance of asking productive focusing questions to initiate the discussion. Participant number three wrote, "Ask an open-ended question to get [students] thinking and activate prior knowledge," while participant number four said, "We should be asking questions that are open-ended and encourage students to share their thoughts. The questions should not be able to be answered with a yes or no response."

Post knowledge survey data suggest that by the end of the course, teachers' understanding of what gathering ideas discussions look and feel like had changed drastically. All seven teachers were able to describe gathering ideas discussions well. For example:

> Students are gathered together facing each other. A question is
>
> asked [by the teacher] and the students respond with their
>
> thoughts. It would be ideal for the students to have this
>
> conversation without the use of hands and with the understanding
>
> that everyone has the right to contribute. A set of rules must be
>
> agreed upon before such discussions are held. Ideally, the teacher
>
> is not the center of the discussion. The students should be
>
> addressing each other, not the teacher. (Participant number four)

Knowledge survey data also show that before the course teachers did not know the meaning of the term 'making meaning discussion.' Like gathering-ideas discussions, during making-meaning discussions students gather in a circle facing one another and the

teacher facilitates a student directed discussion about the evidence they gathered during their inquiry investigations. When asked to describe a making meaning discussion on the pre-survey, six participants said they did not know (e.g., "Not sure." Participant number nine; "Don't have any idea." Participant numbers four). One participant said, "Students have already done some investigating and are comparing findings." (Participant numbers seven). After the course, participants were able to describe making meaning discussions accurately on their post-knowledge surveys, explaining the main purpose of these discussions, which is to share claims supported by evidence gathered from the investigation, to share thinking about what's happening conceptually, and to deepen conceptual understanding together. For example, participant number six said:

> A making meaning conversation has students sharing what they discovered in their investigation, looking at data when possible, making claims and supporting ideas, and coming to a group conclusion. It also campaigns for discovering patterns and connections, new ideas, and coming up with new questions to answer.

Participant number two said:

> A making meaning discussion is a discussion in which students are sharing and discussing claims they made from their inquiry experiment. It is done in a circle and students are sharing their ideas and reacting to others' ideas.

All of the participant responses on the post surveys said that the teachers' role during these discussions is to be the facilitator of the discussion, that the discussion is

about helping the students articulate and share their understanding and that the teachers'

job is to facilitate this process without being the center of the discussion. For example:

> The teacher needs to have a clearly defined purpose for the
>
> discussion and needs to have a clearly refined and focused
>
> question [to initiate the discussion]. The teacher needs to
>
> gradually release responsibility for the flow of the discussion and
>
> really needs to serve more as a facilitator than as an active
>
> participant in the conversation. (Participant number one)

> The teacher is a facilitator who gets the discussion going,
>
> encourages kids to bring forth their ideas, who may at times
>
> refocus the group or try to get kids thinking in another direction.
>
> (Participant number three)

Table 4 outlines a summary of the themes that emerge in the knowledge survey

results. These themes show changes in teacher knowledge of best practices for science

inquiry instruction that uses dialogue and writing to foster conceptual change.

Table 4
Themes in Knowledge Survey Data

Category of Knowledge Survey Theme	Pre-Knowledge Survey Themes	Post Knowledge Survey Themes
Pre-inquiry discussion strategy	KWL Present a photo Present materials with question	Clear understanding of Gathering Ideas Discussion and the goals and strategies to conduct these discussions.
Making Meaning	No knowledge of Making	Clear understanding of

Discussions	Meaning Discussions or how to conduct one with a class	Making Meaning Discussion and the goals and strategies to conduct these discussions.
Role of teacher in Making Meaning Discussions		Teacher as guide and facilitator of discussion that helps students share their ideas.

Interviews

I interviewed all nine study participants near the conclusion of the course. Interviews lasted 15-25 minutes and interviewees smiled and laughed and seemed to enjoy the opportunity to share their thoughts about the course with me. Teachers were comfortable with the voice recorder placed on the table in front of them and appeared relaxed and comfortable sharing their thoughts with me.

Three broad themes emerged from the interview data when considering changes in teacher knowledge of best practices for science inquiry instruction throughout the course. First, participants expressed repeatedly that they now see that the teacher should serve as guide and facilitator of student science learning rather than the dominant person to whom all students look for answers during science inquiry discussions. Interviews also showed that participants understand the importance of creating a classroom culture in which students discuss their ideas about what's happening in an inquiry investigation as a whole class. In particular, participants expressed strongly that, during these discussions, the teacher needs to guide students to explain their reasoning supported by evidence recorded during their investigations. In this way, students work together to refine their ideas through discussion in order to build understanding. To offer descriptive validity

throughout my explanations of the qualitative data in this research, I provide quotes from participant interviews and journals to exemplify each theme.

During an interview at the end of the course, participant number four explained how, through what she learned in the course, she recognizes that during science discussions about inquiry the teacher serves as a guide and does not direct everything:

> The teacher is more of a guide and not as a central person. We're there to guide them but it's not everything should be coming through the teacher. I would like to see more of the students sharing with each other and with the teacher there as a back up and instigator as far as things going if they stall or if they're going in the wrong direction, hopefully to ask the right questions to get them back on track. It's very hard to stand back…I tend to want to control and it's giving up control as far as the teacher goes. It's more like, ' let them do it on their own.' They most likely will get where they need to go without the iron-guidance type thing.

Participant number four goes on to explain that, before the course, "The talking [among students] was not there or the teacher was doing most of the talking and now we really want to make it about them [students]. So, it [the course] has totally changed how I look at it. Like I said, I feel much, much better about science now."

Similarly, participant number one in the interview discussed the facilitator role the teacher takes during the inquiry process discussions, emphasizing the need to guide students to conduct the work of science inquiry in the way that scientists do:

> I like to think ideally of me as teacher being the guide who's helping to facilitate their conversations rather than directing them in a place where I

want them to go….I want to put kids in a position where they are thinking

authentically as kids who are scientists, who have been doing science.

Another theme participants expressed in their interviews is the need for the

teacher to help students use evidence from their investigations to show their reasoning

during science discussions in order to build understanding about the science concepts

they are exploring. For example, participant number seven explained:

There's a big idea that I am trying to get them to right now. It's that

scientists don't just make up ideas and believe them. That they have ideas

for a reason and that reason is based on evidence that they find when they

do experiments and observations. And so, there seem to be a lot of kids

who say, "Well, this is my idea. I like it, so it must be good." I think the

process of having whole group discussions where other people can say, "I

don't agree with that. That doesn't make sense. Prove it to me," has been

really helpful for that. I think one thing I have been doing well with

discussions is bringing it back to the idea that they need evidence and

saying, "Okay. Great. Where's your evidence for that." And that has

really helped.

This Science and Literacy course emphasized the overlap between the Common

Core State Standards in English and Language Arts and the Next Generation Science

Standards. It helped participants recognize that students need to develop evidence-based

reasoning skills in both subject areas. Participant number one speaks of this when he

expresses:

And one thing that I've gotten a lot more insistent upon in all areas of discussion, particularly in our literacy groups and in science is, if you're going to support a claim, 'what do you have in your notebook that you observed?', or 'what is there in this text that's going to support what you're saying?', so it moves them beyond 'well I think..' or 'well, maybe…', It moves them to say, 'Here's my evidence to support why I think this is happening.' And it's really trying to develop a habit of mind in the kids that if they're going to form an opinion, there need to be reasons for that. They need to be thought through. They need to be based in fact somehow. You can't just pull something out of the air. So I think that's one change.

Participant number nine describes well how different the classroom looks when using the types of discussions strategies taught to participants in the Science and Literacy course:

Before this course we dealt mostly with inquiry kits and there was usually a focus on describing what we were going to do in the investigation, we gave the students the materials, they investigated. They wrote up a quick conclusion and then they were done with it. It was, they were hands on in many ways but there were no discussions, which meant students really didn't…..[sic] There was no way for them to know whether their ideas were correct or incorrect and we didn't really have a chance for students to talk about their ideas with others. And when they talk about their ideas with others, we've found that there's a deeper understanding of both the

investigation and what they can do with that knowledge and where that

knowledge might lead in the future.

<u>Teacher Journals</u>

As part of the course requirements, all course participants engaged in online

discussion and journaling in a secure classroom digital site throughout the course. It took

two weeks for all of the teachers to become comfortable with the process of logging

entries and responding to their classmates' posts online, but once settled in, they

expressed that they liked the online discussion and posting of journal entries. One

teacher who was particularly resistant to the online component at the beginning of the

course ended up very proud of herself for learning and becoming good at posting journal

entries and reflections on her classmate's posts in the shared site. Like other participants,

she seemed to enjoy the chance to communicate online about her learning on the shared

site.

Eight of the nine study participants answered the following question at the

conclusion of this course: In what ways has your knowledge of best practices for

teaching science through inquiry changed in this course? The most prominent theme that

emerged from participant responses is the recognition of the importance of structuring

both talk and writing opportunities throughout the inquiry process to help students think

more deeply about their science investigations.   Participant number eight stated that,

"This course has made me reflect on how I can get my students to produce more and

think more critically during science studies." Participant number four stated, "The most

important thing I'm taking from this course is that I must give my students the time to

talk about what they are doing, to share ideas and to challenge respectfully with

evidence…..At this point, I find that I have done my students a great disservice in not allowing them more time to talk about their experiences. I see now that discussion *throughout the inquiry process* [participant emphasis] is essential to deeper understanding of the concept." Two additional examples follow:

> What I've learned in this course, the importance of discussion in the
> inquiry process, has brought back that desire to have kids think
> deeply….Another area that is a huge change for me is having kids use
> science notebooks well. Again, I've done these before with limited
> success. Now that I want kids discussing the inquiry and making their
> claim about what and why something happened, the notebooks have a real
> purpose. Kids are using them to write the engage question, jot their
> prediction, draw and label the experiment set up, write or record their
> observations or results and share out [during discussion]. The evidence
> for their statements is recorded in the notebooks. Beyond this, the
> notebooks provide evidence for the claim they are making and, in the final
> stages, will be used to provide information needed to write a report of their
> findings.
>
> To sum things up, the big change for me is all about discussion,
> oral and written communication and the deeper thinking that comes from
> making connections.

                                    Participant number three

Another participant, number five, said the same theme slightly differently:

I've learned it's okay for students to hear what others are thinking and to

change their initial ideas…..I used to think the science notebook was a

place for my students to show me what they know about a topic. It was a

scary place for them to go to. Now that they are allowed to hear what

others are thinking before they write, it allows them to feel ownership of

the lesson. Letting them change their initial thoughts after a making-

meaning conversation also lets them know that it is okay to make changes

in their thinking.

In summary, data gathered from the knowledge survey, the teacher interviews and

the teacher journals demonstrate substantial changes in teachers' knowledge of best

practices for science inquiry instruction that use dialogue and writing to foster conceptual

understanding through the course. Teachers learned more about the distinct phases of

inquiry and the meaning of the terms 'gathering ideas' and 'making meaning' discussions.

They deepened their understanding of the value of combining these talk strategies with

student science notebook use throughout inquiry science instruction to foster student

conceptual growth. Participants also learned that the teacher's role during science

inquiry is not to be the bearer of all knowledge, but rather to help students construct

meaning from their inquiry by facilitating discussions among students that encourage

them to rely on evidence from their shared inquiry experiences (recorded in their

notebooks). Table 5 lays out a summary of data about changes in participant knowledge:

Table 5

Summary from Data of Changes in Participants' Knowledge of Best Practices

Before Course	After Course
Limited understanding of inquiry cycle	Expanded understanding of the inquiry cycle
KWL for group discussions or teacher calling on students in seats	Understand Gathering Ideas Discussions Understand Making Meaning Discussion
Teacher as director of discussions Teacher as bearer of knowledge	See teacher as facilitator with students learning from students through talk
Students conduct investigations and record salient information.	Recognize students need to talk and write about evidence from investigations

Self-Efficacy

This section addresses the second research question: What effect does

implementation of this PD program have on teachers' self-efficacy for teaching science

through inquiry using dialogic strategies, discourse and writing? I conducted teacher

interviews within two weeks of the conclusion of the course, gathered teacher journal

entries throughout the course, and conducted a pre- and post-STEBI-B to gauge changes

in teachers' self-efficacy. Analysis of this data demonstrates that participants' self-

efficacy for teaching science improved. In particular, their self-efficacy improved for

leading productive whole-class discussions and using student science notebooks to help

students build understanding.

Teacher Interviews

All study participants expressed during interviews an increase in their self-

confidence for teaching science through inquiry. For example, in response to the

question, "Do you feel confident in your ability to teach science through inquiry? How

has your confidence level changed?" participant number two said:

..Science inquiry, yes, because I would say that now I feel like I know

what a science class is supposed to look like. I feel like somebody has

told me you can be sitting down having discussions and these kids are

working together and these are the things you should see when you go into

a science class. I feel like I didn't really know that before. I wanted the

kids to learn these facts and I would present them and they would take

notes and there were certain things that I was not doing before and I was

worried that some of the things I was doing I wasn't supposed to be doing

but now I feel reassurance that, 'Yeh, It's okay for the kids to be doing

these things and making mistakes, and saying things that are not correct.'

Participant number four described the theme this way:

After taking this course I am so much more confident that I can do it. I

was, I have to admit, as a student I was not. I was scared of science. It

was a big mystery to me. I wasn't given the opportunity growing up to do

explorations. It was more the thing of reading and reporting back or if

there were experiments it was something that was over my head. I didn't

understand what was going on. Science was always for the really smart

kids and I really felt at a disadvantage. And, as teacher, I brought that in.

I knew the concepts, you know, I knew I could impart information, but not

necessarily in a way that was beneficial to the children as far as, there was

not real exploration and deeper knowledge of it. I think I gave them a lot

of answers instead of letting them come to their own conclusions. And, I

was not comfortable teaching science. It was something to get through. I

have to do this. And now I feel much more confident that I can, any

concept there is, that I would be able to present it in a way that is most

beneficial to the students.

When asked if they feel they are able to lead productive whole class discussions at

different points in the inquiry process, all teachers said yes. Two participants expressed

the challenges with helping their dominant students allow others to speak. For example,

participant number five explained:

I'd say yes. They enjoy the conversations and they are productive because

they're coming up with good information. I am better at not trying to

guide the conversation where I want it to go but to let it lead to where it

wants to go and just restating what students are saying for everybody else

to hear. The one problem I still have is I have this one student in one of

my classes who is very dominant, and trying to get him to let others have

time to speak [is difficult].

Three teachers also explained they continue to rely on the sentence starters (Talk Moves

from the Talk Science Primer) to facilitate these discussions. For example, participant

number nine explained, "I think I still need to look back once in a while at our discussion

techniques and our list of sentence starters to keep the discussion going when needed, and

definitely on the wrap up part."   (Karen Heath and I stressed throughout the course the

value for teachers of using the sentence starters from the *Talk Science Primer* as they

practiced leading productive discussions and the need for repeated practice to improve

one's discussion leading skills.)

Participants' self-confidence with helping students use science notebooks as tools to construct meaning from their inquiry also improved. Six out of the nine participants (numbers 3,4,5,6,8,9) expressed that they feel more confident in their use of student science notebooks. For example, participant nine expressed:

Much more confident now. We're seeing that there's a lot more uses for the science notebook, not only in the investigation but also throughout every single day, whether you're using them for notes, for the investigation, for reflection, whether you're making a conclusion. There's just so many uses that we never had before. That's a big change.

Participant number four said, "Much more confident. Before, I was happy to get a drawing. A label maybe. And one sentence. Now, I'm going to expect a lot more because they're capable of doing a lot more. I use it [science notebook] much more often."

Participants number one and number seven each expressed a gain in confidence in the area of notebook use but also mentioned that this was the area from this course in which they feel least confident, mainly because they have not had as much practice with it as with discussion techniques by the end of this course (note: The course focused mainly on inquiry discussion strategies and evidence-based reasoning during seven sessions and focused mainly on facilitation of student science notebook writing during three sessions.) Throughout the writing component of the course, participant number one was not teaching a science unit, so did not have the opportunity to try out the course notebook strategies in the classroom and said, "I would say of all the areas, I guess I'm probably least confident there just because I haven't done it yet." Participant number

seven said of her confidence with using notebooks, "Less confident than discussions, but I'm getting there. Writing conclusions is hard still." Also, participant number two expressed, "I'm still working on that. I feel good, I mean, I don't think it's perfect, I mean I still at this point I'm still teaching them how to use their notebooks and I'm figuring it out ….I have used notebooks for quite a few years now but not specifically in the way that we're using it for discussions."

<u>Teacher Journals</u>

In the final week of the course, eight of the nine participants answered the journal question, "Describe how confident you feel in your ability to improve student reasoning using discourse and writing strategies during inquiry." (One participant chose to complete an alternate assignment as his final journal entry.) The eight participants who answered this question claimed their confidence level had grown. Their answers suggest that the course pedagogy helped teachers build confidence because it invited teachers to experience the parts of the inquiry cycle through conducting science inquiry investigations as adult learners while using the discussion and writing strategies they were learning to implement with students. For example, participant number nine explains:

> Every week throughout the Science and Literacy course I have become
>
> stronger in my ability to use talk/discussion and writing strategies to
>
> improve my students' knowledge and reasoning. Before I started this
>
> course, I had done a little bit using science discussion but not as in-depth
>
> as I needed to for deep understanding of the [science] concept myself. To
>
> pass these strategies onto our students we really must have the strategies

solid ourselves. I believe that the way the course was designed with us moving through each part, even investigations; it really gave us insight into what our students go through. Many times we [participants] were at a loss for what to write initially, but everything became clearer after having a discussion, or a quick write and share with partners. The most important part of this for me is to continue to use all of this [in the classroom] so that I don't forget many of the important strategies that we have learned.

Participant number seven said it like this:

I feel much more confident than I did before about my ability to use discourse and writing strategies effectively. Due to our focus on the inquiry cycle and where each type of writing and speaking best fit within it, I know what kids should be talking and writing about when, and how those strategies tie in with developing scientific reasoning and conceptual knowledge. I also have a much better idea of what types of questions to ask to focus students' thinking and get them to reason more scientifically.

Participant number four said it this way:

If you had asked me this question before taking this course, I would have said I had little confidence in my ability. In the past, I have found that science was mysterious and frustrating to me both as a student and later as a teacher…. Over the years, I have taken courses that presented the inquiry method, but not like this course. I now feel that I can engage, encourage, and increase my students' ability to explore their world and be able to communicate their findings both orally and in written form. I feel

confident that I can encourage my students to be independent thinkers who

can present their findings and be able to show proof about their beliefs.

I noted in my instructor journal that Karen and I repeatedly heard from

course participants that seeing video footage of real classrooms in action using the

techniques they were learning was helpful to their understanding of what it looks

like in the classroom. Although it's likely these videos also played into

participants' developing self-confidence for teaching science inquiry using

dialogue and writing strategies, participants did not specifically mention this in

writing in their journals. Unfortunately, I neglected to ask the question as a

journal prompt.

STEBI-B

Study participants completed a pre-course STEBI-B form and a post-course

STEBI-B form to measure changes in their self-efficacy for science instruction during the

course. The STEBI-B is an externally validated data collection instrument developed in

1990 by Enoch and Riggs (Bleicher, 2004). This instrument measures science teaching

self-efficacy and outcome expectancy for pre-service teachers, and looks broadly at

science teaching efficacy. The STEBI-B does not focus specifically, as this course did,

on science teaching through inquiry using dialogic strategies, discourse, and writing.

Both times the STEBI-B was administered in this study, participants completed

their forms within 10-15 minutes and several remarked they were glad this form was

short and did not take long to complete. The afternoon the teachers completed the post-

course STEBI-B, one participant commented alone to me that everyone had to read the

STEBI-B questions very closely in order to answer them accurately because some of the wording of the item against the rating scale could be confusing. She was concerned that she had filled out the form too fast and may not have given accurate enough answers.

The STEBI-B uses a Likert scale to have teachers rate statements. A rating of five indicates 'strongly agree' and one indicates 'strongly disagree'. I reversed scored some of the items including numbers 3, 6, 8, 13, 17, 19, 20, 21, 23 because strongly disagreeing with these items are clearly indicative of stronger self-efficacy. (For example, item three states, "Even if I try very hard I will not teach science as well as I will most subjects," so for this item when a participant circled '5' I scored it as '1'.)

Results of the pre- and post-STEBI-B suggest that teachers' self-efficacy for teaching science improved from the beginning to the end of the course and support the previously described interview and journal data by suggesting that teacher's self-confidence for teaching science improved throughout the course.

The STEBI-B provides an overall self-efficacy score, but also contains two subscales, The Personal Science Teaching Efficacy Belief scale (PSTE) and the Science Teaching Outcome Expectancy (STOE) scale. The PSTE looks at teachers' personal confidence level for teaching science. The STOE measures teachers' belief that the impact of their science teaching may be limited by factors they cannot control (such as student socioeconomic status).

Table 6 displays the average scores from the pre- and post-STEBI-B analysis including overall scores, as well as scores on PSTE and the STOE subscales.

Table 6

Results of Pre- and Post-STEBI-B

Participant	Total B-score	Total A-score	PSTE B-Score	PSTE A-score	STOE B-score	STOE A-score
1	87.0	104.0	52.0	57.0	35.0	47.0
2	87.0	86.0	53.0	49.0	34.0	37.0
3	97.0	102.0	55.0	58.0	42.0	44.0
4	81.0	95.0	39.0	55.0	42.0	40.0
5	71.0	92.0	35.0	52.0	36.0	40.0
6	82.5	97.5	45.5	55.5	37.0	42.0
7	87.0	85.0	49.0	47.0	38.0	38.0
8	75.0	101.0	47.0	56.0	28.0	45.0
9	78.5	98.0	44.5	55.0	34.0	43.0
Average	82.9	95.6	46.7	53.8	36.2	41.8
STDEV	7.7	6.8	6.6	3.7	4.3	3.3

The average overall (total) score before the course rose from 82.9 before the course to 95.6 after the course (Δ 12.7). The average PSTE score prior to the course rose from 46.6 to 53.8 after the course (Δ 7.2). This change in the average PSTE score supports the qualitative data described above that indicates that teacher's self-confidence in their science instruction improved throughout the course. The average STOE score prior to the course rose from 36.2 to 41.8 after the course (Δ 5.6). The increase in STOE scores show that the course helped the participating teachers to believe their science teaching can have an impact regardless of external inputs (like student socioeconomic status). The STEBI-B results seem to strongly support the themes expressed by teachers during interviews and journaling: Their self-confidence for teaching science in general appears to have improved through the duration of this PD course.

Summary of Changes in Self-Efficacy

Interview and journal data suggest significant changes in teachers' self-efficacy for teaching science through inquiry using whole class discussions and notebooks. Participants expressed that the course helped them feel more confident facilitating whole-class discussions. A few participants mentioned the continuing challenges they have with helping dominant students allow their peers to speak and share. A few participants also mentioned their need to continue to rely on the checklist included in the Talk Science Primer from the Inquiry Project (an action my co-instructor and I encouraged participants to continue until the strategies become second nature for them). Participants' confidence with using student science notebooks to help them build reasoning also improved, although this appears to be the area which teachers feel they still need practice to continue improving. STEBI-B data also indicate an improvement in overall self-efficacy for teaching science, thereby supporting the teachers' expression during interviews and journals that their self-efficacy improved through the course.

<div align="center">Implementation</div>

This section addresses the third research question: What effect did implementation of this professional development program have on teachers' inquiry pedagogy? More specifically, what effect did it have on teachers' use of discourse and writing to help students develop evidence-based reasoning during inquiry? I conducted teacher interviews during the final weeks of the course, and participants kept journals throughout the course demonstrating changes in their inquiry pedagogy. The themes from these two data sources suggest substantial changes in teachers' science inquiry pedagogy, specifically on their implementation of class discussions and student science notebook use. I also conducted pre- and post-observations of teachers teaching science

and analyzed voice recordings of these observation sessions using the RTOP.   The

RTOP data, though not statistically significant, support the interview and journal data that

demonstrate changes in participants' pedagogy as a result of the course.

Interviews

I interviewed all nine participants at the conclusion of the course. Themes from

these interviews demonstrate that through the course, teachers' pedagogical use of whole

class discussions changed. Also, the types of questions they pose during inquiry and their

use of student science notebooks changed as a result of what they learned in the course.

Teachers of all grade levels expressed that they had made a fundamental shift in

pedagogy used to conduct whole class discussions. They expressed an increase in the use

of whole class discussions during which students are seated in a circle and conduct the

discussion without the use of hand raising, with the teacher as facilitator rather than

driver of the discussion. Teachers expressed that this pedagogy differs greatly from the

former practice of having students remain in their seats at desks and raise hands to share

with the whole class. Now students are reacting to each other's ideas. For example,

participant number five remarked that:

> It used to be a raise your hand, give me an answer type-discussion.
>
> Totally different atmosphere now. It used to be, 'Stay at your seats, raise
>
> your hand.' Sometimes it used to be sitting on the floor. [Now] I think
>
> the kids are more comfortable sitting in chairs sitting in a circle. We
>
> actually move desks away and they sit in a circle and face one another and
>
> talk and they actually are talking to each other, not at me. Which, when it
>
> started, they would face me…and I'd go…"no, no…." (Pointing at the

other person who is listening).   "Your class is there. Talk with them."

And they do. They forget I'm there, and they start having a conversation.
Participant number two explained what discussions in her classroom looked like before
this course and how discussions have changed through the course:

> "[Before] We would have discussions within their small groups. We
>
> [Students] were always raising our hands and I very rarely ever did circle
>
> discussions….. It was that they sat at their desks, they raised their hands,
>
> they shared. I'm encouraging them now to react to each other more. I
>
> might have rephrased a kid's question to have them react, but now I think
>
> it's purposeful. It's that, you're not answering the question I'm asking,
>
> you might be answering a question your classmate is asking or reacting to
>
> something a classmate is asking, not what I'm asking or what I'm saying.
>
> So…Um…. the discussion piece has grown for my class very much and
>
> it's definitely more student-to-student rather than student to teacher.

During interviews, teachers also expressed a shift that occurred as a result of the course in
the purpose of student talk in their classrooms. Participant number seven explains this
theme particularly clearly when stating:

> I think the purpose has changed as well 'cause before when I had them all
>
> sitting at their desks and called on kids it was more about trying to get
>
> somebody to say the right answer and having everybody either say that or
>
> hear that and know what specific facts, or information was, and that's
>
> certainly still part of the discussions I'm having now. But it's a lot more
>
> about understanding how scientists think about these ideas. So, we know

the facts, but, how can we create predictions based on all the facts we

know? Or how can we come to conclusions about all this data we see?

It's a lot more about reasoning through and connecting what they are

doing to what they are thinking and the facts that they know.

Teachers also expressed during interviews that the types of questions they pose to

students to guide their inquiry changed. In particular, they expressed that, by being more

open-ended and thought-provoking, their questions now lead students to think more

deeply about the topics they are studying. Participant number eight states this theme,

"Before, I did not question them…I'm the first one to admit…I didn't ask the questions

that were drawing the most information from them, and now I feel like I'm asking

questions that lead them to think deeper." Participant number four echoed this theme

when she described the type of questions she tended to ask before the course:

They weren't very meaty questions, as far as [they were] getting a 'yes' or

'no' answer, or directly basically giving them the answer in the question

where they just have to pick or choose (the answer), you know, there were

two options and ..you know really narrowing it down. And I think that's

how I did a lot of my questions but now I know that's not the way to do it.

My questions now are more probing and open-ended.

Participant number nine explained, "I think a lot of our questions just did not probe deep

enough. They were more vocabulary based and yes and no based that went along with an

investigation and went along with reading"

Another theme apparent in the teacher interviews data is that teachers' pedagogy

for use of science notebooks changed throughout the course. Participants express that

they are using science notebooks more frequently than they did in the past and are having students write in them for a greater number of purposes throughout the inquiry.

Participant number six explains, **"**I used them [notebooks] before, but not as much. And I think my notebooks were just kind of…like before I think a lot of my questions were just yes or no things. And I think this is going more open." Participant number five said, "We did notebooks (before). But it was, I would do something and they would write something down in their notebooks and observations." Participant number four stated:

> Before, I was happy to get a drawing. A label maybe. And one sentence.
> Now I am going to expect a lot more because they are capable of doing a
> lot more. I use it much more often. A lot of times we only used it at the
> end of what we were doing (the unit) and now it's everyday…. I want
> them to be jotting down, whether it's a drawing, whether it's their
> thoughts on something, or if there's actual data to put down, I just want
> them writing it.

Teachers also expressed that, pedagogically, since the start of the course, the notebooks now have a deeper purpose because they provide evidence used during discussions to build understanding and evidence-based reasoning. Several examples of teacher's expression of this theme follow:

> I think that the hugest thing that I talked about before is the science
> notebooks. I used them but did not get it I guess (before) about how
> important they were. I always had data there, but when you start taking
> that data down, the question, their prediction, what they noticed or what

data they collected and they are starting to use that to make meaning, on their own first and then in their larger group [discussion], they come back to it [the notebook]. I think that has really made that notebook more important and the kids see it as important and to me that's huge. They see it as, "Oh…I need this.." and they bring it right with them [to circle for discussion]. I never fostered that or modeled it the way I should. I guess I missed that. In the inquiry process that's one thing I really missed out on. Cause I don't think I really understood how powerful it was. I don't know why I didn't. It's like…Duh! But, once you see it happen and them start to use it and they get excited about 'Ha. I can prove it right here.' Or, 'I got these results.' 'Well I got these results.' 'Well, does that mean…' (Participant number three)

I think last year I thought of them as more like a record of what we'd done in class rather than a source of scientific thinking and data from experiments. So, I think they've definitely gotten more purposeful and gotten more specific in the information they include and I think kids, this years class, have a better idea of why we are writing in science than my last year's class. (Participant number seven)

They have to dig deeper and look deeper at what they are doing in the investigation because they have to present it in a discussion and if they don't look deeper at those things while they are doing it (the investigation)

they get to the discussion and they're like, oh….I don't know. They just

don't know what to say while others are looking at their data and really

going back and forth about it. They really see that their science notebook

and what they write in there is important to backing up what they say and

making claims. I think it keeps students more on task in the investigation.

(Participant number nine)

In summary, interview data strongly suggest that participants' pedagogy for use of whole

class discussions, questioning techniques, and student notebooks during inquiry

instruction changed significantly since the beginning of this PD course.

<u>Journals</u>

Participants' online journals also suggest several areas of growth in

pedagogy for using discourse and writing to help students develop evidence-based

reasoning. At the beginning of the course, teachers were prompted with the following

question, "How are you currently using (or have you used) student talk and writing

during science?" Many participants explained both in their journals and orally in class

throughout our PD course that their science block in the daily school schedule was too

short to allow much time for student talk and writing. Participant number nine wrote,

"How do I use science discussion currently?? First, in only 1/2 hour of science daily

there isn't a whole lot of time for discussion, but it is so important to the students and

their understanding that we can easily use a whole class period [1 hour]." Throughout the

course, the lack of official science time in the schedule became so concerning for Barre

teachers that Karen and I suggested they could also use their writing and literacy block

for some of their science investigations, discussions and writing so that they could

adequately allow for the integration of literacy strategies within their science instruction. Teachers reacted positively to this, but also remained concerned that their administrators would not see this as a legitimate use of the literacy block. Karen then spoke with administrators about this on behalf of the teachers participating.

Several other themes emerge in the journal responses to the question posed the first week of the course, "How are you currently using (or have you used) student talk and writing during science." Many expressed that large group discussions were very often KWL discussions. They also shared that most of the talk occurring in their classes occurred with students in small groups working on a science task together. Participant number seven demonstrated this theme by saying, "Most student talk in my class is done in small groups as they are investigating. They share their observations, predictions and questions in small groups. Also, I start the unit with some sort of KWL-like gathering of ideas. Occasionally I have whole-class discussions about their results, but I don't think they are very effective because students are much more interested in sharing than in listening and building upon others ideas." Participant number nine also felt at the beginning of the course that the ways students were using talk and writing in science were not effective:

> In the past I have used science discussions mostly after we do an
>
> investigation. Students bring their notebooks to the circle, much like we
>
> did in class. At this point it really becomes a reporting out from groups,
>
> and not always a discussion. Students sometimes forget to listen to others,
>
> and they are mostly trying to report what happened in their investigations.

Journal entries early in the course also show that many study participants used student science notebooks/journals or logs before this course began. Logs and journals before the course for the younger grade students were used most often after the investigation to record their day's findings through drawing and writing. As participant number eight explains, "Last I would have them go to their science journals to record their day's findings (discoveries) in pictures and in words." Participants who teach older students expressed that, before the course, they were asking students to use their science notebooks to record salient information throughout the steps of the investigation, as participant 2 explains:

> My students have science notebooks in which they write daily. They write
>
> prior knowledge, predictions, observations, descriptions, and plans. My
>
> students often work in pairs or small groups to do investigations. They
>
> discuss what they are doing, seeing, and questioning. Sometimes we have
>
> time to share as a large group; however, I don't often give the students
>
> specific time to react to each other's thinking.

On the final day of this course, teachers turned in written responses to the prompt, "In what ways has your knowledge of best practices for teaching science through inquiry changed in this course?" Many of the responses demonstrated changes in teachers' pedagogical practices surrounding use of discourse and writing to help students develop evidence-based reasoning during inquiry. Themes of changes in teachers' inquiry pedagogy are consistent with themes from their interviews. Because responses to this journal prompt provided powerful insight into changes in pedagogy, I include four of those responses here to demonstrate the themes:

I used to follow a model of instruction, deliver instruction, and give

students too much information. Now, with this [inquiry] model, I feel I

am more involved by observing their discoveries and listening in on their

shared conversations about their thinking and new learning. I am

expecting more from my students now and doing more modeling in the

area of science notebook recording. I am spending more time on how to

interpret data, make diagrams, and how to label the important information.

(Participant number eight)

Before this class, I was very pleased with how I was presenting our

science units. I would give my students the materials and have them do

the explorations. I was happy to receive a drawing with labels and one or

two sentences about what they had observed. There was very little real

science talk and little opportunity to branch out and explore on their own.

…. I did not give my students enough credit for their ability to carry on a

conversation that was not directed by the teacher. The first hurdle was

allowing students to talk without raising their hands. I did not think that

my first graders could do this without total chaos. It is still a work in

progress, but with an agreed upon set of rules, we are having very

productive discussions.

Writing has been another component that is changing due to this

course. We are revamping our science journals to reflect what is

important that our young scientists record. It also became evident that

their writing must be a part of every session, not just something they did at the end of the investigation. We are not just asking for drawing and labeling, but we are asking for their thoughts and conclusions. We have ended each journal section with a chance to change their conclusions if needed and the reason for doing so.

I think that the most important things I have taken from this course are that I not underestimate what my students are capable of achieving and that to give them a chance to communicate with each other throughout the inquiry process will only increase their knowledge of science. (Participant number four)

I have been having students write in science notebooks for years now, but the notebooks my students are creating now are more useful. My students use their notebooks daily and often have to look back to notebook entries from previous lessons. My students are learning that their thoughts are important and create meaning. When kids are observing and writing in their notebooks, I am keeping the kids more focused. When appropriate, I pose a productive question and keep the students on the track to that question. These notebooks lead the students into student-centered discussions.

In past years, I would have my students discuss in small groups. They would share out to the entire group by raising their hands. Students would sometimes react to other people's thinking, but I didn't teach or

encourage it as I do now. I continue to do small group discussions and

pair shares, but I am now doing large group circle discussions. I am

finding these discussions to be very valuable because the students are

learning to appropriately interact with each other, respectfully question

each others' ideas, build meaning together, and gain knowledge from each

other. I don't have to do a lot of talking during these discussions because

they are students centered. I am not lecturing. I am letting them discuss

and figure things out by using each other and their experiences.

(Participant number two)

Previously, when students talked in my science class, they were either

talking over what they were doing as they worked in groups, or were

participating in whole-class discussions. Both of these talk formats still

make up the bulk of talking in my [science] class, but what each looks like

is very different. In small groups, I am more intentional about setting or

having students set a focus question before they work and talk. That way,

their talk is more likely to be productive and to support their content

knowledge and scientific reasoning. I also have a better idea of what

questions I should ask as I walk around and check on groups. I need to

ask questions that get them thinking about what evidence they are seeing

to support/contradict their hypothesis, why certain things are happening,

how their thinking is changing, and what conclusions they can draw. This

will get them thinking much more deeply than just checking in on where

in their experiments they are and what their results are.

For whole group discussions, I am more focused on developing

reasoning skills rather than just reviewing and sharing information.

Before, my discussions looked and sounded like the discussions described

at the beginning of our book. I asked a question, one or a few students

responded to me, and then we moved on to another question. I worked to

review facts or to share some students' prior knowledge and ideas, but it

didn't involve very much student-to-student interaction and it didn't really

get students to think through their classmates' ideas or dig deeper into the

content. Both the introduction of the discussion circle and the talk moves

list [from The Talk Science Primer] have helped me to make discussion

more valuable. (Participant number seven)

In summary, journal data strongly suggest shifts throughout the course in participants'

pedagogy for science inquiry instruction using dialogue and writing. Interviews suggest

that participants' use of student talk and science writing changed significantly as a result

of taking the course.

Reformed Teaching Observation Protocol

The Reformed Teaching Observation Protocol is an externally validated

instrument designed to measure reformed science teaching. It is intended for use by

trained observers. Although I did not receive any formal training, I read the RTOP

reference manual and completed RTOP forms as part of this research to determine if this

quantitative data could provide additional insight and/or support to the qualitative data

gathered in interviews and journals. To use the RTOP, I observed seven of the nine participants on two occasions each: once within the first two weeks of the PD course and once within the final two weeks of the course. (Unfortunately, I was only able to observe seven participants because one participant was not teaching a science unit during the course and another participant sustained an injury that prevented her from being observed in her classroom at the beginning of the course.)

In each observation session, the participant welcomed me into his/her classroom. I sat unobtrusively in the back of each room and took notes while the voice recorder recorded the teacher instructing the science lesson. Students rarely interacted with me during these observations because the teacher told students to ignore me and explained ahead of the lesson why I was there.

During each observation, I wrote in the 'notes' area of the RTOP form the room layout and teacher and student moves throughout the observation session. During the evening following each observation session, I reviewed my notes and recollections of the participants' lesson and used the RTOP's lesson descriptors to rate on a Likert scale of 0-4 the absence/presence of each science lesson descriptor for the observed lesson. (e.g. One descriptor/item reads, "The focus and direction of the lesson was often determined by ideas originating with students." The descriptor was rated on a scale of 0 to 4, with 0 representing "never occurred" and 4 representing "very descriptive" of the lesson). Higher scores on the RTOP Likert scales indicate greater presence of best practices for science instruction. Completion of the pre-course and the post-course RTOP thereby provided a numeric comparison of each teachers' observed pre-course lesson and post-course lesson.

I transcribed the voice recording and then looked again at my notes as well as my RTOP Likert scale ratings to determine if I might need to adjust any prior ratings based on this careful review of the voice recording. I made only two small changes during that process.

Total RTOP scores for the 7 observed participants appear in Table 7. (Note that due to the small sample size and my desire to protect participants' privacy, no participant numbers are listed here. However, each row demonstrates the before-course and after-course RTOP score of each of the seven participants I observed.)

Table 7
Reformed Teaching Observation Protocol Analysis

Participant	Before	After
	52	81
	48	90
	48	90
	61	45
	15	84
	71	96
	55	87
Average	50.0	81.9

The sample size of seven lacks statistical significance. Also, only I rated the RTOP. I did not conduct a peer review because of the enormous time commitment that a second reviewer would need to commit in order to observe all of these lessons. Results from my completion of the RTOP, although not strongly reliable, support teachers'

expressions in their journals and interviews that their pedagogy for teaching science inquiry had changed: The average RTOP score rose from 50 to 81.9.

It is also worth noting that I only observed, voice recorded and completed the RTOP for two science lessons for each participant, one at the beginning and one at the conclusion of the course. This limited exposure to their teaching provided only a short window into participants' instructional shifts, making it difficult to generate broad statements about teachers' changes in practice as a result of the course. One teacher's score dropped from the first lesson to the second lesson. There were many external factors that seemed to affect this. (e.g., students were behaviorally challenged in that classroom during the final observation due to an upsetting event that occurred earlier in the classroom.)

If the RTOP were to be used again for a similar study in the future, the researcher should observe more than one lesson at the beginning and end of the course, and work hard to find a small team of investigators to take part in the analysis using video footage rather than audio recordings (which was not possible for this study). Investigators should also receive formal training to use the RTOP instrument.

While observing, I noticed that many of my pre-course classroom observations showed teachers conducting some inquiry-like investigations with students, but the discussion that occurred in these lessons was largely in small groups. When whole class discussions occurred during these pre-course observations, the teacher conducted discussions at the front of the room asking questions. Students rarely reacted to what their peers said and instead answered the teacher directly, looking at the teacher. Students seemed to enjoy their science investigations or science 'work'.

During each of the after-course observations of participants' science lessons, the teacher being observed used a focusing question about the inquiry they were conducting to center student's thinking during the discussions. Also, all study participants used either the "making meaning" or the "gather-ideas" discussion strategy. Five of the seven observed structured their lesson so that students relied on the records in their science notebooks to provide evidence of their thinking during their discussions. I also observed that during the after-course observation, every participant incorporated opportunities in the lesson for students to 'think-pair-share', or briefly discuss in a small group, their thinking before students shared their thinking in a broader way during a whole group discussion. One teacher did not use student notebooks during her gathering-ideas discussion but did heavily use the think-pair-share and small group discussion techniques to help students share their thinking. She pointed out to students that they would be using their notebooks in the next lesson.

It is likely that participants consciously decided to demonstrate implementation of each of the practices they were learning in the course when I came to observe in their classrooms. My presence as the observer almost certainly biased the results.

It does appear from this research that teachers' inquiry pedagogy, specifically their use of discourse and writing to help students develop evidence based reasoning during inquiry, changed as a result of this course. To more fully witness the long-term effects of this course on teachers' pedagogy, additional observations in teachers' classrooms would be necessary in the future. Ideally, these observations would be conducted by someone who did not also teach the course to participants but who is

trained in similar best practices for using student talk and writing to help students build

conceptual reasoning during inquiry.

INTERPRETATION AND CONCLUSION

Evidence from this study shows that the Science and Literacy professional

development course taught in Barre Supervisory Union in the fall of 2013 changed

participants' knowledge and pedagogical use of best practices for instructing science

inquiry using literacy strategies to support science conceptual understanding and

reasoning. The course also helped participants build confidence in their ability to teach

science concepts effectively using inquiry pedagogy with focused, student-centered

discussions and student science notebook writing to make meaning from that inquiry.

Study participants' increase in knowledge, self-efficacy and pedagogical implementation

of best practices helped them to integrate literacy with science inquiry with the goal of

helping bolster students' development of conceptual reasoning about the science concepts

they investigate through inquiry. Through combining science and literacy in this way,

teachers learned instructional strategies that would address CCSSELA and NGSS

simultaneously.

VALUE

This project encouraged me to develop and use a wider assortment of data

collection instruments than I used previously to determine changes for teachers that result

from professional development. Before this study, when conducting professional

development, I relied heavily on exit tickets, essays and end-of-course evaluations for

formative and summative assessment of teacher learning. Thanks to this project and the

classes I completed as part of this Master of Science in Science Education degree, I now

recognize the tremendous value in using multiple methods to assess outcomes for the same question by triangulating my assessment data sources. I will use more pre- and post-knowledge surveys, online journaling and discussions, and will interview teachers wherever possible in order to more fully understand the effect my courses and facilitation sessions have on teachers' practice. My instruction of teachers has become richer and more effective as I employ these additional formative and summative assessment tools.

This Capstone Project also showed me the impact professional development can have on teachers, and helped me become more emotionally and intellectually invested in my work. In 2005-2007, when I was science specialist for the Barre Supervisory Union, I spent a lot of time in classrooms coaching teachers, but now I contract with several schools and non-profit organizations and rarely find myself in classrooms coaching while school is in session. This separation from the classroom makes it harder for me to witness the changes for both teachers and for their students that I am trying to affect through my professional development facilitation. Conducting this action research study and gathering the data about its effectiveness enabled me see first-hand the changes that can occur for teachers as a result of the professional development sessions I lead in my consultant role. I see from this research that teachers' knowledge base, self-efficacy, and classroom instruction can change significantly with professional development and that my work does have a positive effect on teachers' practice. This spurs me on as an educator.

My end goal through high-quality training of teachers, however, is to improve students' school science experiences and learning. At this time, I assume that the professional development I lead impacts the students these teachers instruct, but there is

no proof in this research to support my assumption. Are students learning science more deeply now through their science talk and writing? Are their attitudes about science changed as a result of my work with their teachers? In the future, I would like to conduct a more involved research study that investigates not only what the participating teachers learn, but also how student outcomes change as a result of their teachers' professional development around best science teaching practices. This type of study would help deepen my grasp on the net affect of the professional development I lead as a science curriculum professional development provider. I recognize that more involved research will require additional time and effort on my part, and it may be best undertaken as part of a future pursuit of a Doctorate in Education. For now, I will continue to employ the strategies I learned through this research in order to continually improve my practice as a science professional development facilitator.
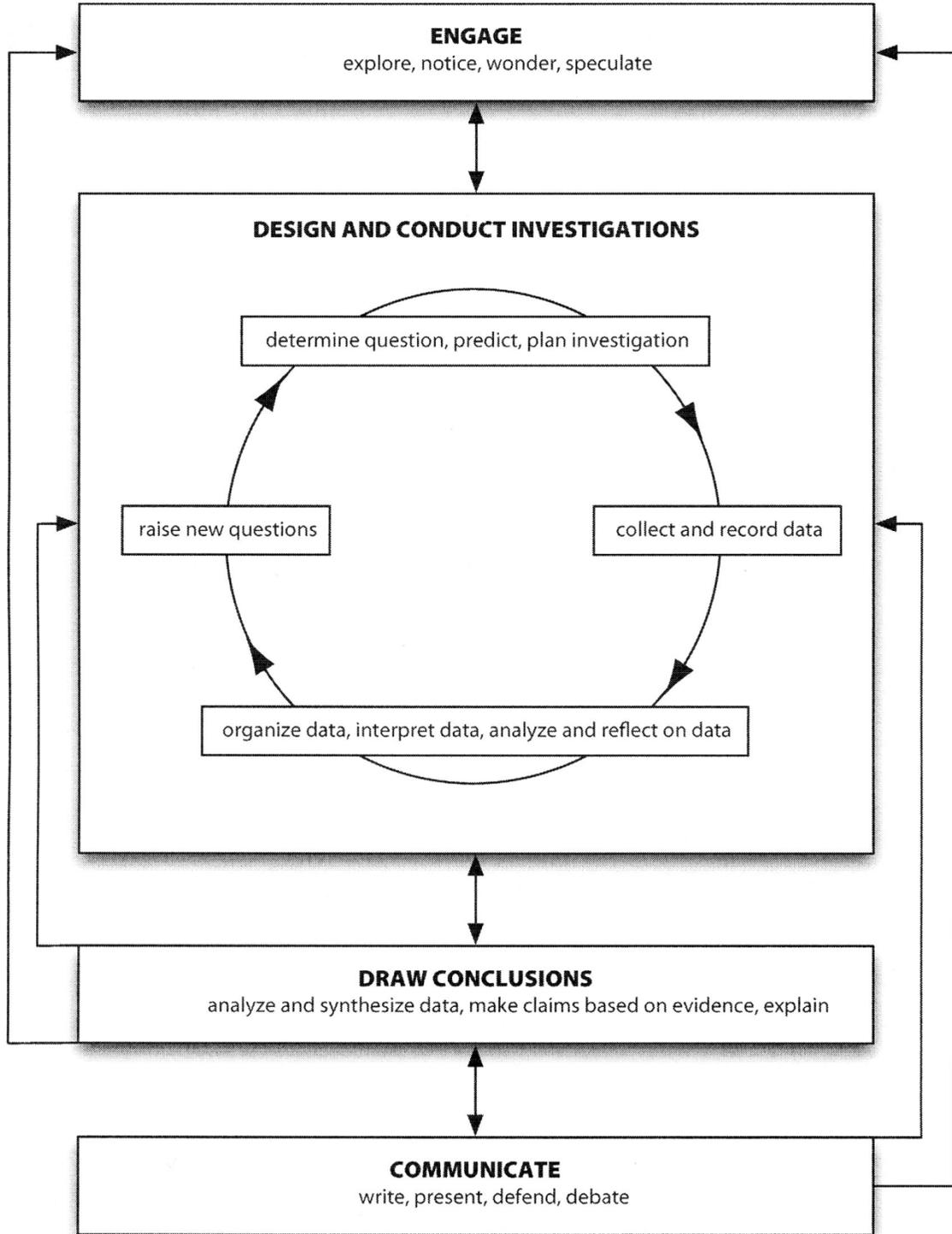
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APPENDICES

APPENDIX A

THE INQUIRY CYCLE

68

ENGAGE
explore, notice, wonder, speculate

DESIGN AND CONDUCT INVESTIGATIONS

determine question, predict, plan investigation

raise new questions

collect and record data

organize data, interpret data, analyze and reflect on data

DRAW CONCLUSIONS
analyze and synthesize data, make claims based on evidence, explain

COMMUNICATE
write, present, defend, debate

APPENDIX B

SCIENCE TEACHING EFFICACY BELIEF INSTRUMENT – B

Science Teaching Efficacy Belief Instrument – Form B

Developed by Larry G. Enochs and Iris M. Riggs, used with permission.

Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate letters to the right of each statement.

	Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
1. When a student does better than usual in science, it is often because the teacher exerted a little extra effort.	A	B	C	D	E
2. I will continually find better ways to teach science.	A	B	C	D	E
3. Even if I try very hard, I will not teach science as well as I will most subjects.	A	B	C	D	E
4. When the science grades of students improve, it is often due to their teacher having found a more effective teaching approach.	A	B	C	D	E
5. I know the steps necessary to teach science concepts effectively.	A	B	C	D	E
6. I will not be very effective in monitoring science experiments.	A	B	C	D	E
7. If students are underachieving in science, it is most likely due to ineffective science teaching.	A	B	C	D	E
8. I will generally teach science ineffectively.	A	B	C	D	E
9. The inadequacy of a student's science background can be overcome by good teaching.	A	B	C	D	E
10. The low science achievement of some students cannot generally be blamed on their teachers.	A	B	C	D	E
11. When a low-achieving child progresses in science, it is usually due to extra attention given by the teacher.	A	B	C	D	E

	Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
12. I understand science concepts well enough to be effective in teaching elementary science.	A	B	C	D	E
13. Increased effort in science teaching produces little change in some students' science achievement.	A	B	C	D	E
14. The teacher is generally responsible for the achievement of students in science.	A	B	C	D	E
15. Students' achievement in science is directly related to their teacher's effectiveness in science teaching.	A	B	C	D	E
16. If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher.	A	B	C	D	E
17. I will find it difficult to explain to students why science experiments work.	A	B	C	D	E
18. I will typically be able to answer students' science questions.	A	B	C	D	E
19. I wonder if I will have the necessary skills to teach science.	A	B	C	D	E
20. Given a choice, I will not invite the principal to evaluate my science teaching.	A	B	C	D	E
21. When a student has difficulty understanding a science concept, I will usually be at a loss as to how to help the student understand it better.	A	B	C	D	E
22. When teaching science, I will usually welcome student questions.	A	B	C	D	E
23. I do not know what to do to turn students on to science.	A	B	C	D	E

APPENDIX C

TEACHER JOURNAL PROMPTS

JOURNAL PROMPTS

1. Week 1: How are you currently using (or have used) student talk and writing during science? How has this worked for you?

2. Week 2: What are some questions you might ask your students during an inquiry science lesson?

3. Week 3: After reading the *Talk Science* Primer explain how this article changed how you view talk in the science classroom. What will you work to do differently in your classroom?

4. Week 3: What questions could you ask to guide gathering-ideas and making-meaning discussions in your classroom? After practicing this with your class, reflect on your experience in your journal.

5. Week 4: After conducting a science discussion using at least one of the instructional strategies you learned in this course, explain what you did and reflect on your experience in your online journal.

6. Week 5: What are some facilitation strategies you use or might use at each stage of inquiry? How and why are they different? How are they the same?

7. Week 7: Reflect on how your knowledge and practice of questioning during science discussions has changed as a result of what you have learned so far in this course?

8. Week 10: In what ways has your knowledge of best practices for teaching science through inquiry changed during this course?

9. Week 10: Describe how confident you feel in your ability to improve student reasoning by using discourse and writing strategies during science inquiry.

APPENDIX D

INTERVIEW QUESTIONS

INTERVIEW QUESTIONS

1. Describe the process of scientific inquiry in your own words. What does science inquiry look like in the classroom? What are students doing?   What is the teacher doing? *(Knowledge)*

2. How confident do you feel teaching science through inquiry? Which parts of the process are easy for you to facilitate (and why)? Which parts challenge you most (and why)? *(Self-confidence)*

3. What strategies do you use with inquiry to support students' development of conceptual reasoning and argumentation? *(knowledge, implementation)*

4. Do you feel you are able to lead productive whole-class discussions at different points in the inquiry process? How well are you able to help students build conceptual understanding, reasoning and argumentation through discussions about inquiry? *(Self-efficacy)*

5. What are the characteristics of an effective science discussion? (*knowledge*)

6. How has your use of discussions during inquiry changed? *(implementation)*

7. How confident do you feel in your ability to facilitate students' use of scientist notebooks as tools to construct meaning from inquiry? *(confidence)* Has your implementation of using notebooks in the classroom during inquiry changed, and if so, how? *(implementation)*

APPENDIX E

PRE/POST KNOWLEDGE SURVEY – BEST PRACTICES

Knowledge Survey – **Science and Literacy, A Natural Fit**   CODE:_____

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

1. Describe a discussion strategy a teacher could use first with his/her class to help students connect with a new science inquiry topic?

   How does this discussion strategy help students?

2. Draw and label a diagram that illustrates the science inquiry learning cycle.

3. Why is it important to encourage whole-class and small-group talk about the content-focus of student science inquiry?

4. Describe a 'gathering ideas' discussion. What does it look like?

5. When should a 'gathering ideas' discussion occur in the science inquiry cycle?

6. What should the teacher do to foster student learning during a 'gathering-ideas' discussion?

7. Describe a 'making meaning' conversation. What does it look like?

8. When should a 'making-meaning' discussion occur in the science inquiry cycle?

9. Establishing a culture of science talk in the classroom requires rules and model setting behavior. List three helpful classroom norms (rules of behavior, examples to set) for conducting productive classroom discussions about science inquiry.

10. Write two productive questions a teacher can ask students during science inquiry and explain why they are productive.

11. Write two unproductive questions that a teacher might use in classroom science conversations and explain why they are unproductive.

12. During class inquiry discussions, why seat a class of students in a circle?

13. What purposes does a student scientist notebook serve?

14. Describe 3 strategies a teacher can use to support students' use of scientist notebooks.

15. Describe two ways you currently use or plan to use scientist notebooks with your students.

APPENDIX F

PRE/POST INQUIRY CYCLE DIAGRAM EXAMPLE

Pre-Knowledge Survey Inquiry Cycle Diagram

9/25/13

While you wait for class to begin, independently draw and label a diagram that illustrates the science inquiry cycle.

(If you have not heard the term 'science inquiry cycle' before this course, don't worry. Describe your thoughts on steps you believe students should take to conduct science inquiry.)

I wonder......

I suspect......

I notice ......

Post-Knowledge Survey Inquiry Diagram

Part 1: Knowledge Pro

The Science Inquiry Cyc

Name:

Directions:
In the space below, please draw and label a diagram that illustrates the Science
Inquiry Cycle.

Engage

- Brainstorm
  - Wonder ○ Speculate ○ Question

Design & Conduct Investigation

? question - predict - plan.
collect - record

ew questions

organize, analyze
reflect on
findings

2

Draw conclusions !!!!

Discuss

Communicate write

Present